Improving the management of spent radiation sources

Problems with old radiation sources once used in industry, medicine, and other fields have highlighted the need for safer practices

by B.G. Pettersson

Early in 1992, the IAEA started a programme to assist countries, particularly those in the developing world, in their efforts to avoid conditions that might result in accidents with radiation sources that are no longer in active use. In the past, accidents involving radiation sources have caused significant overexposure of people, even to the extent of fatalities, and have led to costly decontamination and other cleanup operations.

Radiation sources typically are used in industry, medicine, and research for a variety of beneficial applications, including radiography and teletherapy.

The central problem is caused by the lack of adequate measures when such sources are taken out of service. During the operational lifetime of a radiation source, awareness of its radioactive characteristics is readily maintained, and at least basic radiation protection provisions are applied. But if it is not properly retired from service, the source might easily become detached from safe management and surveillance procedures. A passive retirement may well result in a situation where, eventually, nobody is responsible for essential radiation protection and waste management measures. Information on source and equipment data, as well as on the source's physical location will then be lost, and an accident- or incident-prone situation may soon develop, as some unfortunate experiences with radiation accidents have shown.

This article reviews some important aspects of the problems associated with improper or inadequate management of spent radiation sources. It further reports on efforts now being taken through the IAEA's newly launched programme, particularly those directed at helping countries identify, locate, and safely manage spent radiation sources that could pose public health and safety risks.

Sealed radiation sources

A sealed radiation source is a custom-made piece of equipment, the design of which has been based on requirements posed by its intended use, as well as relevant safety considerations. They are said to be sealed because they are encapsulated in order to contain the radioactive contents. Stainless steel is commonly used for encapsulation, which may be double layered, particularly for gamma emitting sources. Other essentially inert materials, for example platinum and titanium, may be used instead of steel. For early radium sources, gold, silver, brass, and even glass, were used for capsules.

Modern radiation sources are manufactured to standards that are internationally agreed and specific to intended end-uses. The radioactive material itself is in insoluble form (e.g., metal or ceramic). The standards require the sources to be tested to ensure that they are leak-tight. Such sources can usually withstand adverse environmental conditions, such as exposure to heat during unintentional incineration.

Old radiation sources, in particular radium sources, were manufactured to standards lower than those of today. For example, the radioactive material itself was often a powder or a soluble salt, and the technique used to seal the capsule was inferior compared to current practice. What today is considered proper radiological protection management of radiation sources was not always implemented from the outset, which resulted in accidents due to improper handling, use, or storage of radium sources.

Radium. Before the 1950s, radium was virtually the only radionuclide available for use in radiation sources. Medical use (brachytherapy)

Mr Pettersson is a staff member in the IAEA's Department of Nuclear Energy and Safety. More detailed information on this subject is available in a recently published IAEA report, *Nature and Magnitude of the Problem of Spent Radiation Sources*, IAEA TECDOC – 620, Vienna (September 1991).

Year	Location	Type of radiation source/application	Fatalities Worker	Fatalities Public
1962	Mexico City	Lost radiography source		4
1963	China	Seed irradiator		2
1975	Brescia, Italy	Food irradiator	1	
1978	Algeria	Lost radiography source		1
1981	Oklahoma, USA	Industrial radiography	1	
1982	Norway	Instrument sterilizer	1	
1984	Morocco	Lost radiography source		8
1987	Goiânia, Brazil	Stolen teletherapy source		4
1989	El Salvador	Sterilization facility	1	
1990	Israel	Sterilization facility	1	
			5	19

Total: 10 events with 24 fatalities

Note: Accidents caused by X-rays, accelerators, medical treatment, and reactors or critical assemblies are not included.

Source: Oak Ridge Associated University, USA

Reported fatalities from accidents involving sealed radiation sources

dominated. At that time radium was very expensive, meaning that control of sources was essentially linked to economic reasons. Only later, based on lessons learned through the observance of radiation damage to tissue, were controls introduced that were based on radiological protection considerations. More than 100 of the pioneers in the field died from high exposure to radiation.

