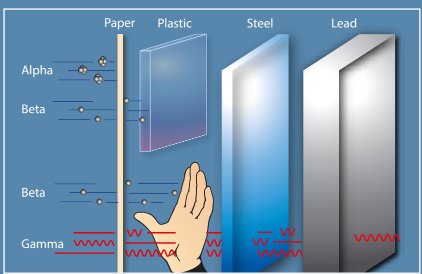
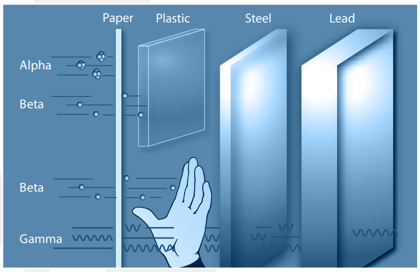
Information, resources, and advice for key groups about preventing the loss of control over sealed radioactive sources.

SEALED RADIOACTIVE SOURCES



IAEA
International Atomic Energy Agency

TABLE OF CONTENTS



SEALED RADIOACTIVE SOURCES

INFORMATION, RESOURCES, AND ADVICE FOR KEY GROUPS ABOUT PREVENTING THE LOSS OF CONTROL OVER SEALED RADIOACTIVE SOURCES.

This booklet contains:

- **Questions and Answers** on radiation and radioactive sources for non-technical audiences;
- Information for **government agencies** —
  which provides an overview for government officials not necessarily familiar with the issue of how to maintain effective control over sealed radioactive sources, as well as the long term management challenges for government officials;
- Information for **industrial users** of sealed radioactive sources —
  which provides a summary of relevant industrial accidents and guidance on preventing the loss of industrial sources;
- Information for **medical users** of sources —
  which provides a summary of relevant accidents and provides advice on preventing the loss of sources in medical settings;
- Information for **those working in the metal recycling industry** —
  which provides a summary of relevant scrapyard accidents, an overview of what sealed radioactive sources are, advice on how to recognize a device containing a sealed radioactive source and what to do should one be found;
- Information for **first responders**, **customs**, and **border control** —
  which provides a summary of issues pertaining to the loss of control of sealed radioactive sources in relation to emergency response by police, firefighters, and customs or border control agents;
- A fact sheet on **IAEA activities** —
  which provides a summary of key IAEA activities related to sealed radioactive sources as a reference for those working in government agencies;
- A fact sheet on key **IAEA publications** related to sealed radioactive sources —
  which provides a summary of key IAEA publications on this topic.

Among its many activities to improve the safety and security of sealed sources, the IAEA has been investigating the root causes of major accidents and incidents since the 1980's and publishes findings so that others can learn from them. There are growing concerns today about the possibility that an improperly stored source could be stolen and used for malicious purposes. To improve both safety and security, information needs to be in the hands of those whose actions and decisions can prevent a source from being lost or stolen in the first place.

The IAEA developed this booklet to help improve communication with key groups about hazards that may result from the loss of control over sealed radioactive sources and measures that should be implemented to prevent such loss of control. Many people may benefit from the information contained in this booklet, particularly those working with sources and those likely to be involved if control over a source is lost; especially: officials in government agencies, first responders, medical users, industrial users and the metal recycling industry. The general public may also benefit from an understanding of the fundamentals of radiation safety. This booklet is comprised of several stand-alone chapters intended to communicate with these key groups. Various accidents that are described and information that is provided are relevant to more than one key group and therefore, some information is repeated throughout the booklet.

This booklet seeks to raise awareness of the importance of the safety and security of sealed radioactive sources. However, it is not intended to be a comprehensive "how to" guide for implementing safety and security measures for sealed radioactive sources. For more information on these measures, readers are encouraged to consult the key IAEA safety and security-related publications identified in this booklet.

Further information can be found at ***http://www.iaea.org***

Requests for more information can be sent to ***radiation.sources@iaea.org***

Clean-up of radioactive contamination from a sealed radioactive source that was opened after control was lost. Credit: CNEN/Brazil.

