Safe Management of Spent Radiation Sources

(Activity Report of SRSM Task Group)

FNCA RWM-R002

March 2003

Radioactive Waste Management (RWM) Group
Forum for Nuclear Cooperation in Asia (FNCA)

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Contents

1. Preface

The safety management of spent radiation sources (SRS) is discussed in this paper based on the task group work in Radioactive Waste Management (RWM) project under FNCA (Forum for Nuclear Cooperation in Asia) framework.

The contents are; Chapter 2. Outline of the project, including the summary of important discussion points, Chapter 3. International activities, which is touching the IAEA's action plan (7 items), historical background, Chapter 4. Regulatory System and Lessons Learned from Accidents in Japan, Chapter 5. SRS Management System in Japan. And Chapter 6 to Chapter 9 are Experiences of SRS management in the Philippines, Thailand, Indonesia, and Korea, respectively.

This kind of information exchange and discussion based on the peer review through on-site fact-finding observation between the neighboring countries will support not only a good practice of RWM of each country but also a fertilizer activities of making up a harmonized international agreement through IAEA.

2. Outline of the Project

2.1 Introduction

The recent events relating to the Spent Radiation Source (SRS) Management occurred in Japan. Those were Orphan Source Accidents; one was in Wakayama Prefecture (Am-Be neutron source and Co-60 gamma source were mixed in the imported iron scrap as orphan source from the Philippines), and the other was in Yamaguchi Prefecture (Co-60 source was found in the imported iron scrap from Taiwan). These orphan sources caused a big confusion in the public through an amplifier of mass media like television, newspaper etc.

To avoid this kind of confusion and to get a more reliability of the radioisotope usage, we would like to discuss on "what kind of method, countermeasure, thinking and framework is effective?" We proposed here the SRS Management project under Forum for Nuclear Cooperation in Asia (FNCA).

FNCA was supported by Atomic Energy Commission in Japan and Ministry of Education, Culture, Sports, Science and Technology (MEXT) to promote cooperation in the field of nuclear energy with neighboring Asian Countries (Australia, China, Indonesia, Korea, Malaysia, the Philippines, Thailand, Vietnam, and Japan). At the earliest stage in this forum 7 projects were listed up. One of them is Radioactive Waste Project. As a task group work SRS activity did several research activities under the support of 5 countries; Indonesia, Korea, the Philippines, Thailand and Japan).

The collaborative work to make a same safety base between these countries is quite important because the interdependence and the distribution through trade in this area are growing up.

But in this activity, the problem so-called NORM or TENORM (Technologically Enhanced Naturally Occurring Radioactive Material) is not handled because the thinking procedure of radioactivity management is different from the artificial radiation sources.

In this report, two years' activity are summarized as listed below.

[Safe Management of Spent Radiation Sources]
Chapter 2. Scheme for Spent Radiation Source Management
Chapter 3. Current IAEA activities related to safety of radiation sources
Chapter 4. Current status of spent radiation source management in Japan
Chapter 5. SRS management operation system in Japan
Chapter 6. Current status of spent radiation source management in the Philippines
Chapter 7. Current status of spent radiation source management in Thailand
Chapter 8. Current status of spent radiation source management in Indonesia
Chapter 9. Current status of spent radiation source management in Korea

2.2 Approach and Present Status of the Spent Radiation Source Management

The approach to the spent radiation source in each country has their own features.

In Indonesia, in 1997 the Act of Nuclear Energy was issued and the regulatory function was separated from BATAN. The name is BAPETEN (English name is Nuclear Energy control Board, NECB). An accident of loss of radiation sources, which were used in a thickness gage, accelerates the promotion of safe management of radiation sources. Recent movement and effort of Indonesian government to making up a new system are expected.

In Korea, in recent, Korean government did a reform of nuclear and radiation related governmental systems. Now the regulatory aspect (safety management and licensing procedure) of radiation source management is covered by Ministry of Science and Technology (MOST). As a regulatory body Korea Institute of Nuclear Safety (KINS) is nominated. Radiation source management is attained together Korea Radioisotope Association (KRIA) and Nuclear Environment Technology Institute (NETEC). KRIA covers a collection of radiation sources and NETEC covers radioactive waste management and disposal. Korea also had several experiences of SRS management events. But now a quite nice radiation source managing system based on the Information Technology was prepared as a complete database and traceability system of radiation sources.

In the Philippines, since 1958 Philippine Nuclear Research Institute (PNRI) has covered both the promotion of nuclear application and the safety aspect of nuclear and radiation field. PNRI takes a position of direct introduction of IAEA safety system. From early stage PNRI joined IAEA's Radium Source Conditioning Project and got a magnificent outcome. They also had several events of radiation source containing scrap. But an enthusiastic effort of the countermeasure with education system introduction, custom monitoring system preparation was done. Combining with the introduction of IAEA action plan and these activities, the situation in this country has been advancing.

In Thailand, a big radiation source loss and irradiation accident was occurred in 2000. Medial use Cobalt-60 went to a scrap yard with no recognition. This caused 3 person's death. This severe event caused a strong impact of reform of Office of Atomic Energy for Peace (OAEP). OAEP is going to spread into two activities, one is research activity, Thailand Institute of Nuclear Technology (TINT), and the other is a regulatory and inspection body, Office of Atoms for Peace (OAP). Now new regulations are preparing in connection with the establishment of this new organization.

In Japan, the regulatory system for spent radiation source management is not so good. We also had experienced in recent days on the miss-management of spent radiation source; radiation source (Co-60 and neutron source) found in iron scrap imported from an East Asian country at Wakayama port in 2000. The other cases were radiation sources (Cesium-137 and Ra-226) containing scrap imported from an East Asian country. Not only imported scrap but also domestic scrap contained an orphan source; e.g. Okayama Prefecture event. After these accidents, several domestic meetings were held to avoid these events. Some results like a manual of radiation check for scrap iron are effective to avoid these events. In detail the expense sharing for the countermeasure works under emergency situation is not yet fixed connecting with the reversion of the responsibility.

To accomplish this activity the deep communication between East Asian Countries will brig a practical effect because the material movement by trade in this area is quite growing. So the countermeasure close to the source is most effective. The FNCA's communication would be important.

2.3 Consideration toward Solving Problems

2.3.1 Subject for Problem Solution

The matters for solution of SRS management are summarized into two aspects; domestic problem and international problem.

<Domestic Aspect>

On the domestic aspect, the correspondences in a software field are important; those are a legal framework preparation, establishments of a source management system, a radioactive waste management system, an inspection system and an emergency preparedness system, a collection mechanism of spent radiation sources and an education.

The correspondences in a hardware field are the preparation of radiation equipment and monitors; e.g. gate radiation monitors for a detection of orphan source in steel works, equipment for conditioning and stabilization of radium source used in medical area, equipment for emergency remediation.

<International Aspects>

On the international aspect, the software correspondences are a clarification of radiation source supplier's responsibility, a joining with the radioactive waste convention, an agreement of quality assurance system, a full use of custom system, an international agreement for a trouble shooting to SRS management, multi-countries' cooperation for emergency medical preparedness.

The hardware correspondences are the standardized radiation inspection monitors in customs, and a preparation of standardized radiation mark plate for clear identification of radiation source.

2.3.2 IAEA Action Plan

IAEA prepared a project of radiation source safe management based on the Code of Conduct through multi-countries' discussion. After that IAEA action plan was decided and applied to model countries' projects. In East Asian region these trials were attempted in Bangkok, Thailand in 2001 and in Tokyo, Japan in 2002. IAEA's paper for the Action Plan states three layer's (national level, regional level and international level) activities are mutually important. The detailed structure of IAEA Action Plan is described in Chapter 3.

2.3.3 Role of FNCA

The Radioactive Waste Management (RWM) field team in the Forum for Nuclear Cooperation in Asia (FNCA) arranged a project of Spent Radiation Source safe management project for the promotion of safety culture in radioactive waste management field. This kind of "horizontal" cooperation will make not only a mutual understanding but also a steering of the preparation of regulatory system and a management system. Through the workshop discussion and on-site observation the peer review was done and a mutual understanding was progressed. This kind of "horizontal" activities should be larded with a "vertical" activity of IAEA. That will cause a synergy effect with each other.

2.4 Conclusion

The solution of the spent source management should be prepared in the international stand point and framework, because, at present, various materials including radiation sources migrate all over the world and the safety framework will be accomplished under a deep consideration of experiences of past accident and an activity of international information exchange. For this purpose the activity of FNCA RWM is expected would work an accelerator for the promotion of safety culture in this region, combining the world wide activity lead by IAEA.

References

1. International Atomic Energy Agency: Code of Conduct on the Safety and Security of Radioactive Sources, December 2000.
2. Radioactive Waste Management Project Group, Forum for Nuclear Cooperation in Asia: The Consolidate Report on Radioactive Waste Management in FNCA Countries, March 2003.

3. Current IAEA Activities related to Safety of Radiation Sources

3.1 Introduction

Radiation sources are used throughout the world for a wide variety of beneficial purposes, in industry, medicine, research and education. The risks posed by these sources vary widely, depending on the amount of activities, the characteristics and chemical form of radionuclide, etc. If sealed sources are not damaged or leaking, sealed sources present a risk from only external radiation exposure. However, damaged or leaking sealed sources as well as unsealed radioactive materials may lead to contamination of the environment and internal exposure. The Goiania accident in 1987 could be listed as one of the biggest accident. After the Goiania accident, such kind of accidents occurred incessantly, Tammiku, San Savador, Nesvizh, Yanango, Hanoi, Soreq, Sarov, Samut Prakarn, etc. These accidents caused 266 individual exposued, 39 fatalities and serious economic consequences.

Recently, the International Atomic Energy Agency (IAEA) has been a growing awareness of these kind of problems associated with radiation sources and has begun several activities. One of the biggest activities concerning to this problem is the Action Plan on the Safety of Radiation Sources and Security of Radioactive Materials. The main purpose of the action plan is to enable the IAEA to develop and implement activities that will assist member states in maintaining and where necessary, improving the safety of radiation source and the security of radioactive materials over their life cycle.

In this report, the background, chronology, contents of the action plan were reviewed.

3.2 Chronology of Development of Action Plan

3.2.1 Dijon Conference

From 14 to 18 September 1998, the international conference on Safety of Radiation Sources and Security of Radioactive Materials took place in Dijon, France. This conference was held intending to address the growing concern about the safety of radiation sources and the security of radioactive materials and to realize the scale and extent of the problem.

The conclusions of conference could be summarized as follows:

(a) radiation sources should not be allowed to drop out of the regulatory control system (meaning that the regulatory authority must keep up-to-date records of those responsible for each source, monitor transfers of sources and track the fate of each source to the end of its useful life);

(b) efforts should be made to find radiation sources that are not in the regulatory authority's inventory (because they were in the country before the inventory was established, or were never specifically registered/licensed or were lost, abandoned or stolen); and

(c) efforts to improve the detection of radioactive materials crossing national borders and moving within countries by carrying out radiation measurements and through intelligence-gathering should be intensified (optimum detection techniques need to be developed, and confusion would be avoided if international agreement could be achieved on quantitative levels that would trigger investigations, for example, at border crossings).

3.2.2 Adoption of Action Plan

The IAEA General Conference held right after Dijon conference requested for the report from experts. Expert meetings were held at Buenos Aires and Washington in December 1998 and January 1999, respectively. In February 1999, the Secretariat submitted to the IAEA Board of

Governors the expert report. The report was taken up by the Board at its March 1999 session. The action plan was developed through the consultants meeting (Prague, May 1999) and the technical committee (Vienna, July 1999). In September 1999, the Board approved the action plan and requested the Secretariat to implement it. In October l999, the action plan was endorsed by General Conference [GC(43)RES/10] and its implementation started by the IAEA Secretariat.

3.2.3 Buenos Aires Conference

The International Conference of National Regulatory Authorities with Competence in the Safety of Radiation Sources and the Security of Radioactive Material, which was held in Buenos Aires from 11 to 15 December 2000, was organized as one of the actions in the action plan which was envisaged under the topic "Information Exchange". The Buenos Aires conference, hosted by the Government of Argentina, was attended by 89 regulatory officials from 57 Member States, 31 of those Member States being participants in the IAEA Model Projects for the strengthening of radiation protection infrastructure, which cover 52 Member States.

A number of "major findings" were concluded at the Buenos Aires Conference. The key words of major findings were listed as follows:

-Education and training — the key factors
-Difficulties in establishing effective systems for the regulatory control of radiation sources
-Maintaining up-to-date knowledge of the situation of the radiation sources
-Effective independence of the regulatory authority
-Arranging for the insurance of radiation sources
-Learning from accidents
-Universal system of labeling
-Radiation source registry
-Continuity of control of radiation sources over the operational lifetime
-Return of disused sources
-Arrangements for handling orphan sources
-Emergency arrangements
-Prevention of the criminal misuse of radiation sources
-Technical assistance by the IAEA
-Immediate future actions to ensure the safety and security of radiation sources
-International follow-up conferences at frequent intervals

3.2.4 Revision of Action Plan

In March 2001, the Board of Governors noted these major findings and requested the Secretariat to assess the implications and to adjust the action plan in the light of those major findings.

In accordance with this request, a consultants' meeting at the end of May 2001 produced a draft revised action plan on the safety and security of radiation sources. This was reviewed and amended during a Technical Committee Meeting, 27-29 June 2001. The revised action plan [GC(45)/12&GC(45)/RES/10] was approved by the Board of Governors and endorsed at 45th General Conference in September 2001.

3.3 Outline of the Revised Action Plan

3.3.1 Scope and Purpose

All components included the action plan should strengthen safety of radiation sources and security of radioactive materials, fit with existing the IAEA sub-programmes and maximize use of existing IAEA initiatives, and identify methods to implement the recommendations in a manner consistent with the views of the Board of Governors.

Regulatory components are aimed at strengthening national regulatory programmes, i.e. systems for notification and authorization (licensing and registration), and responding to emergencies, and regaining control over orphan sources. Moreover, training is an essential component of all of these activities. Supporting components of the action plan are aimed at persons or organizations having an interest in seeing that the orphan source problem is addressed.

3.3.2 Document Outline

The previous Action Plan was structured to cover seven areas, and this structure was still considered as valid. The order of them does not imply any priority.

1) Regulatory Infrastructure
2) Source Management and Control including the Management of Disused Sources
3) Categorization of Sources
4) Response to Abnormal Events
5) Information Exchange
6) Education and Training
7) International Undertakings

Brief explanations of the new actions are described in the following section.

3.3.3 Seven Areas of the Action Plan

(1) Regulatory Infrastructure

1) Develop and implement a mechanism for feedback from all peer review services.
2) Develop a methodology to enable member states to perform self assessments of their radiation protection infrastructures.
3) Encourage self assessments to identify weaknesses in radiation protection infrastructures.
4) Promote mutual assistance using regional networks.

(2) Source Management and Control

1) Facilitate a continuing dialogue among manufactures, regulators and users on:
    a) export and return of sources
    b) definition of operation lifetime of a source
    c) design and manufacture of sources in accordance with ISO standards
    d) radioactive source inventories
2) Develop guidance on a quality management system related to the life cycle of Category 1 and 2 sources

(3) Categorization of Sources

1) Review how the Categorization of Sources is being used, and consider revising it on the basis of this review

(4) Response to Abnormal Events

1) Encourage member states to use the "National Strategies" document to perform an evaluation of the threat, risk, and the potential effects from orphan sources
2) Finalize arrangements for making the Emergency Preparedness Review Service available to member states
3) Prepare a TECDOC on conducting radiological emergency response exercises with associated materials
4) Complete the establishment of ERNET (Emergency Response Network)
5) Develop standardized training material on medical response preparedness
6) Prepare a TECDOC on public information management during radiological emergencies

(5) Information Exchange

1) Organize a Second International Conference of National Regulatory Authorities in 2004.
2) Make the RADEV (database on unusual radiation events) available to member states to establish their own database.
3) Encourages member states to use RADEV.
4) Clarify, modify and rationalize the objectives and interrelationships among the different IAEA databases.
5) Establish and support regional networks to promote further informal mutual assistance.
6) Consider establishing a list server to facilitate communication among those concerned with radiation safety.
7) Create an integrated web-site devoted to the safety and security of radiation site.
8) Apply the lessons learned from all the information exchange processes in the development and revision of training material.
9) Develop an adaptable communications took kit to enable member state to effectively communicate key messages regarding the safety and security of sources

(6) Education and Training

No new actions were proposed, although following 4 items were listed in the previous action plan.

1) Postgraduate educational courses in Arabic, English and Spanish were implemented.
2) More than 30 national and regional practice-specific training courses have been implemented.
3) Complete the standardized practice-specific training modules covered by Category 1 and 2 sources.
4) A "Strategic Approach" to Education and Training in Radiation and Safety (Strategic plan 2001-2010) has been prepared.

(7) International Undertaking

1) Consult with member state on their experiences in implementing the Code of Conduct to compile and disseminate a list of best practices. Following 1), convene a meeting to consider the necessity of further actions relating the Code of Conduct. Follow up on the discussions regarding possible responsibilities of exporting states.

Explore the possibility of developing and implementing a universal system of labelling such that any member of the public is immediately aware of the dangers.
Provide technical advice on the request to non-member states as appropriate and in accordance with previous Board decisions.

3.4 Asian Regional Activities

The action plan on the safety of radiation sources and the security of radioactive materials includes the organization of regional workshops on specific topical issues to target regional needs and provide relevant information to the manufacturers and users of sources and related devices. Based on this action plan, two regional workshops were held at Bangkok, Thailand in 2001 and at Tokyo, Japan in 2002.