Treatment of malignant tumours was the main application of radium. The radioactive material was contained in tubes or small needles, which could be placed in direct contact with the tumour. This provided a great advantage compared to X-rays, which could only be applied from outside the human body.

Radium was also used in luminous compounds for watches, clocks, and instruments. A range of miscellaneous products containing small, if not minute, quantities of radium were available primarily during the 1920s and 1930s. These products derived their marketing potential from the successful radiotherapeutical use of radium. They included, for example, radium emanators for producing "healthy" radon water, radium salve, and radium-containing cloths argued to possess various healing powers. The products, however, were never scientifically proven to provide any of the healing effects that the advertisements promised. In fact, these products were not justified, and their use could be dangerous. A radium emanator could contain up to about 0.5 mg of radium.

Radium was first extracted by Marie and Pierre Curie in 1898. By the time commercial radium extraction was discontinued in 1960, about four kilograms of radium had been produced. More suitable and safe radiation sources, which started to become available in the 1950s, gradually began to replace radium.

Today, radium sources constitute a special problem. It is related to radium's earlier high commercial value, as well as to its characteristics and to the design of sources. Previously, radium sources were provided to developing countries as donations, or they were delivered before these countries had achieved independence. When alternative radiation sources became available, the economic incentive for control diminished, often without proper radiological protection measures being established.

As time progresses the risk increases that, eventually, nobody will know the original number and characteristics of the sources, or where they physically are located. If, subsequently, the physical place of operation is closed down, or moved elsewhere, the traceability of the sources may well be entirely lost.

The other aspect of the problem is associated with the long half-life of radium (1600 years) and with radium decay. Through decay, gas is generated, which means that pressure builds up in the capsule used to contain the radium. If the capsule is not properly sealed, leakage will result, and at least the immediate environment will be contaminated.

Accidents involving sealed sources

Accidents and incidents with sealed radiation sources are reported in scientific and technical literature, but there is no readily available complete compilation of these events. The IAEA has devoted symposia, or symposium sessions, to these occurrences, and the Oak Ridge Associated University in the USA maintains a register providing information. Still, the coverage is limited.

According to information provided in the US register, 10 accidents with fatal consequences have occurred with sealed sources. In five of these, each of which caused one death, the accidents involved sources that were still in use. In the other five accidents, spent sources were involved. Nineteen persons died from those accidents. *(See table.)*

The data suggest that accidents with spent sources result in consequences more severe than accidents with sources still in use. Accidents with spent sources occur because people are not aware that they are handling a radiation source. A long time can therefore elapse before the accident is recognized, allowing high exposure before protective action is taken.

Accidents with spent sources having fatal consequences are usually characterized by a much higher number of over-exposed persons as compared to similar accidents with sources still in use. Over the last three decades there has been a decrease in the number of reported accidents. In terms of number of persons over-exposed the situation is reversed. *(See graph.)*

Accidents can result in significant consequences without the trauma of death being present. Resulting individual doses would be small, but the collective dose could be high. Furthermore, cleanup costs could be substantial.

A particular and unusual case of metal contamination occurred in New York in the 1950s. Spent radon sources, or more precisely the gold used for their encapsulation, found their way to the jewelry industry. Rings and other jewelry were manufactured from this gold without proper decontamination. In 1981, a total of 170 pieces of contaminated jewelry were identified, and nine persons were found to have skin lesions. The persons had, on average, worn their jewelry for 17 years. As late as 1989 three new cases of contaminated gold rings were discovered, two of which had resulted in skin cancer on the wearer's finger.