INTRODUCTION

Emergency response team identifying and segregating contaminated objects following the loss of control of an irradiator containing sealed sources at Mayapuri, New Delhi, India / Credit: Atomic Energy Regulatory Board, Government of India.

In 2010, the University of Delhi in India instituted a campus-wide project to remove unused and unwanted objects. One of the objects identified for removal and disposal was an instrument that had been unused since 1985. It was auctioned in February to a scrap metal dealer and was delivered to the dealer in Mayapuri. No one realized that it contained sealed radioactive sources.

Sometime in March 2010, the owner cut off a sample of a source for testing as the metal had not been identified, and gave it to another dealer who put it in his wallet. By late March, the shop owner developed diarrhoea and skin lesions. In early April, the shop's owner was hospitalized with radiation sickness, which prompted an investigation that resulted in authorities confirming the presence of sealed radioactive sources.

The dealer who had taken the sample developed radiation burns on his buttock and later collapsed. By mid-April, a total of seven individuals were hospitalized with radiation injuries, with one more hospitalized and released. One individual was transferred to another hospital where he died from multiple organ failures due to the high radiation exposure.

Authorities recovered eight sources at the original shop, two at a nearby shop, and one from the dealer's wallet. Many of these were fragments of the original cobalt-60 source. Authorities also removed some contaminated soil.

Sealed radioactive sources such as the sources involved in the Indian accident are used widely in medicine, industry, and agriculture. The radioactive substance within a source is sealed within a protective container. Radioactive substances emit energetic particles or waves, which is called ionizing radiation. Radiation from the sources is used for a specific purpose — by doctors to treat cancer, by radiographers to check welds in pipelines, or by specialists to irradiate food to prevent it from spoiling, for example.

Professionals who work routinely with radioactive sources are able to do so safely because of their skill and training and because they are knowledgeable about the safety features and design of the equipment they are using.

When these sources are lost or stolen, however, they can fall into the hands of persons who do not have such training and knowledge or who wish to use them to cause harm intentionally. In such circumstances, radioactive sources may be a serious risk to anyone who comes too close to them, touches them, or picks them up, particularly if the sources are damaged.

WHAT IS A SEALED RADIOACTIVE SOURCE?

Various Cs-137 and Co-60 sources. Maximum length: 16 mm, maximum diameter: 8 mm / Credit: Eckert & Ziegler.

Sealed radioactive sources are used widely in medicine, industry, and agriculture. A sealed radioactive source is radioactive material that is permanently sealed in a capsule or bonded and in a solid form. The capsule of a sealed radioactive source is designed to prevent the radioactive material from escaping or being released from encapsulation under normal usage and probable accident conditions. Sealed radioactive sources are typically rather small, ranging in size from a few millimetres to several centimetres, with some specialized designs being almost one-half meter in length. The more commonly encountered sealed radioactive sources are near the lower end of the size range, generally up to a few centimetres in length.

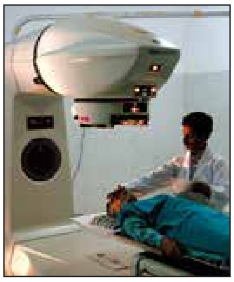
In most practices, a sealed radioactive source is installed in a device that is designed either to allow the source to move safely out of the shielded device to where the radiation beam is used and to be returned to the shielded device after the operation is complete, or to allow a beam of radiation to be released from the device while maintaining shielding around the source. The beam of radiation is used for purposes such as non-destructive examination of pipe welds or treatment of cancer in medical patients. The device may be any of a wide range of designs, depending on its purpose and function. Dimensions of these devices will range in size from several centimetres (e.g., static elimination gauge) to more than a meter (e.g., teletherapy machine or irradiator).

In some situations, sealed radioactive sources may be stored in a shielded container that is designed to reduce and control radiation in the area around the source. Such containers are typically extremely heavy, with most using lead as a shielding material within the container. They most often look like boxes, spheres, or barrels, but could be in a variety of shapes and sizes.