The workshops provided an opportunity to share experience with:

1) Loss of control over radiation sources: Problems dealings with securing radiation sources, with returning or disposing of radiation sources or with finding radiation sources in the public domain are all appropriate topics.
2) Problems with maintenance of devices that may lead to unsafe use: This includes such issues as unavailability of spare parts, insufficient training on equipment maintenance, lack of support from manufacturer's representatives, long waiting times for repairs or difficulties with funding.
3) Issues for gauges that may have been installed many years ago: Loss of corporate memory or labeling damage from normal industrial wear and tear may have resulted in such sources being forgotten.
4) Lack of proper management of spent or disused sources, with such sources being left in inappropriate locations for extended times.
5) National or regional plans to recover control over orphan sources: The roles of such components as inventory databases, administrative searches, physical searches or border/scrap yard monitors need to be discussed and defined.

3.4.1 Thailand Workshop in 2001

The Thailand workshop was held with the participation of IAEA scientific secretary, Bangladesh, Cambodia, China, India, Indonesia, Malaysia, Myanmar, Pakistan, the Philippines, Sri Lanka, Thailand, Viet Nam (12 countries) at Bangkok, August 6-10, 2001.

Through the workshop, the outline of IAEA action plan was introduced by IAEA scientific secretary. Each participated member states presented its current status of regulatory infrastructure, management of disused sources, categorization of radiation sources, response to abnormal events, information exchange and education and training.

3.4.2 Japan Workshop in 2002

The Japan workshop was held with the participation of IAEA scientific secretary, Bangladesh, India, Indonesia, Japan, Korea, Malaysia, Pakistan, the Philippines, Thailand, Viet Nam (10 countries) at Tokyo, November 11-15, 2002.

In addition to the introduction of IAEA action plan and the presentation of each participating country, the exercise on national strategy for orphan source problem was executed as a group discussion. The discussion proceeded on the basis of experiences of each participant referring to the papers provided by IAEA. The workshop not only provided the participants a new outlook to review the effectiveness of the regulatory system with respect to the control and management of disused and orphan sources, but combined the regional activities and the IAEA activities with a synergy effect.

3.5 Conclusion

The action plan pointed out the key common elements which would have the greatest part to improve the regulatory infrastructure, to control disused sources, to avoid orphan source problems, to respond to abnormal events and so on. It is deeply desired to implement the action plan at all stages of regulatory body, manufacturers and distributors of source, and users.

References

1. International Atomic Energy Agency: “Safety of Radiation Sources and Security of Radioactive Materials”, Proceedings of a conference, Dijon, France, 14-18 September 1998.
2. International Atomic Energy Agency: “National Regulatory Authorities with Competence in the Safety of Radiation Sources and the Security of Radioactive Materials”, Proceedings of international conference, Buenos Aires, Argentina, 11-15 December 2000.
3. International Atomic Energy Agency: Revised action plan for the safety and security of Radiation Sources, GOV/2001/29-GC(45)/12 attachment, 2001.
4. International Atomic Energy Agency: Code of Conduct on the Safety and Security of Radioactive Sources, December 2000.
5. International Atomic Energy Agency: Proceedings of Workshop on the Safety of Radiation Sources and Security of Radioactive Materials, Tokyo, Japan, 11-15 November 2000.

4. Regulatory System and Lesson Learned from Accidents in Japan

4.1 Outline of Regulation System in Japan

Radioactive materials other than nuclear material or nuclear fuel are subject to regulation by "the Law Concerning Prevention of Radiation Hazards due to Radioisotope etc". Items listed below are provided in the law.

- Permission and notification for use of radioisotopes
- Permission for selling and leasing business
- Permission for disposing business
- Approval of design for mechanism of radioisotope equipped device and confirmation of its mechanism
- Restrictions on possessing, transferring, receiving and handling of radioisotopes
- Requirements in technical standards for permission
  - Requirements for users:
    Condition of site, structure and equipment of facilities for using, storage and disposing
  - Requirements for sellers and leasers
    Condition of site, structure and equipment of facilities for refilling, storage and disposing
  - Requirements for disposers
    Condition of site, structure and equipment of facilities for refilling waste, storage of waste and disposal
- On-the-spot inspection by the regulatory authority
- Facility inspection by Nuclear Safety Technology Center
- Periodical inspection by Nuclear Safety Technology Center

4.2 Obligations of Licensed Users

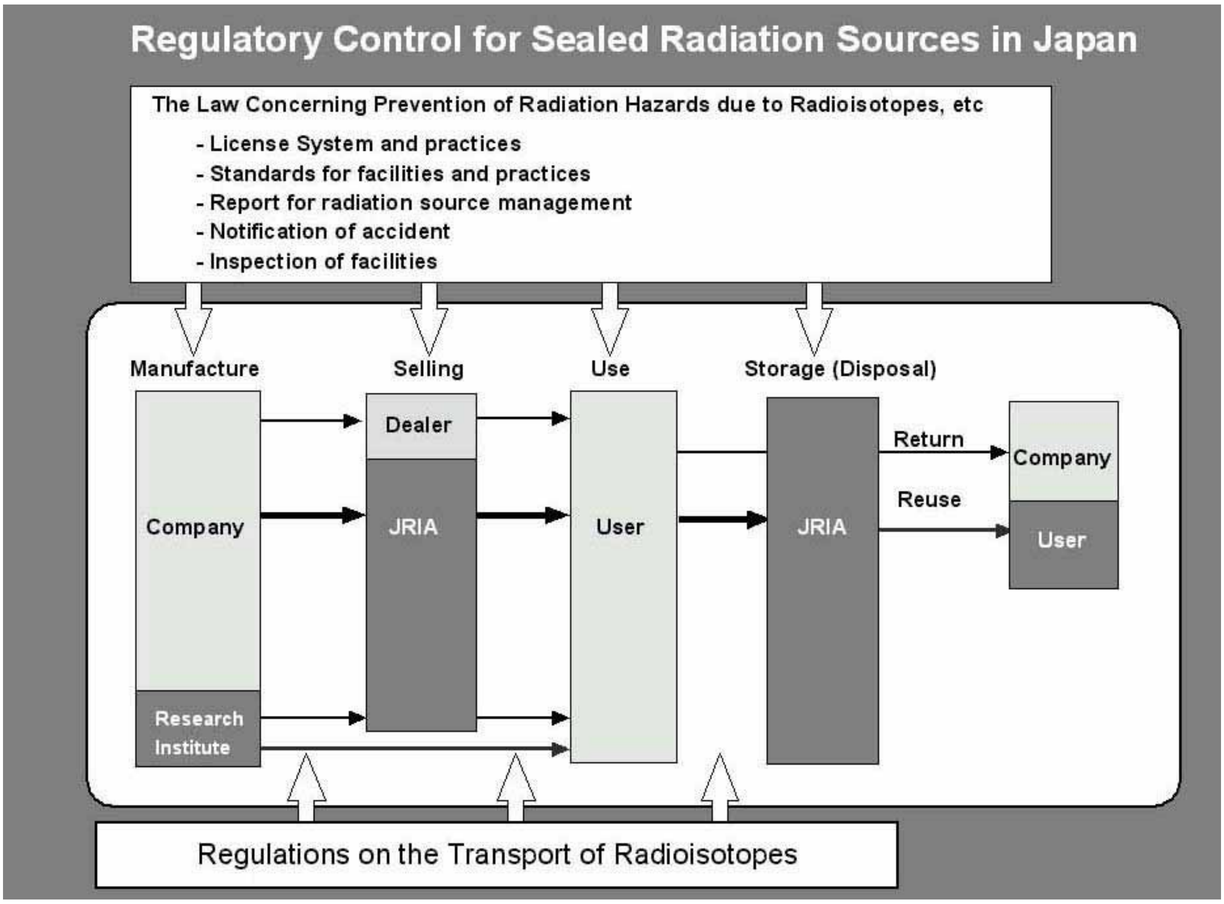
Obligations of licensed users provided in the law are as follows.

- Ensuring the necessary technical standards
- Executing administrative obligations
  - Monitoring
  - Drawing up and submitting the inner rules for the prevention of radiation hazards
  - Education and training
  - Checking up health of persons entering the facilities

- Keeping record of use, etc.
- Reporting about discontinuation of use etc, and taking necessary measures to prevent radiation hazards
- Appointing a supervisor of radiation protection
- Reporting about accidents (to policemen)
- Taking measures at the time of danger
- Reporting about anything necessary for the enforcement of the law

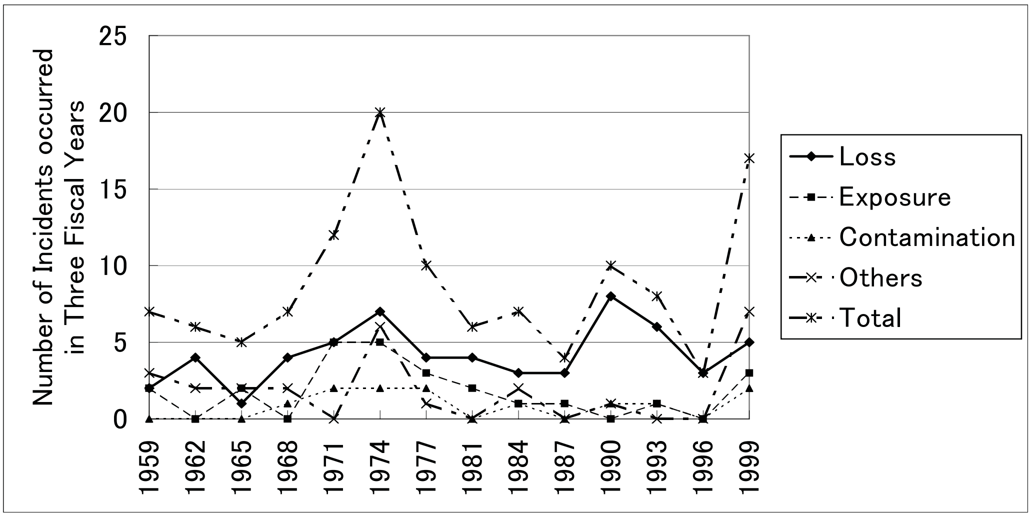
4.3 Regulatory System on Sealed Radiation Sources

Outline of distribution of sealed source and regulatory system on manufacture, selling, use, and disposal of sealed radiation sources is shown in the figure below.

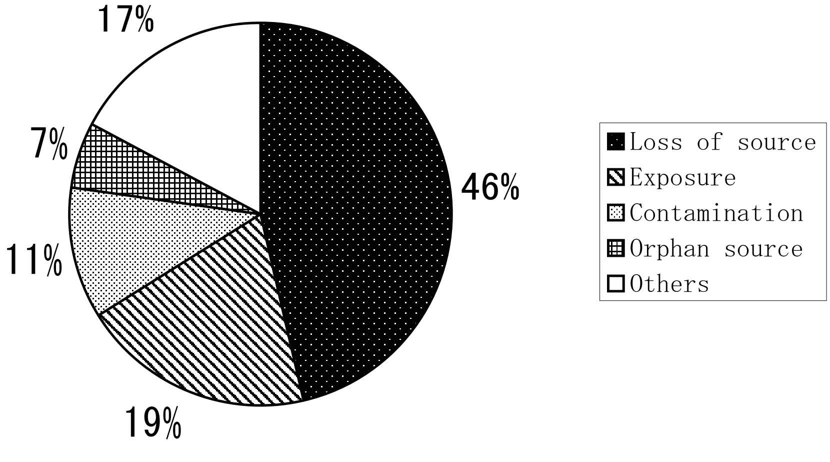


4.4 Status in the Incidents on Radiation Sources Occurred in Japan

131 incidents related to radiation sources were occurred for 43years of the periods from 1958 in fiscal year to 2001. Temporal change in number of incidents is shown in the following figure. From the figure the peak of number of incidents were found in the middle of 1970's which were coincided to the peak of rapid increase of number of authorized user. The tendency of the increase is also found in these 3 years.



Type of incidents can be categorized into Loss of source, Excess exposure, contamination, orphan source, and others which proportion of number of incidents are shown in the following figure.



4.5 Incident of Loss of Radiation Source

Loss of radiation source is one of the most serious problems because this type of incident occurred most frequently and may cause fear of radiation exposure in surrounding peoples.

More than half of incidents related to loss of radiation source were occurred in hospitals or clinical facilities and about 13% of the incidents were occurred in research laboratories, about 10% were occurred in facilities of university, and about 10% were occurred industrial plants.

Proportions of radionuclides of radiation sources related to the incidents of loss or theft are as follows:

Radionuclide	Proportion of incident occurred	Type of source	Activity
Ra-226	38 %	Needle or tube	37－2000 MBq
Co-60	21 %	Medical use	37 – 740 MBq
Ni-63	16 %	ECD cell for GC	370 – 555 MBq
Ir-192	9 %	Medical use	

Needle and tube type of Ra-226 sources used to be frequently utilized for therapy in hospitals. In the many cases of the incident, plural needles of the source were used at once and one of them might be lost after the therapy because of its small size. In the recent case, sources of Ra-226 became to be disused and someone might disposed the source without being aware of its radioactive.

Possible causes of the incidents of loss are generally considered to be as follows,

- Handling by person who has insufficient knowledge of radiation protection or regulation according to law
- Lack of specialist of radiation protection in hospital
- Negligence of record related to use of source

As a unique case, 92 packages of radioactive materials including total activity of about 6GBq were lost due to an airplane crash occurred in 1985. About 65% of packages were recovered by searching activity of experts.

As measures against loss of source, frequent inspection of management of radiation sources by regulatory authorities and education/training program for supervisor of radiation protection and individual user would be effective.

4.6 Incidents of Orphan Sources

Incidents of orphan sources were occurred frequently in these years. Because the companies of steel works or scrap dealers become aware of significance of orphan sources, many of them were equipped with radiation monitor. This has improved the situation of finding orphan sources.

An incident occurred in April,2000 in Wakayama prefecture was the first serious accident in Japan. In the beginning of this accident, radioactivity in the scrap container imported from foreign country was detected by gate monitor equipped in the steel works. After several days, analysis with portable germanium detector revealed that Cs-137 and Am-Be or Ra-Be would be contained in the scrap. The frequent meetings were held to discuss how to recover the sources and prepare the operation. It took almost one month to recover the 230MBq of Cs-137 source and Am-241(1.8GBq)-Be neutron source from the scrap in safety.

The second incident was occurred in Kobe city. Ra-226 source for medical use was found in metal scrap. After the investigation by the police, it was found that the source had been disposed illegally by a hospital.

The third incident was that Cs-137（5.5 GBq）was found in container of stainless steel scrap imported in Yamaguchi prefecture in March 2001. The workers of scrap dealer made efforts to find out the source and recover it by themselves. The dose to the workers during the recovery of source was estimated to be less than 110 μ Sv.

Responding to the series of the incidents occurred in 2000, Japanese government took measures against orphan sources. Five ministries collaborated to develop a document for measures in August, 2000. An ad hoc advisory committee on appropriate management of radioactive materials was established. According to the results of discussion, it should be promoted that custom offices in ports should be equipped with radiation detectors.

An international cooperation project related to safe management of spent radiation sources in the Forum of Nuclear Cooperation in Asia (FNCA) was proposed by the Minister of the Science and Technology Agency. The conferences were held in various Asian countries to discuss issues related to safety management of spent sources between member of regulatory authorities of the countries and Japanese experts.

Various organizations other than the government also took measures against orphan sources.
A committee of Japan Health Physics Society developed a report in which status and useful information about orphan sources in Japan and proposed measures are described.
Manual for dealing with orphan source developed by voluntary action of scrap dealers in corporation with expert groups was published in April, 2002. International activities on safety and security of radiation sources were actively developed and promoted by an action plan of IAEA.

5. SRS Management System in Japan

5.1 Current Status of Using of Sealed Radiation Sources in Japan

Many kinds of sealed radiation sources have been used in various fields, research, industry, medical, etc. **Table 1** and **Table 2** show the number of users of sealed radiation sources in Japan. The number of users of sealed radiation sources is about 4,100 (as of March 31, 2001).

Most of the sealed radiation sources are obtained from overseas suppliers, but some particular sources are supplied by Japan Atomic Energy Research Institute that is only domestic manufacturer. Those sealed radiation sources are carried in to Japan Radioisotope Association (JRIA) facility at first, and they are delivered to the end users after making required inspection tests, and packing.

Table 3 shows major sealed radiation sources and its purposes of use. And **Table 4** shows amounts of major sealed radiation sources distributed in 2000. Major sealed radiation sources are Co-60, Cs-137, and Ir-192. Co-60 is used for radiation therapy in hospital and clinic, and for medical device sterilization in industrial firms. Medical devices, such as dialyses, syringe and needles, gloves, suture are sterilized by the gamma ray irradiation with those cobalt sources. A total activity installed of such sterilization plant amounts from 74PBq to 185PBq. Cs-137 is used for irradiation of transfusion blood. Radioactivity of the source is from 74TBq to 111TBq. Ir-192 is used for radiography apparatus that is Non-destructive tests. Radioactivity of the source is 370 GBq each. A number of Ir-192 is also used as brachytherapy for after-loading.

The other sealed radioisotopes are used for various apparatus. For example, thickness gauges, level gauges, density gauges, gas chromatographs. Ni-63 has been used in the electron capture detector (ECD) of gas chromatographs. Neutron sources of Cf-252 less than 3.7MBq have been installed in many moisture gauges and others. **Table 5** shows number of isotope gauges in use by category of organizations.