Overall, the magnitude of potential problems involving sealed radiation sources, especially those that are spent, can vary considerably. *(See figure, page 22.)*

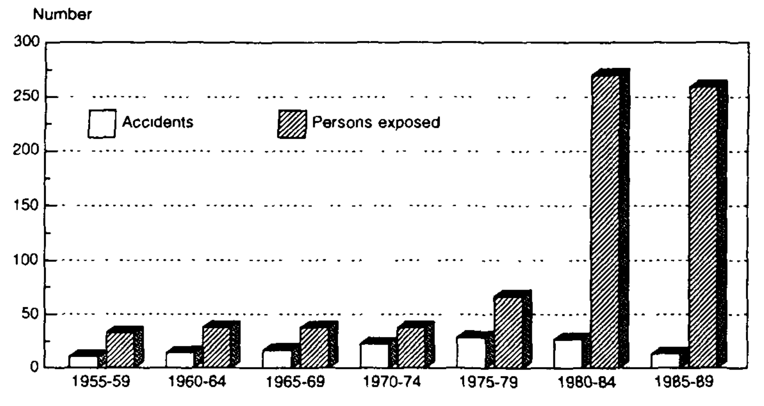
Economic consequences of accidents

The economic costs associated with an accident involving a spent radiation source can only be broadly defined. It should be noted that damage to health, including fatal damage, is not fully included, since it cannot be expressed in monetary terms.

Medical treatment and compensation. Overexposed persons may require specialist medical treatment, and they or other persons may require other kinds of treatment to help them overcome traumatic experiences related to the accident. Additional related costs include monetary compensation to persons involved in the accidents.

Loss of items, products, or plant. Such costs would be caused by unsuccessful decontamination to the extent that the item must be classified as radioactive waste. Even if decontamination is successful, it can often be time consuming, which would lead to, for example, loss of production capacity.

Remedial and follow-up actions. The exact cause of events before the accident was recognized may not be known, and in such cases extensive surveillance or monitoring efforts to identify lost sources and contamination may be called for. The sources and any contaminated material will have to be handled and processed



Reported accidents with sealed radiation sources and persons exposed

as radioactive waste that needs to be stored and ultimately disposed of safely.

Only estimates, or illustrative figures, of these costs can be provided. Costs for specialist medical treatment of highly exposed persons is very expensive. Total costs for treating a seriously exposed person can exceed US $500 000. Costs for monetary compensation to persons are virtually impossible to illustrate, because they would depend on factors such as national policy and particulars of national law.

Similarly, loss of value of investment cannot be indicated because of its case-specific nature. However, if contamination is involved such costs can be significant, on the order of millions of dollars.