When used as designed, sealed radioactive sources have far-reaching benefits. When these sources are lost, stolen, or make their way into untrained or malicious hands, the consequences can be equally far-reaching, and even deadly in some cases. How can theft, loss, intentional misuse, and accidents be prevented? How can radioactive materials be detected before they make their way into the public domain?

In most countries, radioactive materials and machines that produce ionizing radiation are regulated. Those working with sealed radioactive sources are required not just to have proper authorization, but also specialized training and support to deal with unexpected circumstances that may arise when a source is used. Despite these measures, theft of sources and accidents continue to occur. Serious or life threatening injuries from exposure to radiation have been reported to the International Atomic Energy Agency (IAEA). Examples of accidents and incidents that have occurred due to loss of control of sealed radioactive sources are presented in this booklet.

1–4




5–8

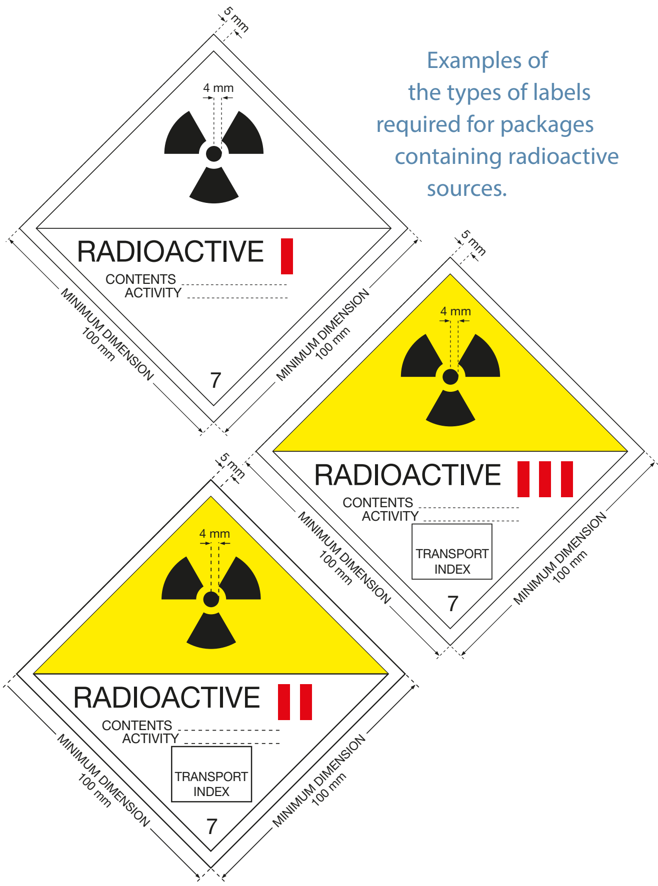



1 — Teletherapy machine / Credit: IAEA.
2 — Antiquated teletherapy device / Credit: D. Mroz (IAEA).
3 — Co-60 teletherapy source in a tungsten holder / Credit: Oak Ridge Associated Universities.
4 — Industrial radiographer wearing a TLD badge (thermoluminescent material in a special holder) used to measure radiation exposure.
5 — Various Kr-85, Sr-90 and Pm-147 sources. Maximal length:10 mm, maximal diameter: 22 mm / Credit: Eckert & Ziegler.
6 — Sealed radioactive sources / M. Al-Mughrabi, Waste Technology Section (IAEA).
7 — Blistering of the palm of the right hand caused by an overexposure to radiation (IAEA).
8 — Conditioning of a sealed radioactive source / M. Al-Mughrabi, Waste Technology Section (IAEA).

Basic ionizing radiation symbol: to signify the presence of ionizing radiation and to identify sources and devices that emit ionizing radiation.

Ionizing-radiation warning — Supplementary symbol: to warn of the presence of a dangerous level of ionizing radiation from a high-level sealed radioactive source.

Examples of the types of labels required for packages containing radioactive sources.



COULD THAT BE A SEALED RADIOACTIVE SOURCE?