The licensee should submit the report concerning management of sealed radiation sources once a year, the report should be stated about the result of check of facility condition and the contents of sealed radiation sources (type, the number, activity, etc.). Tables 1, 2 and 5 show the summary inventory of users.

5.2 Collection System of SRS in Japan (JRIA Collection Service for SRS)

SRS, installed to instruments, should be returned to the instrument manufacturer, or to JRIA. Some SRS are transferred to the instrument manufacturer first, finally returned back to JRIA. JRIA is a non-profit organization that distributes radioisotope products to domestic users and manages radioactive waste generated from user's facilities.

Figure 1 is the flow of the management of SRS in Japan. On arrival at JRIA facility the SRS are unloaded and then separately classified, checked and tested before being assigned to the proper waste treatment route described below.

a) Reuse and Recycle

Some kinds of SRS may be transferred to reuse route after confirming the quality required for its application. Certain kinds of neutron source and high-energy gamma-ray source had been reused to the RI loaded industrial gauges.

b) Return to the foreign Manufacturer or Distributor

JRIA negotiates with the foreign manufacturer or distributor for returning the SRS as much as possible. If possible, the SRS are shipped to the manufacturer after confirmation of the quality required for its reuse.

c) Storage

SRS incapable to be transferred to recycling and returning route has to be stored in the storage facility equipped enough shielding against radiation. Some SRS such as Ra-226, H-3, are packed into specially treated container for long term storage.

Procedures of JRIA collection service for SRS are preceded by three steps as follows:

-Step 1: Contact with JRIA

At first, users ask JRIA to collect SRS by "SRS collection request sheet". JRIA asks the user a few simple questions about user's SRS in order to confirm the safe collection procedure according to the detail of SRS as follows:

a) Content of user's license
b) Specification of SRS (if need, asked some question about detail of SRS)
c) Method of packing and transportation
d) Schedule of transportation
e) Dose estimation

-Step 2: On-Site Customer Services

After the radiation dose is monitored and the surface contamination is checked, the SRSs are sorted according to radionuclides or source activity and packed in to the proper transport container by JRIA (if necessary, extract SRS from instruments or gauges). Some low level SRS (for example, Ni-63 of ECD) are to be transported by user's responsibility. Some instruments and gauges equipped SRS (for example, level gauge) are transported by manufacturer.

-Step 3: Handling Process and Storage at JRIA

On arrival at JRIA facility the SRS are ordinary treated as follows:

a) Unloaded at JRIA facility
b) Checked the consignment document
c) Tested and treated for appropriate waste stream (if necessary, some are repacked)
d) Storage (some SRS are packaged within a suitable container for long term storage).

Finally, SRS assessed the appropriate treatment route: Recycle, Reuse, Return to Manufacturer, or long term Storage.

Through all procedure, the user and JRIA should record matters prescribed by the Radiation Hazards Prevention Law.

5.3 Disposal of SRS

With regarding to disposal of radioactive waste, including SRS generated from medical, industrial and research facilities, the dedicated subcommittee was organized under Atomic Energy Commission at 1995 to submit fundamental concept of these issues. And the other subcommittee was organized under Nuclear Safety Commission to discuss conceptual design and acceptance criteria for disposal facility.

Table 1 Number of Users by Category of Organizations

(as of March 31,2001)

Category	**Sealed Radioisotopes**
Total	4,059
Hospitals & Clinics	450
Educational Organizations	338
Research Institutions	524
Industrial Firms	1,843
Other Organizations	904

Table 2 Number of Users of Major Sealed Radioisotopes by Category of Organizations

(as of March 31, 2001)

Category Major Nuclides	Total	ratio*(%)	**Hospitals &Clinics**	**Educational Organizations**	**Research Institutions**	**Industrial Firms**	**Other Organizations**
3H	48	1.2	-	7	17	16	8
14C	9	0.2	3	1	2	3	-
55Fe	83	2.0	-	10	14	58	1
57Co	124	3.1	9	65	34	14	2
60Co	593	14.6	252	50	57	219	15
63Ni	2564	63.2	21	224	462	942	915
85Kr	324	8.0	-	2	18	301	3
90Sr	323	8.0	141	27	23	127	5
109Cd	54	1.3	-	8	8	38	-
119mSn	44	1.1	-	26	18	-	-
125 I	30	0.7	21	2	5	2	-
137Cs	522	12.9	143	58	62	213	46
147Pm	153	3.8	-	4	13	135	1
170Tm	11	0.3	-	2	5	3	1
192 Ir	243	6.0	116	7	9	108	3
198Au	72	1.8	67	-	5	-	-
204Tl	12	0.3	-	3	6	3	-
210Po	12	0.3	-	5	6	1	-
222Rn	0	0		-	-	-	-
226Ra	137	3.4	60	23	31	17	6
241Am	327	8.1	11	43	46	220	7
252Cf	63	1.6	1	10	21	28	3

* Ratio to the total number of users (4059) of sealed radioisotopes. (See Table1)

Table 3 Major Sealed Radiation Sources distributed by JRIA

Medical use

Source type	Nuclide	Typical Unit	Purposes of use
Large γ Sources	Co-60	111TBq	Tele-therapeutics
	Cs-137	111TBq	Blood Irradiator
Medium & Small γ Sources	Co-60	75GBq (×3 pieces)	Remote after-loader
	Cs-137	740MBq	Brachytherapy
	Cs-137	26.6GBq	Remote after-loader
	Ir-192	370GBq	Remote after-loader
	Ir-192	370MBq	Brachytherapy
	I-125	7.4GBq	Bone Mineral Analyzer
	Gd-153	3.7GBq	Bone Mineral Analyzer
	Au-198	185MBq	Brachytherapy
β Sources	Sr-90	370MBq	Ophthalmic apparatus

Research & Industrial use

Source type	Nuclide	Typical Unit	Purposes of use
Large γ Sources	Co-60	370TBq	Radiation processing
		18.5TBq	Radiography
Medium & Small γ Sources	Co-60	37GBq	Level Gauge
	Cd-109	185MBq	Fluorescent X-ray Analyzer
	I -125	7.4GBq	Scientific research
	Cs-137	18.5GBq	Industrial Gauges
	Eu-152	37MBq	Reference Source
	Yb-169	185GBq	Radiography
	Ir - 192	370GBq	Radiography
	Am-241	18.5GBq	Industrial Gauges
β Sources	H-3	4.8GBq	Gas Chromatograph(ECD)
	Ni-63	370MBq	Gas Chromatograph(ECD)
	Kr-85	15.5GBq	Thickness Gauge
	Sr-90	740MBq	Industrial Gauges
	Pm-147	13GBq	Thickness Gauge
	Tl -204	185MBq	Reference Source
α Sources	Am-241	□3.7MBq	Smoke Detector
Neutron Sources	Am-241/Be	18.5GBq	Moisture Gauge
	Cf-252	18.5GBq	Industrial Gauges
Positron Sources	Na-22	11.85GBq	Positronium study
	Ge-68	370MBq	Positron Camera
X-ray Sources	Fe-55	1.66GBq	Fluorescent X-ray Analyzer
	Co-57	925MBq	Moessbauer Spectroscopy
	Sn-119m	370MBq	Moessbauer Spectroscopy
	Sm-151	1.85GBq	Moessbauer Spectroscopy
Target	H-3	370GBq	Neutron Generator

Table 4 Amounts of Major Sealed Radioisotopes Distributed by Category of Organizations in Fiscal Year 2000

〔MBq〕

Category / Nuclides	Total	Hospitals & Clinics	Educational Organizations	Research Institutions	Industrial Firms	Other Organizations
^{3}H*	68,476,000	-	68,476,000	-	-	-
^{22}Na	5,550	-	-	5,550	-	-
^{51}Cr	0	-	-	-	-	-
^{55}Fe	6,845	-	-	-	6,845	-
^{57}Co	39,035	-	26,085	11,655	1,295	-
^{60}Co	1.2005E+11	1,792,650,000	1,110	6,573,525,605	1.11685E+11	888
^{63}Ni	289,710	-	-	-	289,710	-
^{68}Ge	13,510	10,687	-	2,238	-	585
^{85}Kr	1,532,540	-	-	-	1,532,540	-
^{90}Sr	13,690	-	-	-	13,690	-
^{109}Cd	1,628	-	-	-	1,628	-
^{119m}Sn	740	-	370	370	-	-
^{125}I	7,410	7,400	-	-	-	-
^{137}Cs	170,717,214	127,795,073	-	130,055	5,610,236	37,001,850
^{147}Pm	938,135	-	-	185	937,950	-
^{151}Sm	-	-	-	-	-	-
^{153}Gd	3,700	3,700	-	-	-	-
^{169}Yb	25,382,000	-	-	-	25,382,000	-
^{192}Ir	560,602,279	112,752,579	1,113,700	5,180,000	441,556,000	-
^{198}Au	330,595	330,595	-	-	-	-
^{241}Am	192,400	-	-	-	192,400	-
^{241}Am+Be	5,550	-	-	1,850	3,700	-
^{252}Cf	54,500	-	-	-	54,500	-

* Unsealed Radioisotope.

Note: The Radionuclides below 100MBq are omitted.

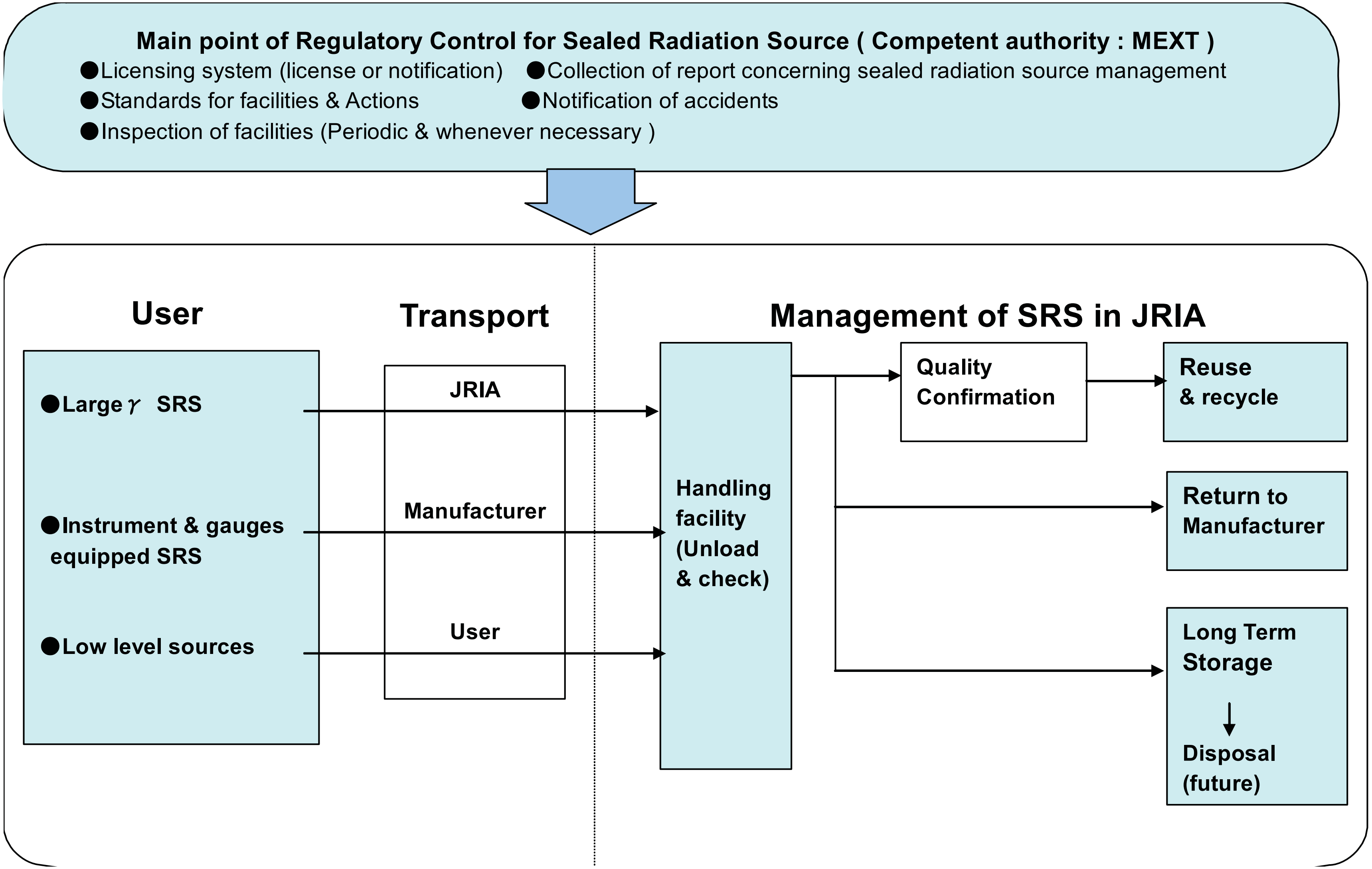


Fig.1 SRS Management in Japan

6. Spent Sealed Radiation Source Management in the Philippines

6.1 Introduction

The Science Act of 1958 created the Philippine Atomic Energy Commission, presently known as the Philippine Nuclear Research Institute (PNRI), under the Department of Science and Technology (DOST). The PNRI is tasked with the dual role of promotion and control of the peaceful application of atomic energy. To carry out its mandate of regulation and control on the use of radioisotopes in various fields, the PNRI had promulgated and issued specific regulations known as the Code of PNRI Regulations. The PNRI is also responsible, among others, for the management of radioactive wastes generated by all authorized users of radioisotopes, including about 200 medical and industrial users.

The use of both radiation and radioisotopes in the Philippines has been increasing steadily over the past decade. Recent developments in the field of nuclear energy applications have indicated the need to further strengthen radiation protection infrastructures including those for radioactive waste management in many countries including the Philippines. The goal of any government policy for the management of radioactive waste from it's nuclear application program is to protect the health and safety of those working in these programs, the general public and the environment.

The PNRI with the technical assistance provided by the International Atomic Energy Agency establish a low level radioactive waste management facility in the country and subsequently upgraded its waste management infrastructure.

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6.2 Sources of Radioactive Waste

The number of PNRI licensees which are essentially the waste generators are shown in **Table 1**. The licensees are categorized according to their specific type of application. It will be noted in **Table 2**, which shows distribution of these licensees by region that National Capital Region (NCR), or Metro Manila has the largest number of licensees.

Table 1 Number of Licensed Organizations as of May 2002

Type of Licensee	Number	Percent (%)
Commercial	41	13.1
Nuclear Medicine/RIA	25/22	15.7
Research/Education	24	7.7
Brachytherapy	10	3.2
Teletherapy	17	5.4
Industrial Radiography	28	8.9
Nuclear Gauges	102	45.7
Cyclotron Facility	1	0.3
TOTAL	313	100

Table 2 Geographical Distribution of Licensed Organization (End of May 2002)

Region	No. of Authorized Users
I	2
II	-
III	25
IV	44
V	2
VI	8
VII	15
VIII	2
IX	2
X	4
XI	10
XII	4
CARAGA REGION	2
ARMM REGION	-
CAR REGION	4
NCR REGION	189
TOTAL	313

Table 3 Distribution of Licensed Users According to Geographical Location and Classification as of May 2002

Region	MATERIAL LICENSEES						Facility	TOTAL
	Commercial	Hospital	Industrial Radiography	Research	Physician	Industry	Radiation Producing Accelerator	
I		1				1		2
II								
III		1	2	1		21		25
IV		2	1	2		39		44
V		1				1		2
VI		3		1	1	3		8
VII		5		4		6		15
VIII						2		2
IX		1				1		2
X						4		4
XI		5				5		10
XII				1		3		4
CARAGA						2		2
ARMM								
CAR		1				3		4
NCR	41	54	25	15	1	52	1	189
TOTAL	41	74	28	24	2	143	1	313

Table 4 Spent Sealed Sources as of EO2001

Radionuclides	No. of Units	Range of Activity per Unit
Cs-137	140	2MBq-18.5 TBq
Co-60	154	37 MBq-92.5 TBq
Ir-192	33	
Sr-90	125	74 MBq-740 MBq
Co-57	3	
Ba-133	1	
Fe-55	11	740 MBq
Ra-226	263	37 MBq- 481 MBq
Am-241	919	370 kBq
H-3	15	
Kr-85	8	
Ni-63	346	370 kBq
Pm-147	18	2.67 MBq – 1.29 GBq
Tl-204	8	
Cd-109	1	
Po-210	208	37MBq – 740 MBq
Pb-210	4	47 MBq
C-14	1	Less than 370 kBq
Ce-144	1	Less than 370 kBq
Zn-65	1	Less than 3.7 MBq
Pu-238	10	

6.3 Waste Management Strategies

Based on the waste arisings and waste characteristics described in the previous section, there are essentially two basic waste treatment and conditioning options that are adopted. These are:

- Waste collection and packaging for decay storage for final disposal as ordinary refuse in a conventional waste dump
- Waste collection, segregation, treatment applying volume reduction where appropriate, conditioning and packaging followed by interim storage awaiting disposal in a final repository

Conditioning by cementation prevents unauthorized removal of the source because of the bulk weight and robust nature of the package. It also provides a barrier against loss of containment of radioactive material. Such packages would weigh about 450 kg to 600 kg. Removal and transportation would require mechanical equipment, e.g. fork lift.

On the basis of spent sealed sources collected and stored at the PNRI site in the past, it is estimated that this would result to around 30 – 40 drums of conditioned spent sealed sources, corresponding to volumes of 6 – 8 cu. M. The new trench translated to an additional storage capacity equivalent to five years waste generation volume. Two (2) more trenches are proposed to be constructed which would translate further to an additional ten (10) years waste generation capacity. It is hoped that at the end of this period, a final site would have been established.