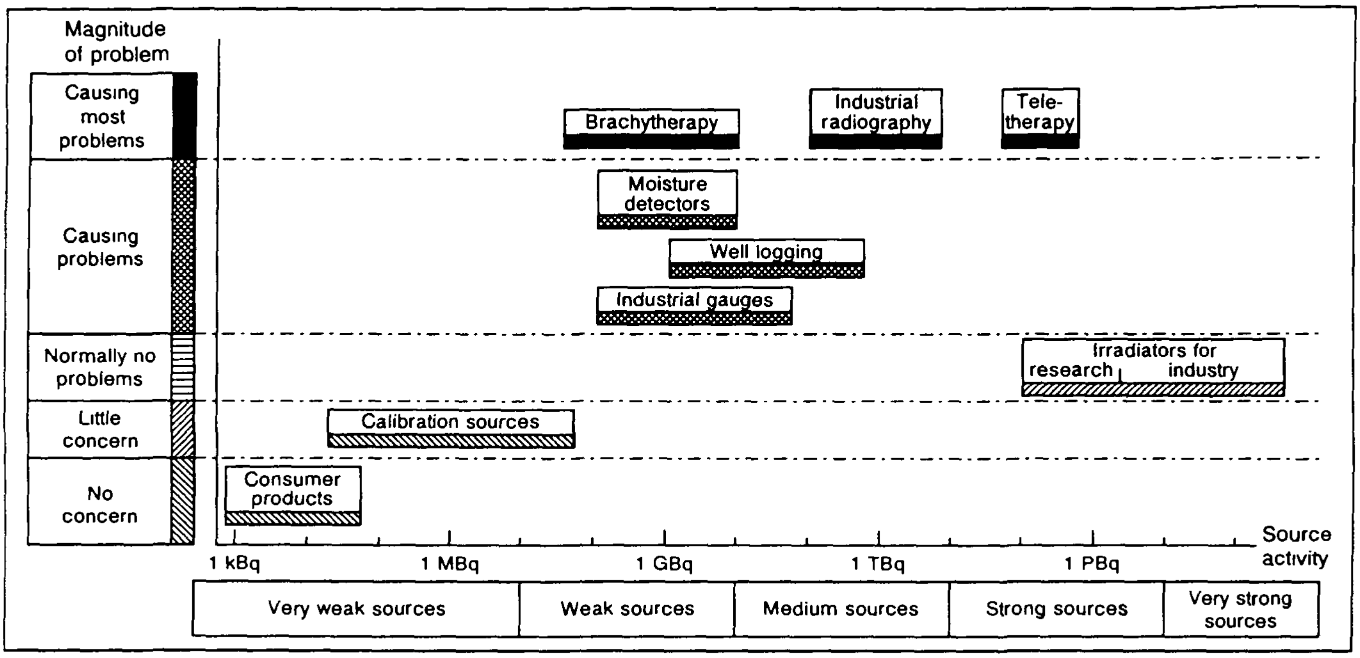
Costs for radiation surveys needed to determine the extent of contamination can be anything from trivial to more than US $100 000. Decontamination costs depend heavily on the nature and extent of contamination. Again there is potential for a wide cost range up to, or exceeding, US $1 million.

Costs for the management of radioactive waste will be specific to each case. Necessary activities include on-site collection of waste, conditioning, interim storage, transport operations, and final disposal. The cubic metre cost for final disposal is estimated to fall in the range of US $1000 to $10 000.

Recognizing, and preventing, problems

Experience confirms that accidents with spent radiation sources can indeed happen. Understanding what action is necessary to avoid accidents requires a combination of awareness and capability.

Awareness means the understanding or recognition of the dangers associated with spent radiation sources. An associated element is basic knowledge that radiation sources have been, and



Magnitude of problems from selected applications of spent radiation sources

are, in use in the country. Capability includes all those conditions and actions necessary to successfully identify and locate, and to properly manage, the sources.

In a generalized way, it can be concluded that countries lacking an infrastructure for radiation protection and waste management do not properly recognize the risks of spent radiation sources. If there is no evidence, or suspicion, of the existence of spent radiation sources, it might be said that there is nothing to be aware of. The infrastructure element, therefore, becomes of utmost importance. It may well be that awareness can only come after establishing appropriate legislation, and a government agency with responsibility and enforcement power in the field of radiation protection and waste management.

Given awareness, additional conditions must prevail in order to set up the capability for suitable waste management operations. There are several elements involved:

- Again, the infrastructure for radiation protection and waste management is of major importance. Other than necessary legal and organizational arrangements, qualified staff is required. This infrastructure must not be seen in isolation. On the contrary, successful operation requires smooth co-operation with other infrastructures in the country, or in other countries, in areas such as training and supply of equipment.
- Financial considerations are likely to be of importance in many developing countries. The limited financial resources may have to be deployed for other purposes simply because the associated needs are greater.
- In many cases, knowledge of identity and location of spent radiation sources is lacking.

The IAEA's strategy and response

With regard to the urgent need to improve safe management of spent radiation sources, the IAEA has developed a multi-faceted strategy. Its main elements are to:

- Promote establishment and improvement of waste management infrastructure.
- Foster the return of spent radiation sources to suppliers as a first alternative for developing countries.
- Facilitate management of spent radiation sources in developing countries by preparing technical manuals and training material, providing training opportunities, and by evaluating national situations through expert missions under the IAEA's Waste Management Advisory Programme (WAMAP) and subsequent technical co-operation projects.
- Provide countries which are lacking a waste management infrastructure with practical assistance to safely manage their existing spent radiation sources.
- Foster regional co-operation for the establishment of shallow-land repositories for short-lived spent radiation sources and for interim storage facilities for long-lived spent radiation sources; and foster co-operation for multinational or bilateral agreements that facilitate the ability of developing Member States to dispose of long-lived spent radiation sources in licensed

deep geological repositories for high-level wastes when those are established.