Various devices that may contain sealed radioactive sources / Credit: D. Mroz (IAEA).

Serious injuries and even death have occurred in the past when a radioactive source is found and the person handling the source is not aware of the risk.

The same radiation that can penetrate metal or kill tumours can also be harmful, if it is not properly controlled. Excessive exposure to radiation can result in injuries such as skin burns. Being too close to a high activity source for too long can cause radiation sickness. Prolonged exposure to a high activity source can kill.

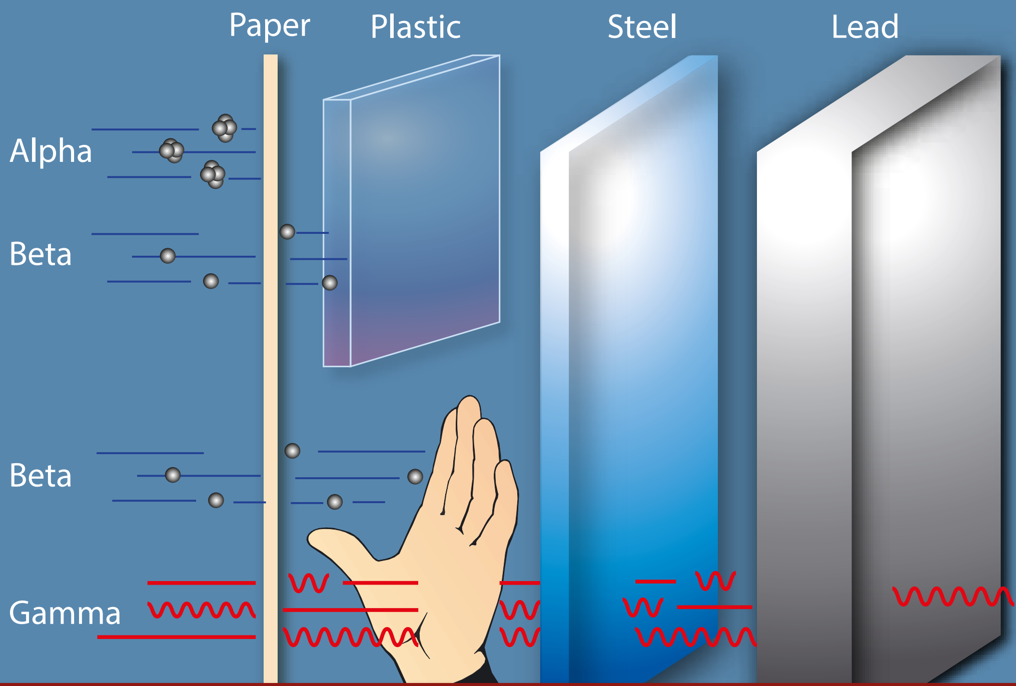
Radiation injuries can look like a burn, but unlike thermal burns, they do not heal easily. High levels of radiation exposure may also result in symptoms of nausea, diarrhoea, and fever. Anyone with these symptoms, who has been near to or touched a package or metal container with a radioactive symbol, should see a doctor immediately and be certain to inform the doctor about any contact with a radioactive source. Remember, a person does not have to touch a radioactive source in order to be exposed to radiation.

To inform people of the presence of radiation, radioactive sources have special labels. The trefoil is the international symbol that appears on all containers, materials, or devices that have a radioactive component. The word "radioactive" and the number I, II, or III may also appear on the packaging used to transport radiation sources.

Sources are sometimes lost on construction sites or when old equipment is thrown away. Lost or discarded devices containing sealed radioactive sources can end up in scrap metal yards.

People who collect scrap metal need to know how to recognize a device containing a sealed radioactive source. Old equipment, particularly if it is unusually heavy for its size, should be checked for the radiation symbol and other warning symbols.

- Anyone finding a package or metal container with a radioactive symbol should stay at least 30 meters away.
- Do not touch it or pick it up.
- Contact the appropriate authorities or the police.