6.4 Conditioning of Radium Sources

Radium sources have been used for medical as well as other applications, not only in the Philippines, but also all over the world. In a few countries, their use have even predated the establishment of national regulatory authority thus creating problems later on related to lack of regulatory control. Because of their undesirable characteristics, the international radiation protection community has repeatedly discouraged its continued use. Most countries have already replaced them with other radiation sources. The long half-life of radium makes it necessary to eventually dispose of the sources in deep geological repositories. However, these will not be available for many years to come (e.g., 40-50 years). In order to avoid accidents that can arise from improper storage, it is necessary to collect the sources and to condition them for safe storage until disposal can be made.

The IAEA programme was established in 1991, with the specific purpose of assisting Member States in their efforts to avoid situations that might result in unnecessary exposure or accidents with spent sealed sources. The program includes, inter alia, one activity specifically related to the conditioning of spent radium sources for safe storage. The radium conditioning approach, developed by the IAEA jointly with the Austrian Seibersdorf Laboratories, comprised the encapsulation of radium sources in a stainless steel capsule followed by placing the capsule in a steel lined lead container and placing the package inside a 22 L steel drum filled with concrete in such a way that future retrieval of the capsule for disposal is possible.

The Agency’s assistance to Member States in the field of radium conditioning can be classified in three major categories:

- Active involvement – An expert team (contracted by the IAEA) carries out the conditioning of all identified and collected radium sources. This approach is adopted where the infrastructure in the country is not fully developed, only modest experience with sealed sources management exists and experience with radioactive sources encapsulation has not been gained in previous activities.

- Advisory involvement - The Agency will only provide advice in the form of documents and, if needed an expert who can provide on-the-spot advice. In this case, the Agency role is more of an advisory in nature. This approach is adopted where the Member States have the necessary infrastructure and technical capability to carry out such a task on their own. Further assistance is possible in terms of transfer of know-how, training for a particular skill and providing specific equipment.

- Information Technology involvement - This approach .is adopted for a country with a fully developed infrastructure and experience with encapsulation of radioactive material in stainless steel capsules for any purpose. The Agency’s involvement is limited to providing documentation, technical procedures and advice.

The Philippines participated in the above program under an IAEA advisory involvement scheme in which a national team was identified to undertake the project with the IAEA providing an expert and specialized tools/materials/equipment. The national team is composed mainly of technical staff members of the Radiation Protection group of the PNRI responsible for the routine operation of the centralized facility for radioactive waste management in the country. The original project schedule was 18-22 September 2000, was moved to March 26 – 30, 2001 due to some delay in the shipment of the lead shield. Mr. Qamar Ali of Pakistan served as IAEA Expert for the Philippine radium-conditioning project.

6.4.1 Radium Project Action Plan

The status of radium sources in the country was validated and confirmed through the issuance of a PNRI Information Notice No. 99-01. The notice informed all concerned users and licensees that the regulatory body will no longer authorize the use of Ra- sources for human use effective January 31, 2000. Authorized users of radium sources were encouraged to transfer all these sources to the centralized waste treatment facility for safe and proper management. In spite of the deadline imposed by the PNRI Information Notice, the last batches of licensed Ra sources from the Philippine General Hospital Cancer Institute in Manila and the Ledesma Cancer Clinic in Iloilo City, were not received at the PNRI Centralized Waste Treatment Facility until August of the same year. In addition to these Ra sources being turned over due to the PNRI Information Notice, a total of approximately 615 mg of Ra 226 (22.75 GBq) were previously collected and stored, awaiting conditioning.

Further, in the early 1990s, another 450 mg (16.65 GBq) were conditioned in cement in 200 L drums using the “old procedure” of incorporating activated charcoal with the Ra sources prior to overcrowding with cement, without being TIG welded. All the radium sources that were previously collected were retrieved from interim storage and segregated in batches to facilitate documentation and easy transfer to stainless steel capsules. Activity and geometrical dimensions were noted in the segregation process. This Ra 226 inventory however, does not include those which have been authorized for medical use but were later reported/confirmed to be lost and subsequent efforts to recover the same have been terminated.

In preparation for the actual conditioning of the Ra sources, construction of the workbench and work area was undertaken including the installation of the mobile filtration system provided by the Agency for the project.

Fig. 1 Working bench/area showing the three distinct zones: the transfer zone, the welding zone and the leak testing zone

The workbench/working area (shown in **Fig. 1**) was divided into three distinct zones; the transfer zone, the welding zone and the leak-testing zone. The bench was lined with lead bricks (4 inch x 8 inch x 4 inch) about 16 inch in height, front and sides. A lead glass was installed on top of the lead brick in the transfer zone to facilitate direct viewing of the sources during transfer to the stainless steel (SS) capsule. The Agency additionally provided 25 pieces of standard size stainless steel capsules and 2 pieces of the big sized capsules for odd shaped sources, including a lead shield that will hold ten of the small sized SS capsules and one big sized SS capsule. These capsules and the lead shield are shown in **Fig. 2**.

6.4.2 Conditioning of the Radium Sources

The conditioning process was undertaken directly under a plastic hooded working bench fitted with a mobile filtration system. The radium sources in glass test tubes were moved one by one using a transport car with lead shielding into the working area. The glass test tube containing the radium sources was then picked up using a 24-inch handling tong and the sources are laid out in a polyethylene lined tray inside the transfer zone. The sources are then loaded into the stainless steel capsule one by one taking note each time of the reading in the digital survey meter positioned one meter away from the capsule being loaded with radium. A maximum load of not more than 50 mg or approximately 50 mR/hr at one meter is maintained.

Fig. 2 The small stainless steel capsules and the big sized capsule shown with the steel lined lead container for the ten small capsules and one big capsule

After the maximum load is attained, the capsule is transferred to a shielded slot in the welding zone using a handling tong. Since the bottom lid has already been TIG welded and tested prior to the actual conditioning operation, only the top lid remains to be welded and tested. After a cooling period of 3-5 minutes, the capsule is transferred into the leak-testing zone for a bubble test, using a dessicator containing glycol evacuated by a pump at 25 kPa. If no bubbles appear, it is said that the capsule has passed this test and that it is fully sealed.

After passing the leak test, the capsule is emplaced into the lead shield that is designed to hold ten standard sized capsules and one big capsule at the center. After all the capsules are loaded and placed inside the lead shield, dose rates on contact and at one meter away are measured and recorded. The loaded lead shield is then lifted by an overhead crane and placed inside a 200 L steel drum pre-lined with cement. The drum is then monitored and marked on the outside surface with a final code number previously assigned.

6.4.3 ALARA Program

The main conditioning team was divided into two groups, 3 persons in each group; one will be responsible in transferring the Ra sources from the lead pot to the stainless steel capsule in the transfer zone, one will undertake the TIG welding of the SS capsule after the Ra is placed inside and the third, will undertake the leak testing and eventual transfer of the SS capsule into the lead shield. The first group is tasked to do the first five small capsules and the second group, the remaining five small capsules and the big capsule.

The supporting team includes those who will move the radium sources from the storage location to the work area. It also includes those who perform routine monitoring of external exposures, air monitoring and routine contamination checks of lead pots, cover shoes, disposable gloves, etc. of the main conditioning team inside the controlled area. The supporting team was likewise grouped according to assigned tasks and duties alternately to optimize exposure to radiation.

Cold runs involving all aspects of the conditioning process were undertaken using ordinary construction nails to simulate the radium needles/sources for two consecutive straight days, jointly with the IAEA Expert, using the remote handling tongs and all the protective devices to be used in the actual operation. Particular attentions were given to the elapsed time in performing specific aspects of the whole procedure. Slight modifications in the wok area had to be done in the interest of ALARA, prior to the hot run.

Remote handling tools were used as far as practicable to reduce exposures of the hands and fingers. Protective clothing, gloves and cover shoes are worn at all times during actual operation and routinely checked during the operation. Reading and recording of the pen dosimeters of all the personnel inside the controlled area were done after each capsule is welded and transferred to the lead shield. This allowed us the opportunity to closely monitor individual exposures of personnel directly involved in the conditioning operation. Fresh TLD whole body and finger badges were issued to all personnel during the actual operation in addition to the badges previously issued for routine use for a specified monitoring period. These special badges were meant to assess personnel exposures attributable to the actual radium conditioning operation itself

The immediate vicinity of the work bench/area were lined with polyethylene sheets to contain possible contamination. Handling tools and devices were provided or lined with disposable sticky tapes or plastic covers to facilitate disposal of contaminated articles. All items, including rubber gloves and cover shoes of the personnel who were inside the controlled area were checked for possible contamination and subsequently segregated and/or cleared. A designated and labeled waste bin, which is foot operated, was positioned near the work area to contain possibly contaminated materials.

A check list of all possible materials and supplies were anticipated, prepared and made available prior to the actual operation to optimize the time spent in the actual operation and thus minimize exposures of personnel. Observers, for training purposes, were limited to certain areas where the radiation levels are constantly monitored and were provided with personal dosimeters and subjected to routine contamination check. Digital images and video footages were taken of the cold runs and the actual conditioning operations for documentation/QA purposes and to allow for a retrospective analysis of the conditioning operations and related safety measures.

A digital monitoring system was set up to facilitate actual monitoring and control of the radium sources being transferred from the lead pots to the SS capsules in terms of activity. The standard sized SS capsule is designed to hold not more than 50 mg of Ra. The set up was done in such a manner that the readings are observed from a distance without the possibility of being exposed unnecessarily to radiation.

6.4.4 Dose Assessment

A total of 560 mg Ra (20.52 GBq) were encapsulated and TIG welded in 10 stainless steel capsules (9 standard sized and one big one) and emplaced in the lead shield provided by the IAEA. The maximum contact dose rate at the external surface of the lead shield is 1.2 mSv/hr. A Capsule Information Form containing the details is filled out for QA/ record purposes.

A 55 mg Ra (2.03 GBq) source was encapsulated, TIG welded and leak tested in the second big sized SS capsule due to its odd shaped dimension. As it was not possible to place this source in the lead shield provided by the Agency, the SS capsule was placed in a 2.5 inch thick lead container, properly marked for temporary storage. The contact dose rate on the external surface of the lead container is 1 mSv/hr and at one meter, 30 μSv/hr. This will be transferred later to a standard lead shield similar to that provided by the Agency and into a 200 L pre-lined steel drum. A Capsule Information Form containing the details is also filled out for record purposes.

The lead shield was then lifted and transferred, by overhead crane to a pre-lined 200-liter steel drum. The contact dose rates at the external surface of the steel drum are 130 μSv/hr at the side and 170 μSv/hr at the top.. A Package Information Form containing the results of the measurements is likewise filled out in compliance with transport safety requirements.

Contamination checks on the work areas showed slightly contaminated disposable materials. These materials were segregated and collected in properly labeled containers for proper management. All personnel were cleared for possible contamination using the hand and foot monitor at the designated control points of the radioactive waste treatment area.

TLD results, both for whole body and extremity monitoring showed values all within acceptable limits and indicative of an effective ALARA program.

6.5 Regulations on Radioactive Waste

Disposal of radioactive waste is covered by Chapter IV of Part 3 Standards for Protection Against Radiation, the latest version of which is currently being revised to conform to the new international safety standards published by the International Atomic Energy Agency.

In its effort to establish specific requirements within the framework of the proposed final repository site and to guarantee the effective treatment and conditioning of radioactive waste accepted, the PNRI issued Administrative Order (AO) #01, Series of 1990 to all radioactive material licensees, providing guidelines for the acceptance of low level raw radioactive wastes from off-site generators. The set of criteria and requirements set in the AO were established pursuant to Part 3 , Standards for Protection Against Radiation and Part 4, Transport Regulations of the Code of PNRI Regulations.

Acceptance criteria for final disposal of radioactive wastes are currently being drafted. A set of regulations specifically on radioactive waste management is seriously being considered in the interest of public health and safety among others.

6.6 Philippine Action Plan on the Safety and Security of Radiation Sources

Following the International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials held in Dijon, France in 1998 and the International Conference of National Regulatory Authorities with Competence on the Safety of Radiation Sources and the Security of Radioactive Materials in Buenos Aires in 2000, the IAEA has put in place an Action Plan for the information and guidance of Member States. This Action Plan has been revised in June 2001 and was the basic document, among others, used in formulating the Philippine Action Plan on the Safety and Security of Radiation Sources.

The Philippine Action Plan involves activities related to the establishment and update of a more comprehensive national database of radiation sources currently in use and those which have been spent and disused, including recovered and identified orphan sources. Issues related to trans-boundary movement of radiation sources in scrap metals importation/exportation are being addressed through the conduct of dialogues with relevant government and private institutions and the further strengthening of regulatory infrastructures already in place. The Philippine Action Plan has been institutionalized and widely disseminated for the information and/or compliance of concerned sectors. The activities that are being pursued under this initiative are constantly monitored and assessed to determine its effectiveness in attaining the set objectives of the Action Plan.

6.7 IAEA Regional Demonstration Centers

The Philippines have hosted two (2) regional IAEA Demonstration Course on Pre-disposal Waste Management Methods and Procedures in 1998 and 1999. The objective of the demonstration course is to demonstrate to Member States one or more waste management methods and procedures which are documented in the IAEA Technical Reports or Technical Documents and which are in agreement with internationally accepted standards and criteria. The hands-on waste demonstration will provide the developing Member States with appropriate technologies and the practical experience of all pre-disposal steps needed to manage waste from their nuclear applications. The Philippine Nuclear Research Institute through its centralized facility for radioactive waste management has developed in close collaboration with the IAEA a demonstration manual which consists of three modules, one of which is on the pre disposal treatment and conditioning of spent sealed sources.

6.8 Siting Studies for a Near Surface Disposal Facility

6.8.1 The Regional Site Screening Methodology

The Philippines is divided into 12 regions excluding the National Capital Region where Metro Manila belongs. Initially, the site assessment process made use of about 8 appropriate maps of differing scales. These maps describe the litho-logical conditions, major faults, shorelines, freshwater bodies, groundwater potential, slopes, and protected areas. A Geographical Information System (GIS) was employed wherein the various criteria for site suitability were applied.

6.8.2 Application of Siting Criteria

The Hydro-geological component of the site screening criteria was analyzed to determine the hydro-geological framework for assessment. This framework basically translates to the identification of sites with the lowest potential for groundwater and surface water transport of contaminants. Equivalent mapping units reflecting the different characteristics that are deemed favorable or unfavorable for the proposed facility were applied. The units were identified based on the presumptive hydrologic characteristics of particular landforms, soil units and rock formations as well as the regional climato-logical characteristics as published by the local weather administration, the PAGASA.

6.8.3 Preliminary Results

The resulting map from the activities described in the preceding section showed the geologic, hydro-geologic and environmental considerations that were utilized in the site assessment process. The maps correspond essentially with the hilly to mountainous sections of the country. If each of these resulting maps were overlaid, about 90% of the country will be eliminated from being suitable for radioactive wastes disposal. The final map listed about 40 candidate sites to date. This map will be used as a primary map and will serve as an input to subsequent analysis. The political boundaries of the various regions were delineated and used to divide the whole area into segment with the aim of identifying an area, considering that a buffer zone of limited land use will be imposed for the disposal site. Final candidate sites will be identified after the application of the criteria on land use, access and population.

References

1. International Atomic Energy Agency Technical Document 886, Conditioning and Interim Storage of Spent Radium Sources, 1996.
2. International Atomic Energy Agency, Management of Small Quantities of Radioactive Waste, TECDOC-1041, Vienna, 1998.
3. Valdezco, E.M., Marcelo,E.A. , Caseria, E.S., Salom, D.S., Dela Cruz, J. M. “ A National Strategy for the Management of Disused Radium Sources in the Philippines” poster presented at the International Conference on Management of Radioactive Waste from Non-Power Applications-Sharing the Experience, 5-9 November 2001, Malta.
4. Geo-sphere Technologies Inc. Final Report on Site Characterization Study for a Near Surface Disposal of Radioactive Wastes Project, Subcommittee on Radioactive Waste Management, Nuclear Power Steering Committee, Philippine Nuclear Research Institute, 2000.
5. Proceedings of the IAEA International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials, Dijon, France, 14-18 September 1998.
6. Proceedings of the IAEA International Conference of National Regulatory Authorities with Competence on the Safety of Radiation Sources and Security of Radioactive Materials, Buenos Aires, 2000.
7. Manual for the IAEA Demonstration Course of Pre-disposal Radioactive Wastes Management Methods and Procedures, Philippine Nuclear Research Institute, 1998.

7. SRS Management in Thailand

7.1 Current status of using of sealed radiation sources in Thailand

Radionuclides are used in various applications in medicine, industry, agriculture, research and education and other applications. At present, there are about 700 licensees of non-nuclear power applications in Thailand. The summary of the number of licensee by category of organizations is shown in **Table 1**.

Sealed radiation sources have been used in Thailand for more than 40 years. All sealed radiation sources are imported from oversea suppliers. The use of sealed radiation sources are classified by different applications as follows:

- Medicine

Major large gamma sources used in Medicine are as Co-60 and Ir-192 for tele-therapy in hospitals. The activity of large gamma sources are in rage of 500-13,000 Ci. The medium and small gamma sources are as Cs-137, Co-60, Ir-192, Au-198 and Ra-226 for remote after loading and brachytherapy. Such kinds of beta source is Sr-90 used for eye applicator. Details of the types of sealed sources and their purpose of use can be seen in the **Table 2**.