Under point one, radioactive management infrastructure, the strategy encompasses, for example, legislation, regulations, a competent authority, trained and experienced staff, and facilities/equipment to perform the tasks involved in management/disposal of the sources.

Regarding point five, the bases for establishing regional shallow-land repositories, as well as for interim storage facilities, should be the region's common need to resolve a problem, and mutual understanding that a particular option is best suited to satisfy the need.

Deep geological repositories are unlikely to be constructed in most of the developing Member States. The costs are likely to be out of proportion in relation to the small quantities of spent radiation sources, in terms of both volume and radioactivity. It would seem reasonable to assume that, on radiological protection and safety grounds, such small additional amounts could be accepted for disposal in geological repositories that are being designed in some Member States to handle large volumes of high-level waste. Legal issues and acceptance criteria could be established in the framework of bilateral agreements.

Action plan. Based on the above strategy the following action plan has been developed for implementation by the Agency:

Regional training courses. These will focus on identification and location of sources; transport; conditioning of sources, or their return to suppliers; storage options; and final disposal. A training material package is foreseen, which would enable States to arrange their own training courses. IAEA-arranged training courses are planned annually.

Methods for identifying spent radiation sources. A technical document will provide advice on how to practically go about locating spent radiation sources. It would provide examples of where such sources are likely to be found, what they look like, what instruments would be suitable in searching for sources, and how to best use them, among other practical guidance.

Development of a database package for checking sealed radiation sources. To ensure that relevant information is available when a source becomes spent, and also to facilitate its identification and location, a general-purpose database software package for maintaining records will be developed. Suitable for use on a personal computer, the package would be provided for use by national competent authorities.

Establishment of a database on accidents. The purpose of this database is that it would serve as a source of information on lessons to be learned, and the countermeasures to be taken in order to avoid, or mitigate, the effects of accidents with spent radiation sources.

Conceptual design of a standardized central interim storage facility. This effort aims at providing developing countries with necessary information for siting, constructing, and operating an interim storage facility for spent radiation sources of limited radioactivity.

Safety practices document on the conditioning and interim storage of radioactive waste from small users. Within the IAEA's Radioactive Waste Management Safety Standards (RADWASS) programme, a series of safety practices will be produced to support and expand on advice and guidance given in other, more conceptual, RADWASS documents. Current plans indicate that the subject matter of conditioning and interim storage of radioactive waste from small users will be included in an appropriate RADWASS document on safety practices.

Expert assistance missions to help identify and manage existing spent radiation sources in developing countries. Assistance would be given to those Member States that do not have a nuclear research programme, and that lack waste management infrastructure. It would be provided for the purpose of "cleaning up" an existing situation, and it would be given once only.

Assisting efforts to establish regional interim storage sites for conditioned radioactive waste. It is envisaged that the Agency's support, initially, would be restricted to initiating and participating in discussions among developing countries already belonging to established regional groups.

For implementation of the action plan, a 5-year period is foreseen. The first five items are part of ongoing activities.

Summary

The Agency's new programme on spent radiation sources is organized with the aim of assisting Member States, in particular developing countries, to prevent potential accidents with spent radiation sources. Through various channels, the intention is to help them to improve, and, where necessary, to establish, safe waste management practices.

The programme's primary focus is on strengthening national infrastructures and human resources for effective waste management. However, to a limited extent through missions of international experts, countries also will receive direct practical assistance for identifying, locating, and conditioning existing spent radiation sources. ❒