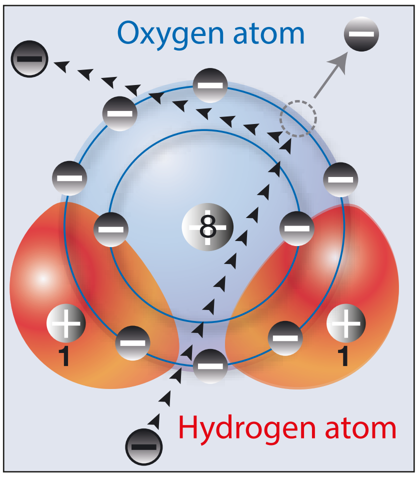
RADIOACTIVITY AND RADIATION: Questions and Answers

WHAT IS RADIOACTIVITY AND RADIATION?

Radioactivity occurs when unstable isotopes release energy as invisible waves or particles that are called radiation.

Ionizing radiation includes cosmic rays, X rays and the radiation from radioactive materials. Non-ionizing radiation includes ultraviolet light, radiant heat, radio waves and microwaves.

There are five main types of ionizing radiation, classified by the type of energy particle or waves they produce: alpha particles, beta particles, gamma rays, X rays and neutrons. This booklet will refer to ionizing radiation simply as "radiation".



Ionization of a water molecule by a charged particle.

WHAT DOES RADIATION DO?

The effect of radiation will depend on its ability to penetrate human tissue, which in turn depends on the type of energy particle or wave released.

Alpha particles (helium nuclei) can barely penetrate the outer layer of human skin, so are only hazardous when they are taken into the body by breathing or eating or through a wound. Beta particles (electrons) can penetrate only about a millimetre of tissue, so they are hazardous to superficial tissues, but not to internal organs, unless they too are taken into the body. Gamma rays, X rays and neutrons can pass through the body.

HOW ARE RADIOACTIVE MATERIALS USED?

Because radiation can penetrate matter, radioactivity and radioactive materials have many uses in medicine, agriculture, industry, mining and oil exploration, and research.




Industrial process gauge containing Am-241 / Credit: E. Reber (IAEA).
Typical blood irradiator / Credit: MDS Nordion.
Portable moisture/density gauge containing Cs-137 and Am-241/Be sources / Credit: Troxler Electronic Laboratories, Inc.
Typical ^{137}Cs oil well logging source bull plug / Credit: Schlumberger.

Radioactive pharmaceuticals can be given to medical patients to test for changes in normal functioning of the organs. Radioactive iodine is used to treat thyroid disease. Radiation is used to kill cancer cells and radiation can also be used to sterilize medical equipment.

In agriculture, food can be exposed to a short burst of radiation to kill harmful bacteria without affecting the food. Irradiation is used to prevent early sprouting of seeds, and it can also be used to sterilize insect pests, like the Mediterranean fruit fly, so that they cannot reproduce when released into the environment.

In industry, radioactive materials are used in special gauges to measure the thickness of materials, the flow rate of liquids, and the level of materials in tanks. In gamma radiography, radioactive materials are used in special devices to inspect the quality of welds on gas and water pipelines during construction. Radioactive materials can be used in special equipment to prospect underground soil and rock formations for minerals, oil, or water.

WHAT ARE THE DANGERS OF RADIATION?

Technologies that use radiation have both benefits and risks. The level of risk depends upon the type and amount of radiation produced. High doses of radiation can damage healthy tissues, causing skin burns and an increased risk of cancer. To avoid overexposure, radiological protection measures include equipment design, special procedures by users, and regulations limiting radiation doses. The ultimate goal is to ensure that exposures are as low as reasonably achievable and within acceptable limits.

HOW CAN I TELL WHEN RADIOACTIVE MATERIALS ARE BEING USED?

Because ionizing radiation is invisible, special equipment is needed to detect it. In most countries, regulations require radiation monitoring wherever radioactive materials are used. Equipment capable of producing radiation and radioactive materials should have radiation warning labels. Areas where radioactive materials are regularly used, such as hospital cancer treatment wards, will also have warning signs. The trefoil is the radiation symbol used around the world. The word radiation or radioactivity may also appear on the label.