- Industry

Thai industry uses sealed radiation source in a variety of applications such as using Cs-137, Co-60, Kr-85 for level and density gauging of uncountable goods and for automatic thickness measurement respectively. The radiography gamma sources (Ir-192) are also applied for non-destructive material testing of metal construction. Major large gamma source used in industrial application is Co-60 for irradiation purposes such as sterilization of medical and hygienic products and sterilization of food and agriculture products. The activity of large gamma sources are in range of 500,000-3,000,000 Ci. **Table 3** shows details of sealed source used in industrial applications.

- Research & Education

Research & Education authorities use many kinds of sealed radiation sources for their training and education purposes. OAEP itself uses Co-60 as gamma irradiator for research on agriculture such as insect- sterilization, plant-mutation, polymerization of natural rubber and etc. **Table 4** shows details of sealed source used in research and education.

- Other applications

Some radionuclides are used for other purposes, Am-241 and Ra-226 are still used as ionization source for lightning preventors, depleted uranium is used in mass balancing applications in aeroplanes and yachts and also used as shielding material in nuclear industry. The summery of nuclides used in this category can be seen in **Table 5**.

Table 1 Number of Users by Category of Organizations

(as of fiscal year 2001)

Category	Number of License	Total activity (Ci)
Hospitals & Clinics	92	323,842.01
Research & Education	174	7,811,186.81
Industries	258	686,468.97
Others	167	1.20
Total	**691**	**8,821,498.99**

Table 2 Major Sealed Radiation Sources in Medical Use

Source Type	Nuclide	Activity/unit	Total Unit	Purposes of use
Large Gamma Sources	Co-60	500 -13,000 Ci	29	Teletherapy
	Cs-137	1,700 Ci	1	Blood Irradiator
Medium & Small Gamma Sources	Co-60	5000 mCi	11	Remote after-loader and Brachytherapy
	Cs-137	1000-1300 mCi	63	
	Ir-192	12000 mCi	7	
Beta Sources	Sr-90	50 -100 mCi	27	Eye Applicator

Table 3 Major Sealed Radiation Sources in Industrial Use

Source Type	Nuclide	Activity/unit	Total Typical Unit	Purposes of use
Large Gamma Sources	Co-60	500,000-3,000,000 Ci	3	Irradiator for Sterilization of Medical Products
	Co-60	500,000 Ci	1	Irradiator for Sterilization of Agricultural Products
Medium & Small Gamma Sources	Co-60	30 Ci	2	Radiography
	Co-60	1-5 Ci	58	Logging
	Co-60	1-3 Ci	141	Level Gauge
	Cs-137	1-5 Ci	29	Logging
	Cs-137	500 mCi	484	Level Gauge
	Ir-192	500 Ci	16	Radiography
Neutron Sources	Am-241 Be	1 Ci	31	Moisture Gauge
Alpha Sources	Am-241	65 mCi	155	Level Gauge
Beta Sources	Ni-63	10 mCi	10	Gas Chromatograph
	Kr-85	150 mCi - 1 Ci	120	Thickness Gauge
	Sr-90	50 mCi	37	Industrial Gauge
	Pm-147	700 mCi	15	Thickness Gauge
	Po-210	20 mCi	55	Industrial Gauge
X-ray source	Fe-55	45 mCi	10	Fluorescent X-ray Analyzer
	Cd-109	5 mCi	10	

Table 4 Major Sealed Radiation Sources in Research and Education

Source Type	Nuclide	Activity	Total Unit	Purposes of use
Large Gamma Sources	Co-60	7,000-656,000 Ci	5	Irradiator for research works
Medium and Small Sources	Co-60	0.05 μCi-50 mCi	86	Standard Source
	Cs-137	0.5 μCi-50 mCi	110	Standard Source
	Am-241	0.01 mCi-10 mCi	63	Standard Source
	Am-241,Be	1 Ci	51	Moisture gauge
	Ra-226	0.1 mCi	6	Standard Source
	Fe-55	10 mCi - 1 Ci	23	Fluorescent X-ray Analyzer
Beta Sources	Sr-90	0.02-20 mCi	12	Standard Source
	Kr-85	10 mCi -1Ci	24	Standard Source and Thickness Gauge

Table 5 Major Sealed Radiation Sources in Other Applications

Source Type	Nuclide	Activity (mCi)	Total Unit	Purposes of use
Alpha Source	Am-241	3 -10	277	Lightning Preventor
	Ra-226	0.5 -1	31	Lightning Preventor
Alpha Source	Am-241	0.001	267	Smoking Detector
		Total	575	

7.2 Inventory of Spent Sealed Radiation Sources in Thailand

The inventory of Spent Sealed Radiation Sources in Thailand has been assessed by Radioactive Waste Management Division, OAEP since 1974. The data keeping is now developing by computer programs. The details of accumulation of disused sources can be seen in the **Table 6**.

Table 6 Major Spent Sealed Radiation Source Inventory at Waste Management Division, OAP

(as of October,15 2002)

Source Type	Half life	Activity	Inventory (Number of Piece)	Present status of Management
Am-241, Be	432.7 y	50 - 3,000 mCi	10	Not yet conditioned
Am-241	432.7 y	2.4 - 150 mCi	161	Not yet conditioned
Au-195	186.1 d	1 mCi	1	Delay for decay
Cd-109	462 d	0.33 - 10 mCi	15	Delay for decay
Co-57	271.8 d	1.8 mCi	11	Delay for decay
Co-60	5.271 y	less than 1 Ci	125	Not yet conditioned
		1 Ci - 50 Ci	8	Not yet conditioned
		420 Ci	1*	already conditioned in September 2002
		400-1000 Ci (Teletherapy Units)	12	Interim storage or Return to Original
Cs-137	30.17 y	less than 1 Ci	154	Not yet conditioned
		1 -50 Ci	66	Not yet conditioned
		Unknown	7	Not yet conditioned
DepleteU	4.47E9 y	Unknown	61	Reuse
Fe-55	2.73 y	2.08 mCi-20 mCi	13	Delay for decay
Ir-192	73.84 d	Unknown	8	Not yet conditioned
		1000 mCi	1	Not yet conditioned
Kr-85	10.76 y	Unknown	8	Not yet conditioned
		8.39 mCi-500 mCi	22	Not yet conditioned
Ni-63	92 y	Unknown	15	Not yet conditioned
Pm-147	2.6234 y	Unknown	1	Not yet conditioned
		2.25 mCi-5,000 mCi	18	Not yet conditioned
Po-210	138.38 d	Unknown	1	Delay for decay
		0.002 mCi-12 mCi	19	Delay for decay
Ra-226, Be	1600 y	3-7 mCi	3	Plan to condition around June , 2003
Sr-90	29 y	Unknown	6	Not yet conditioned
		0.075 mCi-106.4 mCi	58	Not yet conditioned
Ra-226	1600 y	4823.6 mg(total)	948	already conditioned in 10 drums
		4000 mg	1	Plan to condition around June , 2003
		1818.2002 mg(total)	165	Plan to condition around June , 2003
		unknown	35	
Tl-204	1.60E3y	0.6 - 500 μCi	28	Not yet conditioned

Note * The Co-60 Source from the radiological accident in year 2000, was successfully conditioned in September 2002.

7.3 Current topics of SRS Management

OAEP has been the central of radioactive waste management in Thailand. All radioactive wastes including disused sealed sources which can not be returned to manufacturer have to be sent to OAEP for further management and storage. Spent sealed radiation sources received from users are kept in shielded containers. Most of them are un-conditioned but planed to condition in the near future. Large sources are still kept in the original packages. Small sources will be conditioned by cementation in appropriate container.

a) Conditioning of Radium-226

Sealed radium-226 source is the primary radiation source used in medicine for more than 40 years in Thailand. Radium-226 has been used in the form of needles and tubes for Brachytherapy or applicators for external betatherapy. The strategy of safe management of spent radium sources is the optimization of conditioning techniques. The approach comprised the encapsulation of spent radium sources in a stainless-steel capsule , lid welding, capsule leakage testing followed by placing the capsule in a lead container, and placing the package inside a 200 L concrete-lined steel drum. For safe interim storage, the drums were closed by their lids with appropriate security seal.

In the early year 2001, the radium conditioning operation was co-operated with the support of International Atomic Energy Agency (IAEA) and Korean Hydro Nuclear Power (KHNP). As a result of conditioning operation, 4,823.6 mg (178.47 GBq) of radium sources were conditioned in 10 packages (200 L concrete-lined steel drums)and stored at an interim storage facility, OAEP. The details is shown in **Table 7**.

Table 7 Package Code and Dose Rate of Final Radium Waste Form

Package Code	Dose rate on Lead Container (μSv/h)	Dose rate on Final Package (μSv/h)		Measuring Date
		Surface	1 m. Distance	
CRA012001	1,780	134	14	21-02-2001
CRA012002	1,840	142	15	21-02-2001
CRA012003	2,460	182	24	21-02-2001
CRA012004	1,620	122	12	27-02-2001
CRA012005	1,980	142	15	21-02-2001
CRA012006	2,402	172	21	21-02-2001
CRA012007	1,780	151	19	21-02-2001
CRA012008	1,950	120	18	21-02-2001
CRA012009	2,560	186	23	21-02-2001
CRA012010	2,370	183	24	21-02-2001

b) The Radiological Accident from the Scrap Metal

Outline

A serious radiological accident occurred in Samut Prakarn, Thailand, in late January and early February 2000, when a disused ^{60}Co teletherapy head was partially dismantled, taken from an unsecured storage location and sold as scrap metal. Individuals who took the housing apart and later transported the device to a junkyard were exposed to radiation from the source. At the junkyard the device was further disassembled and the unrecognized source fell out, exposing workers there. The accident came to the attention of the relevant national authority when physicians who examined several individuals suspected the possibility of radiation exposure from an unsecured source and reported this suspicion. Altogether, ten people received high dose from the source. Three of those people, all workers at the junkyard, died within two months of the accident as a consequence of their exposure.

Discovery

After the physician from the Samut Prakarn Hospital called the OAEP about the patients and expressed his concern about a possible unsecured radiation source in the environment, the OAEP immediately dispatched two officers (health physicists) to see the physician and his patients. The OAEP officers arrived at the Samut Prakarn Hospital at 12:30 on 18 February 2000 to investigate the case further. From the information provided by the patients and the owner of the srap meatal shop, the OAEP officers, jointly with local public health officers, initiated a search to find the unsecured radiation source. During their journey towards the junkyard, the officers had their radiation detectors switched on. In the direction of the junkyard, they noted a significant increase in radiation levels about 20 times normal. There, a radiation level of over 1 mSv/h was measured at the side entrance of the yard, confirming the presence of an intense gamma source. At this point they recognized that this was a serious radiological accident and called for assistance.

Recovery

Recognizing the seriousness of the radiological situation, the OAEP officers called upon an emergency response team. A command and co-ordination post was then established in the vicinity of the junkyard. The radiation level survey found a dose rate of up to 10 Sv/h in the junkyard and around the pile of scrap where the source was located. The local area was cordoned off at radiation level of 300 μSv/h, which occurred about 10 m from the junkyard. Access to the junkyard was restricted and the street outside was closed to traffic. The very high radiation level prevented the emergency response team from getting close enough to pinpoint the exact location or determine the physical shape of the source among the scrap material. Further field operations to locate the source continued throughout the night until 04:00 on the morning of 19 February 2000. The operations until later that morning and the police secured the entire area.

Later on the morning of 19 February 2000, the local public health authorities resumed recovery operations at the junkyard. At approximately 150 m from the junkyard, a dose rate of 1.7 μSv/h was measured. This level increased to 200 μSv/h on the sidewalk across from the junkyard at a distance of approximately 20 m from the source.

Meanwhile, the emergency response team recovery operation resumed its activities at the OAEP. Personnel watched the videotapes taken the previous night and planned the retrieval operations, and gathered the necessary tools and equipment for the source recovery. Then the emergency response team returned to the junkyard. The planning included rehearsals using a dummy object in order to familiarize emergency response team members with the tools and techniques for retrieving the unknown source when it was finally located. To clear a path to the location of the source within the junkyard, a heavy iron fenced entry gate and some scrap were removed with the help of a mechanical excavator. This excavator was also used to place a lead wall 5 cm thick by 1 m wide by 2 m high near the source to provide some shielding to individuals trying to find and recover the source. The dose rate behind this shield was reduced more than twenty-fold. Spotlights and two closed circuit television (CCTV) cameras and monitors were installed to facilitate the operation.

Finally, in an effort to locate the source accurately, a fluorescent screen was used. The fluorescent screen was of a size suitable for image intensification for diagnostic X-ray films. Personnel had to wait until the moonlight had diminished for suitable darkness in which to use the screen accurately. At around 21:00 on 19 February 2000, the position of the source within the remaining pile of scrap was accurately determined. However, many pieces of scrap metal still surrounded the source.

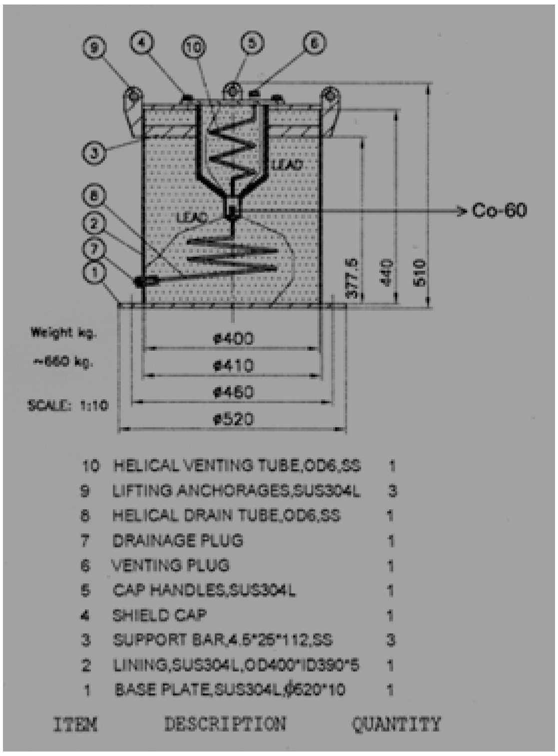
Having now located the source, OAEP emergency response team personnel innovated a means of retrieving it by attaching an electromagnet to a length of bamboo. Other grasping tools were not long enough to afford adequate personnel protection, and spending time trying to grapple the source with tongs would have resulted in personnel receiving radiation doses from the intense radiation field.

On 20 February 2000 at 00:20, the source, which had been estimated to be about 4 cm long and 2.5 cm in diameter, was retrived. Tongs 2 m in length were used to pick up the source and place it into a lead shielding container. In situ gamma spectrometry was performed and the source was identified to be ^{60}Co. The source activity was estimated at roughly 15.7 TBq (425 Ci)

The source was transported to safe storage at the OAEP on 20 February 2000. The lead container containing the source was placed under 4.5 m of water in what was formerly a spent fuel storage pool.

Conditioning

At present, the Co-60 source was moved to a safe dry storage facility at OAEP. A lead shielded container designed, based on the concept of surface dose rate less than 2 mSv/hr. The conditioning of Co-60 source was successful operated on 6-7 September 2002. The details of lead shielding is shown in **Fig. 1**.



ITEM	DESCRIPTION	QUANTITY
10	HELICAL VENTING TUBE,OD6,SS	1
9	LIFTING ANCHORAGES,SUS304L	3
8	HELICAL DRAIN TUBE,OD6,SS	1
7	DRAINAGE PLUG	1
6	VENTING PLUG	1
5	CAP HANDLES,SUS304L	1
4	SHIELD CAP	1
3	SUPPORT BAR,4.5*25*112,SS	3
2	LINING,SUS304L,OD400*ID390*5	1
1	BASE PLATE,SUS304L,ϕ620*10	1

Fig. 1 Details of Lead Shielded Container for Co-60 Source for Long Term Storage

C) Experience of Steel Works

In the year 2001, a private steel factory accidentally melted radioactive sources with other scrap metals. While the radiation exposures of factory workers and the public have thus far, been low and below regulatory limits, but the financial consequences have been large because of the costs resulting from decontamination, waste management and lost revenue during temporary shutdown.

With the assistance of OAEP staff from Radioactive Waste Management Division and Health Physics Division, those melted steels contaminated with radionuclides were carefully carried out as Radioactive Wastes and kept in the safe place at OAEP for further management.

Many scrap metal recycling facility in Thailand have been suggested by OAEP that they should install the radiation surveillance systems at scrap metal entrance gate and the scrap processing facilities to detect radioactive sources that may be in incoming shipments of metal scrap. But the problem is that these systems are sophisticated in design, very sensitive, and correspondingly expensive.

Some private scrap metal recycling facilities did agree to the OAEP suggestion, and they have been successful in identifying radioactive sources or devices containing radioactive sources in scrap metal.

From the incident report on radiation sources in Thailand (Suwat, 2001) reported that imported scrap metal contained radionuclides was found 3 time in a private iron factory in the year 2000. Later, in April, 2001, a 50 mCi of Cs-137 was melt down in furnace at a private iron factory. The OAEP was informed and then OAEP staff went there to give the assistance. The OAEP staff reported that 20 tons of contaminated dust was found as well.

In August 2001, regarding to the discussion/survey meeting on SRS Management was held in OAEP, Bangkok, Thailand. The Japanese expert team and Thai experts were invited to visit that private iron factory and was reported by the Radiation Safety Officer there about the Radioactive Material Incident Report of this factory as shown in **Table 8.**

Table 8 Radioactive Material Incidents at a private iron factory

Date	Radionuclide	Dose rate (mR/hr)	Source
12/05/2000	Cs-137	40	East Europe
28/06/2000	Cs-137, fission products	40	East Europe
10/10/2000	Ba-133	> 6000 cps	local scrap dealer
16/12/2000	Ba-133	2.5	East Europe
17/12/2000	fission products	3224 cps	East Europe
06/02/2000	fission products	0.5	East Europe
26/04/2001	Cs-137	unknown	unknown

d) Waste Storage Facilities

At present, the OAEP has two radioactive waste storage buildings. One of them is used to store disused sealed sources, and conditioned Ra-226 sources. The other one is used to store the Radioisotope (RI) Wastes.

In the future, there will be the establishment of the new nuclear research center (Ongkharak Nuclear research Center, ONRC) at Ongkharak district, Nakornnayok province. The Centralized Waste Processing and Storage Facility (WPSF) is attached to this center. The WPSF will serve low level radioactive waste arising in the country including disused sealed sources. WPSF comprises two main buildings i.e., waste processing building (WPB) and waste storage building (WSB). The WPB houses are safe and high performance on management of radioactive wastes i.e., collection, segregation, treatment and conditioning.

When the ONRC project finishes, the existing disused sealed sources will be transferred to ONRC.

All radioactive waste packages including disused sealed sources packages will be stored in the WSB at ONRC (as shown in **Fig.2**). The dimensions of WSB are approximately 58mx44mx6.3m in height. The WSB is designed to have a capacity to store 200L waste drums about 8,520 drums. Moreover, WSB provides temporary storage room for disused sealed source prior to conditioning.

Fig.2 The three main facilities of Ongkharak Nuclear Research Center (ONRC)
(1) Reactor Island,
(2) Isotope Production facility
(3)&(4) Waste Processing and Storage Facilities

References

1. International Atomic Energy Agency, " *Conditioning and Interim Storage of Spent Radium Sources"*, IAEA-TECDOC-886, International Atomic Energy Agency, Vienna, Austria (1996).
2. International Atomic Energy Agency, "*The Radiological Accident in Samut Prakarn",* IAEA-Publication ISBN 92-0110902-4,International Atomic Energy Agency,Vienna, Austria (2002).
3. Korea Electric Power Corporation, " *Spent Radium Sources Conditioning Operation in Thailand",* NETEC-RPT-01/2001, Nuclear Environment Technology Institute, Korea Electric Power Corporation (2001).
4. Al-Mughrabi, " *Working Material* ", Technical Manual for Conditioning of Spent Radium Sources, International Atomic Energy Agency, Vienna (1998).
5. OAEP, Annual Report of Office of Atomic Energy for Peace*,* Bangkok, Thailand (2001).

8. Indonesian Experiences on the Management of Spent Radiation Sources

8.1 Introduction

There is a wide variety of uses of radiation sources in Indonesia. Many uses involve sealed sources with the radioactive materials firmly contained or bound within a suitable capsule or housing; some, also, involve radioactive materials in an unsealed form. The risks posed by these sources and materials vary widely, depending on the radionuclides, forms, activities, etc. Unless breached or leaking, sealed sources present a risk from external radiation exposure only. However, breached or leaking sealed sources, as well as unsealed radioactive materials, may lead to contamination of the environment and the intake of radioactive materials into the human body.

Radionuclides produced artificially in nuclear facilities and accelerators have become widely available, not only radium-226, but also cobalt-60, strontium-90, caesium-137 and iridium-192. The risks associated with the use of radioactive materials must be restricted and protected by the application of appropriate radiation safety standards. The risks associated with the planned use of radiation sources and radioactive materials are generally well known and the relevant radiation safety requirements generally well established. Nevertheless, accidents can occur during use.

Sealed sources or their containers can have a certain attractiveness because of their appearance or their apparent value as scrap metal. Due to this reason, in October 2000, 25 units of radiation sources have been stolen from the warehouse of Krakatau Steel Co. (a state-owned steel company), and only 3 units of Co-60 have been found so fat, while the rest of 22 units still under inverstigation.

Handling of radiation sources and containers by workers and members of the public unaware of the inherent hazards can give rise to external irradiation or, if tampered with, the possibility of internal exposure. This has led to serious injury and in some cases death. Sources incorporated into scrap metal for subsequent recycling can lead to the contamination of plant and the environment, possibly with serious economic consequences.

A spent source is not necessary waste. There may be other uses for such a source in other applications, which should always be considered first. If for any technical or economic reason, no further use is foreseen, the spent SRS can then be declared radioactive waste.

Purpose

The primary purpose of this paper is to describe experiences of and the effort so made by Indonesia to develop and implement activities in maintaining and improving the safety of spent sealed radiation sources.

8.2 Principles of Management of Radiation Sources in Indonesia

(a) Sources of ionizing radiation must have sufficient protection to allow for safe normal operations.
(b) The possibility of accidental exposures involving radiation sources must be anticipated and there must be appropriate safety devices and procedures
(c) Regulatory function (embedded to the Nuclear Energy Control Board, NECB) for the control of radiation sources is supported by the Government of Indonesia to act independently and to maintain oversight of all radiation sources in Indonesia.
(d) Radiation sources should not be allowed to drop out of the regulatory control system. This means that the NECB must keep up-to-date records of the person responsible for each source, monitor transfers of sources and track the fate of each source at the end of its useful life.

NECB was established in 1998, evolving from BATAN, as required by the new act of 1997 on nuclear energy. The act provides NECB with sufficient authority and with sufficient human and financial resources to function effectively.

8.3 SRS Management Practices

Legislative Framework

In anticipation of possible expansion of the nuclear energy application in Indonesia and in order to contribute to the global nuclear safety culture, the Government of Indonesia has issued in April 1997 the Act of the Republic of Indonesia No. 10/1997 on Nuclear Energy. This law covers various arrangements, including the establishment of Nuclear Energy Control Board (NECB) or BAPETEN by the Presidential Decree No. 76/1998 in May 1998, the basic principles of the regulation practices in the application of nuclear energy, the basic arrangement of waste management and the liability of nuclear damage.

As stated earlier, the Act No. 10/1997 on Nuclear Energy also stipulates some basic arrangement on waste management. The basic arrangement is accommodated in Chapter VI with 6 articles. It stipulates inter alia that:

- the radioactive waste management shall be conducted to mitigate radiation hazards to the workers, the public and the environment {Article 22(1)}
- the Executing Body shall accomplish the radioactive waste management, which may designated a state or private company or cooperative to conduct commercial waste management activity (Article 23)
- the user generating low and intermediate level of radioactive waste shall to obligate to collect, segregate, or treat and temporarily store the waste before being transferred to the Executing Body {Article 24 (1)}
- the radioactive waste storage shall be subjected for fee and the amount of storage fee will be stipulated by the Degree of The Minister of Finance (Article 26)

- the transportation and storage of radioactive waste shall consider the safety of workers, public and environment {Article 27 (1)}
- the provisions on radioactive waste management including the waste transportation and disposal shall be further implemented by Government Regulations {Article 27 (2)}.

Furthermore, the article 25 stipulates the following:

1. The Executing Body shall provide the final repository for high level radioactive waste
2. The siting of final repository under paragraph (1) shall be stipulated by Government after getting an agreement from the House of Representative of the Republic of Indonesia

Elucidation of Article 25 prohibits the use of any part of Indonesia territory by any foreign or other country as a radioactive waste repository.

Regulatory on SRS

According to the Act of the Republic of Indonesia No. 10/1997 on Nuclear Energy, the Regulatory Body is separated fully from the Executing Body. The regulation is prepared to regulate and control the nuclear activities by regulatory compliance early on the planning of project in the manner of environment impact analysis preparation, licensing demand, regulating and controlling of activities. Certain necessary rules and regulation for management of radioactive waste have been issued as indicated in **Table 1**.

Table 1 List of Existing Indonesian Government Regulations Concerning Radioactive Waste Management

No.	Name of Regulation
1.	Government Regulation of the Republic of Indonesia No. 11/1975 on Working Safety Against Radiation
2.	Government Regulation of the Republic of Indonesia No. 12/1975 on Licensing of Utilization of Radioactive Materials and or Another Radiation Sources
3.	Government Regulation of the Republic of Indonesia No. 13/1975 on Transport of Radioactive Materials
4.	Government Regulation of the Republic of Indonesia No. 51/1993 on the Preparation of Environment Impact Analysis
5.	Decree of Ministry of Environment No. Kep.-42/MENLH/1994 on General Guidelines on Environmental Audit
6.	Decree of Ministry of Environment No. Kep.-39/MENLH/1996 on Activities Criteria Obligate to Prepare the Environment Impact Analysis
7.	Act of the Republic of Indonesia No. 10/1997 on Nuclear Energy
8.	Act of the Republic of Indonesia No. 23/1997 on Environment Management
9.	Decree of President of the Republic of Indonesia No. 76/1998 on Nuclear Energy Control Board
10.	Decree of Chairman of the Nuclear Energy Control Board No. 01/Ka. BAPETEN/V-99 on Working Safety Provision Against Radiation
11.	Decree of Chairman of the Nuclear Energy Control Board No. 02/Ka. BAPETEN/V-99 on Radioactivity Dose Value on the Environment
12.	Decree of Chairman of the Nuclear Energy Control Board No. 03/Ka. BAPETEN/V-99 on Safety Aspect of Radioactive Waste
13.	Decree of Chairman of the Nuclear Energy Control Board No. 04/Ka. BAPETEN/V-99 on Radioactive Materials Transport Safety
14.	Decree of Chairman of the Nuclear Energy Control Board No. 06/Ka. BAPETEN/V-99 on Construction and Operation of Nuclear Reactor
15.	Decree of Chairman of the Nuclear Energy Control Board No. 07/Ka. BAPETEN/V-99 on Quality Assurance of Nuclear Installation
16.	Government Regulation of the Republic of Indonesia No. 16/2001 on Tariff of Radioactive Waste Management.
17.	Government Regulation of the Republic of Indonesia No. 26/2002 on Safety of Transportation of Radioactive Materials.
18.	Government Regulation of the Republic of Indonesia No. 27/2002 on Radioactive Waste Management.

8.4 Management of Spent Sealed Radiation Sources

The policy of government of Indonesia for spent radiation sources stipulates that, whenever possible, spent sealed sources should be returned to the originator. DC-RWM has a general principle that sealed sources should not be removed from their holders prior to dispatch to DC-RWM, or the holders should not be modified physically (excepted from this requirement is Ra-226 needles, smoke detector and lighting preventer).

DC-RWM is developing the management information system (MIS) comprising the database of all wastes stored in DC-RWM storage facilities. This system is used to identify accurately and immediately on the transportation and storage of the radioactive waste. The other objective of MIS is to have control on the record of the waste history (transportation, treatment/conditioning, and storage).

Present development of detailed records for all spent sealed sources in storage includes:

- Identity code (if known);
- Radionuclides present;
- Original activity/date;
- Physical and chemical form:
- Source dimensions, geometry;
- Details of shielding (e.g. gross weight - including shielding containers);
- Results and date of a previous leak test;
- Measured dose rate and details of measurement equipment used (type, -model, serial number);
- Supplier of the source;
- Owner, last user of the source (details and persons responsible).

The NECB is informed when a sealed source is taken out of use, and becomes a spent source in storage.

Spent sealed sources is segregated and collected separately because of their potentially high radiological hazard. Spent sealed sources generally are not removed from their associated shielding or source holders unless adequate precautions are taken to avoid exposure to radiation and contamination. Peripheral components of large irradiation equipment (i.e. those not directly associated with the source) are removed, monitored and disposed of appropriately. Sealed sources are not subjected to compaction, shredding or incineration.

Special conditioning techniques are required for spent radium sources. Spent radium sources are stored in an appropriate interim storage area with strict access control and radiation monitoring. DC-RWM has a strategy to handle the radium by applying simple but effective methods of increasing the security of spent sealed sources. A potentially suitable method of securing spent sources is to contain the spent sources or source holders in a suitable size concrete metal drum (200 L). A convenient way to embed the source in concrete would be to place it in the center of the 200 L drum that filled with concrete.

When immobilizing spent sealed sources the need for security and possible long-term retrievability of the drum is always considered.

Quality Assurance

A comprehensive quality assurance program has been established in DC-RWM and periodically inspected by regulatory body. This program is in progress, and integrated to the administration of radioactive waste management. For the management of spent radiation sources it particularly includes the following items:

- Quality of the capsule material and the-capsule welding process.
- Quality of the operational procedures (handling, segregation, characterization, treatment and conditioning, packaging, storage and disposal of radioactive waste at the centralized radioactive waste management facility, and transportation).
- Quality of the calibration of all monitors and radioactivity measurement.
- Quality of the documentation of information and their retrieval.

Quality assurance programmes aim to ensure confidence that all operations are optimally managed, waste disposals and discharges are within authorized limits, and conditioned waste packages are produced in accordance with the specifications for storage, transportation and for possible disposal. Training of personnel is an integral part of quality assurance. Procedures are required for all operations involving the management of waste at the user's premises and at the centralized radioactive waste management facility.

Below is flowchart of organization structure of quality assurance of radioactive waste management in DC-RWM and the rellation with NECB.

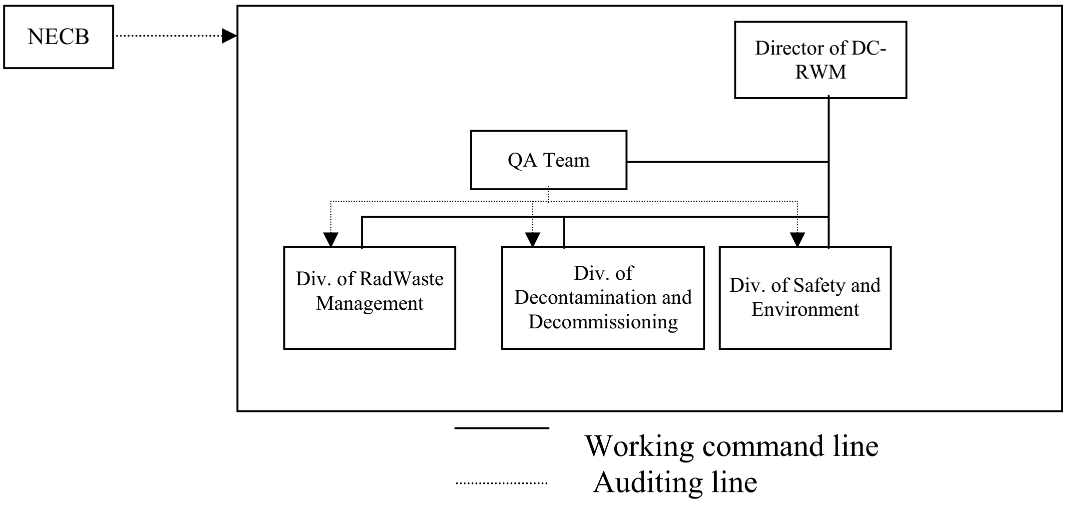


Fig. 1 Flowchart of QA in DC-RWM and relation with NECB

A quality assurance program is developed as part of the license application by DC-RWM and reviewed and approved by the regulatory body. The program define and describe the organization, responsibilities relevant quality assurance steps and organizational interfaces involved in predisposal waste management. A system for document control and records provide evidence that the required quality has been achieved. One of the references of quality assurance program is the IAEA safety series No. 50-C/SG-Q.

Technical Requirements for Conditioning of Spent Sealed Sources

The main aspects covered in this section are manpower requirements and their qualifications, operational requirements including materials/consumables, equipment and tools for conditioning of spent radiation sources.

Man Power:

One supervisor (Team Leader):	To supervise the whole operation;
One health physicist:	To conduct all safety and radiation protection related work (have an assistant for the source transfer); DC-RWM has 6 health physicists, and in the activity for SRS conditioning, all health physicists are employed in shift;
One qualified welder: (for Ra-226 conditioning)	Certified welder for stainless steel;
Worker (manual labor):	For dismantled the radiation sources from the house (only for lightning preventer, smoke detector and Ra-226 needle), preparation of drums with a concrete liner and operation of the lifting equipment.

Personnel Qualification

The DC-RWM team conducting the operation has good experience and proper qualification to undertake this work. The *team leader* is the head of the solid waste treatment subdivision who shall be a first university degree in engineering physics or related field. He has to have enough experience in the field of waste conditioning and related R&D area. This team leader has experience in leading similar operations. The *health physicists* are to have a first university degree in nuclear physics, engineering or a related area. They all have to have enough experience in radiation protection work and have participated in some major operations involving work in radiation areas, major decontamination or conditioning. The *welder* shall be qualified for operating TIG welding process (for Ra-226 conditioning).

Facilities (including tools)

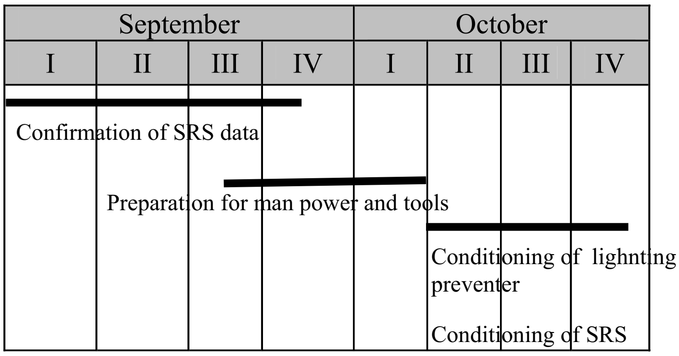
The operation requires storage facilities and a laboratory area (operational area) adjacent to the storage facility or nearby for convenience. DC-RWM has a laboratory for Ra-226 conditioning, and also for dismantling the lightning preventer. This laboratory is just 100 m from the interim storage where the conditioned spent radiation sources are placed. Almost all facilities and tools are available, except some tools specifically required for Ra conditioning whose part of it has been provided by IAEA.

Work Plan

An *action plan* is initially developed. It identifies all actions to be carried out from the time of the approval of the conditioning operation upto the end of the conditioning process of the sources. Below is the work plan of the recent action by DC-RWM on the conditioning of spent sealed sources.

Table 2. Schedule for conditioning spent radiation sources

(September-October 2002)



Preliminary Work

DC-RWM has all information regarding the sources inventory and specifically the total activity, the number of individual sources, their geometry and the hermeticity of the sources (this will be developed and integrated in our management information system of radwaste data). The shielding device is designed using, a suitable dose assessment to optimize the shielding container from weight, radioactivity capacity, volume and external dose rate points of view. The shielding container is prepared prior to. Stainless steel capsules for the encapsulation of the radium sources need to be manufactured. The capsule size needs to take into consideration the source size and shielding device geometry.

In March 2001, DC-RWM has conditioned all Ra-226 (needles and lightning preventers) stored in DC-RWM supproting by IAEA. But still DC-RWM is in progress for the agreement with Public Health department for conditioning of Ra-226.

Table 3 Total data of Ra-226 in Indonesia

No.	Type	Stored in DC-	Stored in	Total (Ci)*)

		RWM	Hospital, etc.	
1.	Needle	17	576	3 Ci
2.	Lightning preventer	320	320	0.4 Ci

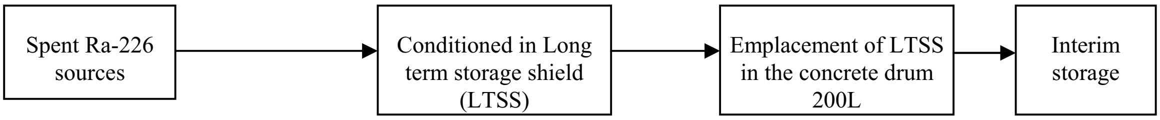
*) Approximately

At the end of this stage, all sources is stored in an Interim Storage.

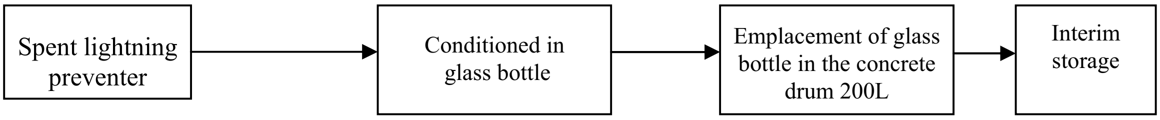
Conditioning Phase

Proper procedures are adopted for source transfer from the temporary storage to the conditioning area. The ALARA principle is well observed with regard to the exposure rate of the operating staff. Drum preparation is carried out according to technical procedures and prior to the conditioning operation in order to have the drums ready for final use. DC-RWM uses the concrete drums of 200 *l* for lightning preventer and Ra conditioning, and use the concrete shell 950 *l* to emplace the other spent sealed sources. These are the simplest ways to ensure the integrity and security of the sources. During the entire operation, no work which has not been anticipated and planned, involving radioactive materials is conducted. Continuous and systematic monitoring and control of contamination are carried out.

Flowchart of the Ra-conditioning (needle and lightning preventer)



Flowchart of the conditioning of lightning preventer (non Ra) and smoke detector



Flowchart of the conditioning of SRS (other than above criteria)

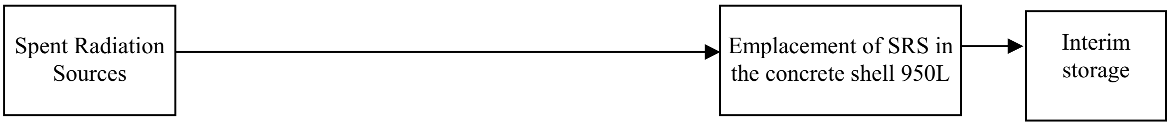


Fig. 3 Flowcharts of conditioning processes

8.5 Management Hurdles

The major obstacle faced by Indonesia in the spent radiation source management is funding. Limited budget is not only experienced by BATAN who is responsible to ultimately process all SRS coming to its facility at Serpong, but even greater problem in funding is faced by users outside of BATAN, especially the hospitals.

Most hospitals are reluctant to provide budget to manage and send their SRS to BATAN as demanded by regulation due their lack in funding. They also argue that all SRS were inheritted from old management without regard of providing special fund to manage the SRS. To overcome such hurdles the regulatory body BAPETEN and BATAN have invited the radiation source users (including the Ministry of Health) to series of socialization meetings to find solution of the situation. With regard to SRS in state-owned hospitals there has been an agreement made that the Ministry of Health will provide necessary fund to manage SRS from government hospitals to BATAN for conditioning and disposal.

There is less problem with the industry and private hospital since they are more adaptive to budget change and increase. Therefore there is no special agreement so made. The meetings are however a good medium to socialise the proper transfer of SRS in order to minimise or even avoid practice of illicit trafficking.

8.6 Reported Incidents on Radiation Sources in Indonesia

There were 14 incidents in the application of radiation sources in the year 2000, mostly having no effect on human and environment. However, in October 2000, 25 units of radiation sources have been stolen from the warehouse of Krakatau Steel Co. and only 3 units of Co-60 so far have been found. The rest of 22 units are still under investigations.

In 2001, 6 incidents recorded by NECB. These incidents had no effect on human health and the environment.

Possible causes of incidents of lost radiatian sources:

(a) Lack of security, since the containers of sealed sources can have a certain attractiveness because of their appearance or their apparent value as scrap metal.
(b) Handling by person with insuficient knowledge of radiation protection or regulation.
(c) Lack of radiation protection personels in hospital and industry.
(d) Negligence of record for use of source.

Tabel 4 Incidents in the application of radiation sources in 2001

No.	Date	Incident	Effect
1.	18 September	Rubber irradiator: Panel control showed the Co-60 in storage position, however the source was still in exposure position.	No effect
2.	13 September	Oil exploration: stucked sources of Am241-Be 16 Ci and Cs-137 1.7 Ci	No effect
3.	4 October	Oil exploration: stucked sources of Am241-Be 16 Ci and Cs-137 1.7 Ci after drill side track	No effect
4.	5 October	Oil exploration: stucked sources of Am241-Be 16 Ci and Cs-137 1.7 Ci.	No effect
5.	24 October	Oil exploration: stucked sources of Am241-Be 16 Ci and Cs-137 1.7 Ci.	No effect
6.	3 December	Handle close/open gamma ray did not work properly.	No effect

References

1. IAEA, Management of small quantities of radioactive waste, IAEA-TECDOC-1041, Vienna, 1998.
2. NECB, Report on Nuclear Safety in Indonesia, NECB, Jakarta, 2000.
3. IAEA, Quality Assurance for Safety in Nuclear Power Plants and Other Nuclear Installation, Safety Series No. 50-C/SG-Q, Vienna, 1996.
4. DC-RWM, Internal Report on Spent Sealed Radiation Sources, DC-RWM, Serpong, 2001.
5. IAEA, Regional Training Course on Management of Spent Radiation Sources and other waste from small nuclear application, PNRI, Manila, 1995.
6. NECB, Draft of the Regulation of Radioactive Waste (under progress), NECB, Jakarta, 2001.
7. DC-RWM, Summary Report of Ra-226 Conditioning, DC-RWM, March, 2001.
8. DC-RWM, Quality assurance program in Indonesia, Revision 6, DC-RWM, November 2001.
9. NECB, Nuclear safety report in Indonesia, NECB, January 2002

9. Current Status of Spent Sealed Radiation Source Management in Korea

9.1 Introduction

Many kinds of radioisotopes (RI) have been used in various fields, such as university, research institute, industry, hospital, etc. Radiation from radioisotopes is widely used for the diagnosis and treatment of cancer, X-ray photography, radio-sterilization, agricultural research, non-destructive testing and so on. Use of radioisotopes has been increasing steadily in Korea since 1980s. In recent several years, the number of radioisotope users showed 10% increase every year, so did the amount of radioisotope waste from the users. **Table 1** shows the number of RI users in Korea as of the end of 2001.

Table 1. The Number of RI Users by Category of Organizations

(as of December 31, 2001)

Organization	RI Users	RG Users	RI+RG Users	Total
Industrial Firms	455	332	100	887
NDT Firms			36	36
Sales Firms	39	49	8	96
Public Organizations	162	74	15	251
Hospitals & Clinics	76		53	129
Educational Organizations	67	63	66	196
Research Institutions	121	57	38	216
Others	9	2		11
Total	**929**	**577**	**316**	**1,822**

Note) RG: Radiation Generators

Most of the sealed radiation sources are supplied by overseas manufacturers, but some particular sources such as Iridium and short half-life isotopes are supplied by Korea Atomic Energy Research Institute (KAERI). When purchasing a sealed radiation source, the source should be sent to the Korea Radioisotope Association (KRIA) for inspection tests before its delivery to the end user.

Once disused, the spent radiation sources (SRS) are considered as radioactive waste that should be managed in a safe manner. Korean regulatory framework and SRS waste management system will be discussed in this paper. In addition, radiation incident experience in Korea and scrap monitoring system will be briefly introduced.

9.2 Regulatory Framework

The use of sealed radiation source is under the control of the Korea Institute of Nuclear Safety (KINS) on behalf of the Ministry of Science and Technology (MOST). Organizations for the management of spent radiation source in Korea are shown in **Fig. 1**. The Atomic Energy Commission, the highest policy making body on nuclear matters, establishes national basic policy on the SRS management. The Deputy Prime Minister is the chairman of the AEC. Ministry of Science and Technology, MOST, is responsible for nuclear research and development, nuclear safety, and licensing. Ministry of Commerce, Industry and Energy Resources, MOCIE, is responsible for disposal of radioactive waste including SRS and interim spent fuel management. Nuclear Environment Technology Institute (NETEC), a branch organization of Korea Hydro and Nuclear Power Corporation, undertakes all activities related to the radioactive waste disposal under the control of MOCIE. Korea Institute of Nuclear Safety, KINS, performs safety review and inspection for nuclear facilities, and develops safety standards. Korea Atomic Energy Research Institute, KAERI, is in charge of R&D on HLW disposal and reuse of spent fuel.

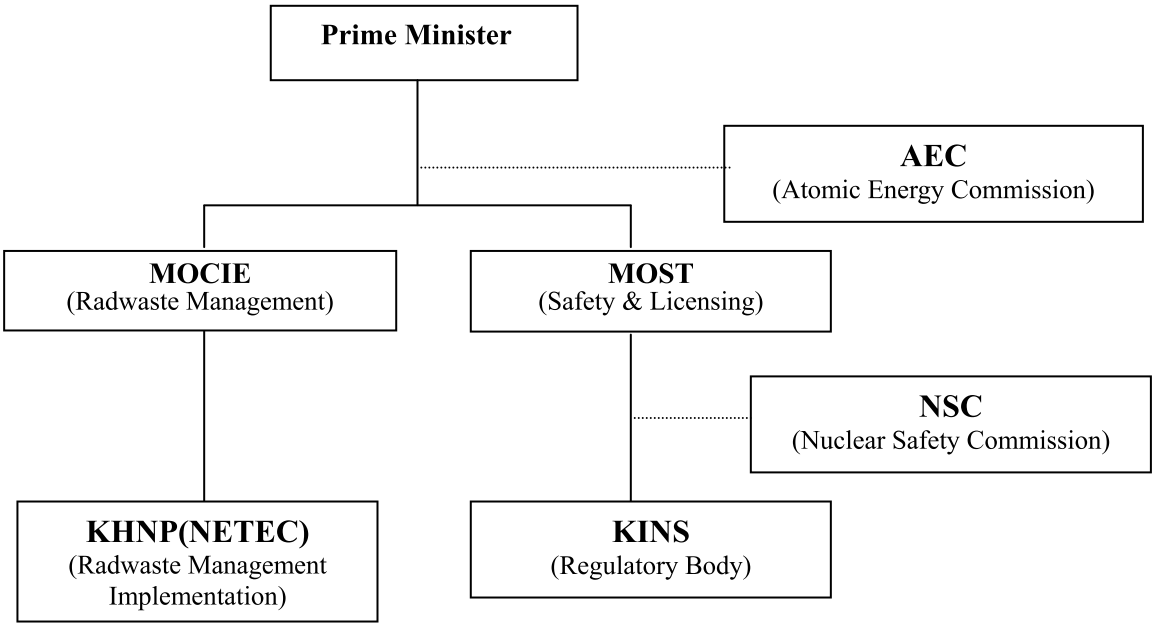


Fig. 1 Governmental Organization for Radwaste Management in Korea

9.3 Collection System of SRS in Korea

Most of sealed radiation sources in Korea are supplied by KRIA. Once used, the spent radiation sources (SRS) are directly sent to NETEC. SRS generators may consign the transportation of SRS to NETEC. NETEC is currently collecting radioisotope wastes from hospitals, industries, and research institutes, then storing them at a dedicated storage facility.

Some kinds of SRS can be reused after confirming the quality necessary to its application. Certain kinds of neutron sources and high-energy gamma-ray sources were reused in RI loaded industrial gauges.

KRIA collects the unsealed radioisotope wastes from the RI users and delivers them to NETEC. The received RI waste is checked and stored in an assigned room according to its physical, chemical, and radiological characteristics. **Fig. 2** shows the procedure of SRS management in Korea.

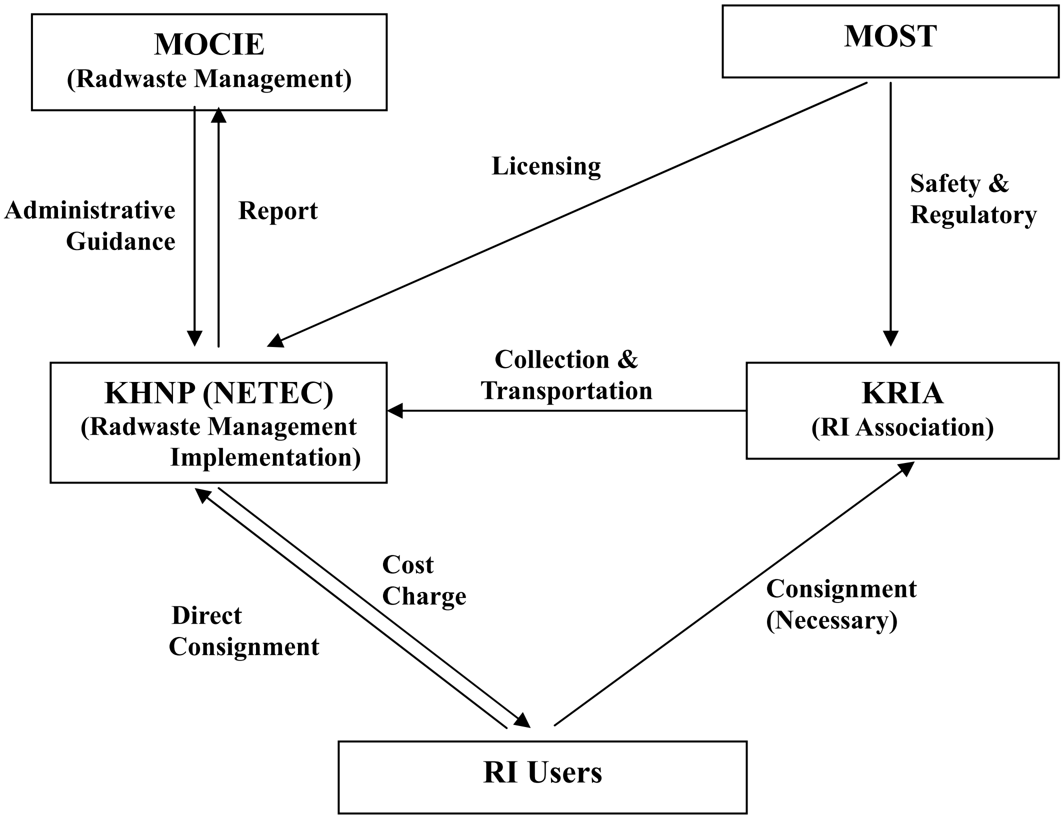


Fig. 2 RI Waste Management Procedure in Korea

9.4 Radioisotope Waste Generation

Typical RI wastes are plastic tubes, injections, paper towels, glass vials, frozen animals used for experiments and off-gas filters. About 400 drums by 200 liter RI waste drums are annually collected from various RI users. The collected RI wastes are stored at a dedicated interim storage facility in NETEC-KHNP. The interim storage capacity is no more than ninety-three hundred drums. The accumulated number of RI waste drums reaches about forty-six hundred as of August 31, 2002. KHNP will dispose of these wastes at the final repository to be constructed by the year 2010. **Table 2** shows the storage status of RI wastes in the NETEC storage facility.

Table 2 Storage Statue of RI wastes in the NETEC Storage Facility

(As of August 31, 2002)

Classification		Cumulative Amount	Convert into 200L drums	Storage Capacity (200L drums)	Percentage (%)
Unsealed Source Waste	Combustible	7,741 (100L)	3,871	8,800	
	Non-combustible	359 (100L)	180		
	Non-compactible	506 (100L)	216		
	Spent Filter	106 ea	62		
	Carcass Waste	- (50L)	-		
	Organic Liquid	983 (20L)	98	117	
	Inorganic Liquid	41 (20L)	4		
	Subtotal		4,431	8,917	50
Sealed Source Waste		1,353 box	172	360	48
Total			4,603	9,277	50

As shown in the above table, the existing storage facility may not accommodate all the RI wastes to be generated until 2010. Therefore, NETEC tries to apply some techniques for volume reduction of the stored RI wastes. For unsealed source, the volume of non-combustible waste is reduced by compaction. And the volume of combustible waste and organic liquid waste will be greatly reduced by incineration.

Sealed sources are kept in appropriate lead containers embedded in concrete blocks or in shielded casing as provided by the manufacturer. They are stored in a radioisotope waste management facility. The volume of spent sealed sources is strongly dependent on the container type, material, and shape. So the volume can be reduced consolidating several sources in a specially designed container. One example is an Ir-192 source. The Ir-192 source is separated from the remaining pigtail by cutting machine. Then, several sources are stored in a specially designed consolidated container. We performs the cutting job inside the receiving and inspection equipment room for sealed source

The consolidated container contains thirty cylindrical type guide tubes. Each guide tube equips with six tubes. Two hundred Ir-192 sources are placed in a tube. In order to keep the ambient radiation level below the determined level, the consolidated container is put in a concrete shell of which volume is twenty-four hundred liters. In such a way, the volume reduction ratio over fifty was achieved. **Fig. 3** shows the consolidated container for Ir-192 sources and the tubes. And **Fig. 4** shows the RI waste treatment flow diagram at NETEC after collecting RI wastes.

(a) (b)

Fig. 3 Consolidated Container for Ir-192 Sources(a) and Tubes(b)

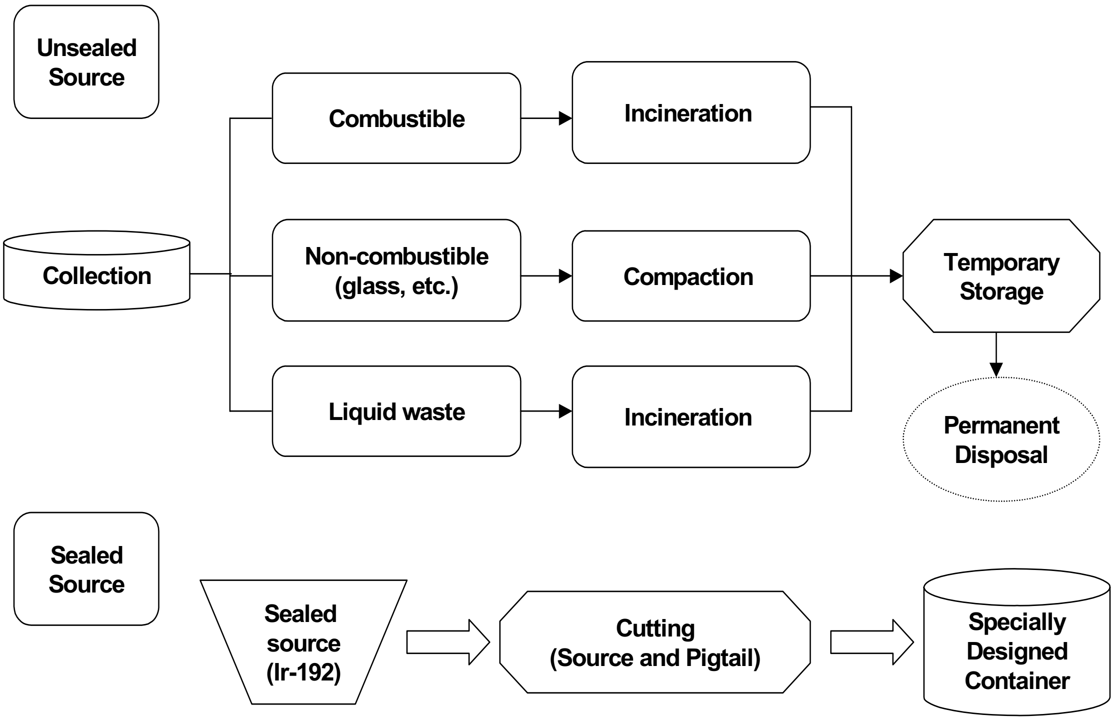


Fig. 4 RI Waste Treatment Flow at NETEC after Collecting RI Wastes

For strong Co-60 and Cs-137 sources, which are not suitable for LILW repository, we developed another type of consolidated container. This package will be exclusively used for spent sealed sources, especially for strong gamma sources such as Co-60, Cs-137. The conditioning is performed by the encapsulation of the source in a stainless steel capsule followed by placing the capsule in the cylinder.

The consolidated container contains eight small capsules and one large capsule. This container is classified as Type A package satisfying the Korea Atomic Law and the IAEA safety standard series 1. Therefore, the radiation level at any point of the external surface should be kept below 2 mSv/hr. To satisfy this requirement, maximum radioactivity placed in a capsule should be kept below 11 Ci for Co-60 and 20 Ci for Cs-137, respectively. **Fig. 5** shows schematic diagram for the treatment of strong gamma sources at NETEC facility.

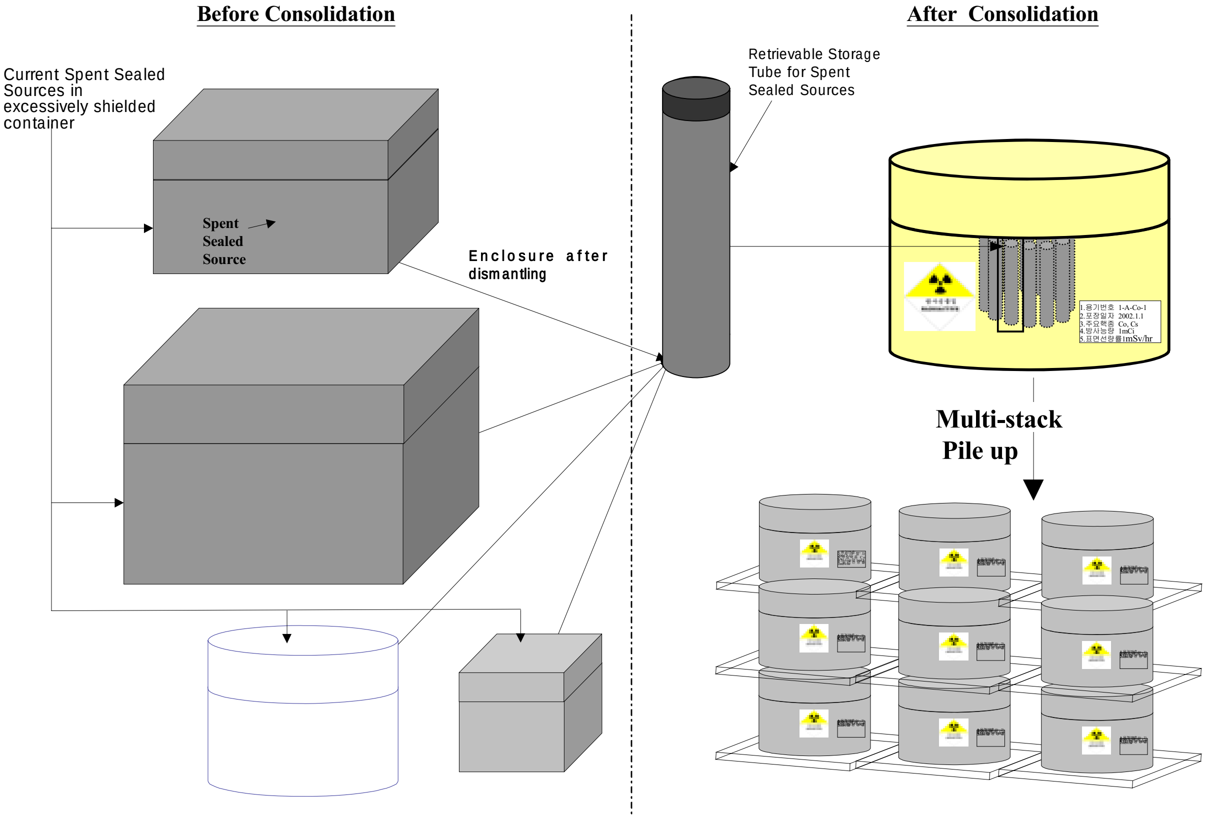


Fig. 5 Schematic Diagram for Consolidating Strong Gamma Sources at NETEC Facility

9.5 Radiation Exposure Incident in Korea

A careless radiation exposure incident was occurred on 22 November 2000 in the City of Ulsan, Korea. A non-destructive examination job was completed as planned. But they could not retrieve the source. Two technicians tried to remove the source capsule stuck inside the guide tube, but they couldn't. For the next trial, they decided to cut the guide tube of the irradiator using a portable grinder. Unfortunately, they cut through the source capsule with the guide tube, and source particle was dispersed all around.

The source was 20 Ci Ir-192, and the irradiator was Amertest 600B supplied by Amershem. In this consequence, one technician was directly exposed to the broken dispersed source, and the surrounding area was contaminated. He was sent to the hospital for medical treatment. Fortunately his exposure level was quite low, so no serious medical symptom was observed. The surrounding area was sealed off completely, and emergency measure was taken into action to prevent further spread of contamination. The decontamination and clean-up activities had already finished.

The reason of incident has known to be ignorance of work procedure. Even in the emergency situation, the procedure was ignored. It was beyond common sense.

Considering that we have 1,500 radioactive source users and the number of users increases about 10% every year, we are going to make all effort to enhance operational safety of radioisotope application in Korea.

9.6 Scrap Monitoring System

One important issue in the SRS management is to prevent from reusing inadvertently contaminated scraps. Once the contaminated scraps are melted in the smelting furnace, the whole batch is contaminated. Then it may cause large and high exposure of general public. Therefore, Korean steel companies are asked to equip an appropriate scrap monitoring system to find any contaminated scraps.

There are two kinds of scrap monitoring systems. One is the fixed monitoring system, another is the portable monitoring system. Two large area plastic scintillators are generally used as a fixed monitoring system. Relative readings from two detectors are measured to compensate self-shielding effect by scraps. By doing this, it is possible to detect any SRS placed inside the pile of scraps from small difference of the readings although the measured dose rate is small because of the self-shielding effect. The fixed system is generally used to judge whether or not the contaminated scraps are contained in a vehicle.

More sensitive NaI (Tl) or CsI (Tl) scintillator than plastic scintillator is used in the portable monitoring system. But these scintillators have limitation in their size, and are very costly. The portable system is used to locate a radioactive source from the pile of scraps after the inclusion of contaminated scraps is confirmed with the fixed system. In addition, it is possible to distinguish radioisotopes by analyzing detector signals using a MCA. However, it is very difficult to judge the inclusion of small SRS in a pile of scraps with the only portable monitoring system because of the self-shielding effect. Therefore, two monitoring systems (fixed and portable) should be equipped for the effective scrap monitoring in a steel company.

In order to detect radioisotopes in a moving vehicle, a special measure algorithm, so called Advanced Digital Filter (ADF), is applied. ADF is an intelligent ratemeter function with a self-adjusting time constant. It provides automatic adaptation to the velocity of a moving source or detector and to the variable intensity of radiation. **Fig. 6** shows responses from a conventional fast filter and from the ADF.

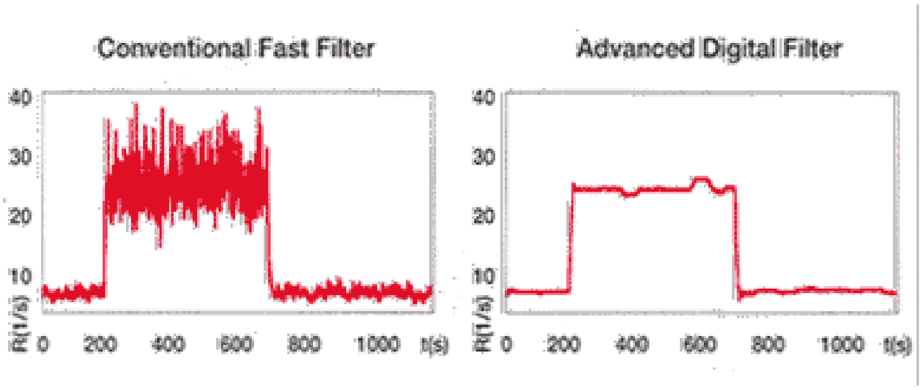
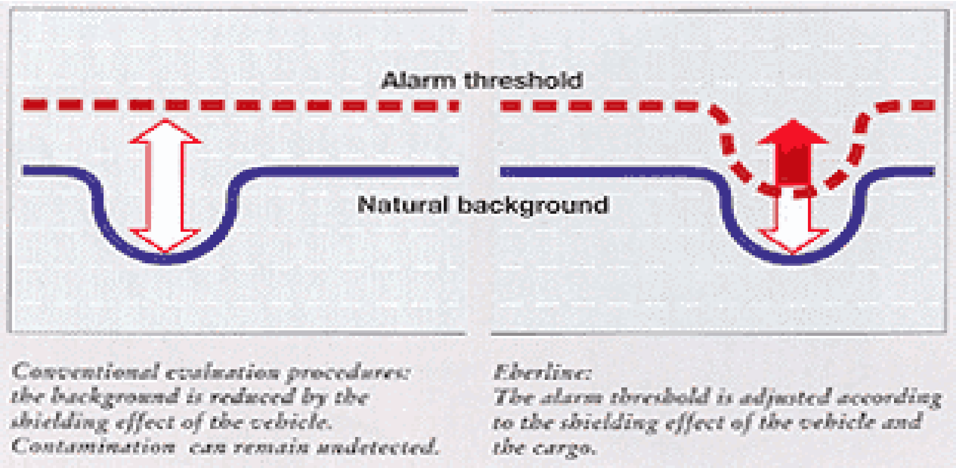


Fig. 6 Comparison of the Response from a Conventional Fast Filter with that from a ADF

If the vehicle enters the scrap monitoring system, detector responses are decreased because of natural background shielding effect by scraps and vehicle itself. Therefore, Alarm threshold should be automatically adjusted by considering the reduction in the natural background. **Fig. 7** shows the concept of alarm threshold adjustment.

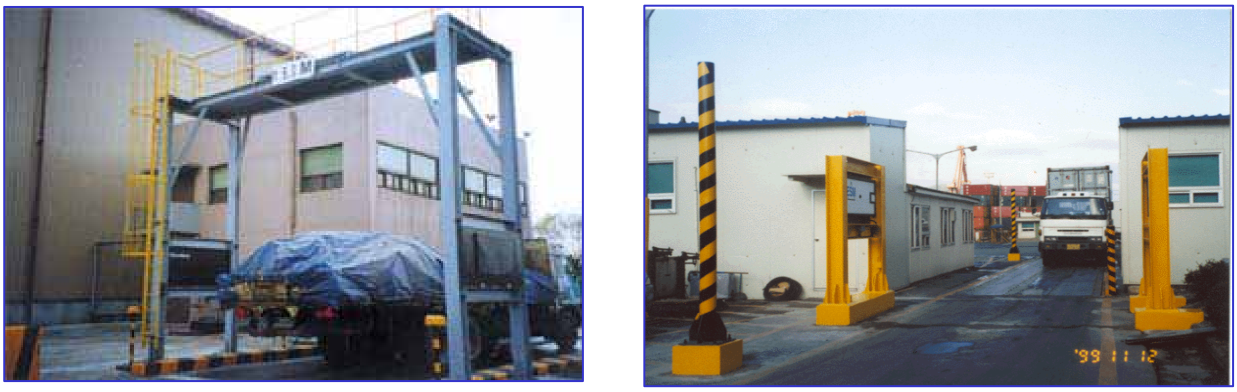


Conventional evaluation procedures: the background is reduced by the shielding effect of the vehicle. Contamination can remain undetected.

Eberline: The alarm threshold is adjusted according to the shielding effect of the vehicle and the cargo.

Fig. 7　Adjustment of Alarm Threshold by Natural Background Reduction

Fig. 8 shows two pictures of scrap monitoring systems installed in Korean steel companies. A truck loading scraps is passing by the system in Fig. 8(a), and a truck is entering the system in Fig. 8(b).



(a)　**(b)**

Fig. 8　Scrap Monitoring Systems Installed in Korean Steel Companies

9.7　Conclusion

Use of radioisotopes has been increasing steadily in Korea since 1980s. In recent several years, the number of radioisotope users showed 10% increase every year, so did the amount of radioisotope waste from the users. Therefore, the safe management of SRS has become a important issue in Korea. In this paper, Korean regulatory framework was briefly introduced. Nuclear Environment Technology Institute(NETEC) is in charge of collection and disposal of RI wastes under the control of Ministry of Science and Technology(MOST) for safety and regulatory issues and Ministry of Commerce, Industry and Energy Resources(MOCIE) for administrative affairs. After collecting RI wastes from users, NETEC stores them at a dedicated storage facility until they are disposed permanently. For the effective management of the RI wastes in the storage facility, NETEC applies some volume reduction technologies, such as compaction, incineration, and consolidation. In order to highlight the importance of sealed source management, a radiation exposure incident on November 2000 in Ulsan, Korea was analyzed. Finally, types and basic principles of scrap monitoring systems are described.

References

1. Ministry of Science & Technology (MOST) and Korea Radioisotope Association, "Statistics on Radiation Practices in Korea", 2001.
2. Ministry of commerce, and Industry and Energy, "Regulation for the consigning radioactive waste and its cost", MOCIE Notice No. 2002-67, 2002.
3. Choi K.S., et. Al., "Radioactive Waste Management Activities in Korea", Proceedings of International Symposium on Radiation Safety Management (ISRSM), 2001.

10. Postscript

Here we could summarize the project result of the Spent Radiation Source Management Task Group's activity under Radioactive Waste Management (RWM) Project of FNCA. The authors are expecting this information will be widely used to promote a good practice of safe management of spent radiation sources.

March 2003.

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