WHAT IS A SEALED RADIOACTIVE SOURCE?

A sealed radioactive source is radioactive material that is permanently sealed in a capsule or bonded and in a solid form. The capsule of a sealed radioactive source is designed to prevent the radioactive material from escaping or being released during normal usage and under probable accident conditions.

WHAT ARE THE DANGERS OF SEALED RADIOACTIVE SOURCES?

In most countries, the use of sealed radioactive sources is regulated and users are required to be properly educated and trained in radiation safety and protection. The manufacture of the equipment itself is also regulated, so that radiation doses received by users, bystanders, and patients are tightly controlled. Dose limits for individuals have been adopted by the International Community in the Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards for protecting people and the environment (Interim edition), General Safety Requirements Part 3, No. GSR Part 3 (Interim) (2011).

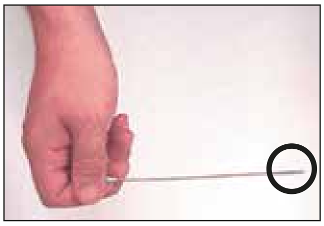
The major risks from these sources occur when the source is lost, stolen, forgotten, or otherwise outside of regulatory control. These so-called orphan sources (orphan meaning they are no longer under proper control) can pose a significant danger if someone obtains or finds such a source and does not realize that it is radioactive. Injuries or death are possible when a source is found and someone unknowingly takes it home or tries to open it.

HOW CAN I RECOGNIZE A SEALED RADIOACTIVE SOURCE?

Unfortunately, sealed radioactive sources can look quite innocuous — like a small piece of harmless metal. The only certain way to recognize them is by use of radiation detection instruments or from their radiation label called the trefoil, although many small sources may not have this symbol. Depending on the size of the source, it may also have the word “radioactive” engraved on the source itself or its container. Most sealed radioactive sources are used and stored inside a larger piece of equipment, protected by heavy shielding. Because of the weight of the shielding, such equipment is much heavier than it looks. If you find a metal container that is unusually heavy, it may have a sealed radioactive source inside and should not be opened. Seek expert assistance.

WHAT SHOULD I DO IF I FIND A SEALED RADIOACTIVE SOURCE?

Stay away from any object with a radiation label. Do not touch it or pick it up. If you find an object with a radiation label or find an unusually heavy piece of metal equipment, contact the appropriate authorities or the police immediately. Do not let anyone else near the object, until trained help arrives. If you feel unwell, see a doctor immediately. Be sure to tell them that you were near to a possible source of radiation. Radiation injuries can look like burns, but do not heal as a regular burn would. Symptoms of radiation overexposure include nausea, diarrhoea, and vomiting.



Type B transport package for radioactive material (IAEA).

A radium applicator once used for insertion into a patient's nasal passageways to shrink the lymphoid tissues. (Oak Ridge Associated Universities 1999).

Injuries suffered from radiation burns.

Sealed radioactive sources were found in an old military transport scrapyard at the Lilo Training centre in Georgia (IAEA).

ISSUES FOR GOVERNMENT AGENCIES

Rubble from houses contaminated with radioactive material from a sealed radioactive source over which control was lost / Credit: CNEN/Brazil.

REDUCING RISKS FROM LOSS OF CONTROL OF SOURCES

SEALED RADIOACTIVE SOURCES USES AND HAZARDS

Radioactive sources have many beneficial uses such as:

- killing bacteria in food, medical supplies and equipment
- treating cancer and other diseases
- mapping underground sources of water and prospecting for oil and gas reserves
- non-destructive testing for integrity of pipe welds, pressure vessels, and other mechanical structures
- checking levels of liquids in vessels during manufacturing operations
- measuring density of soil for construction projects

Two broad types of devices exist that entail radiation hazards: those that generate radiation electrically and those that contain radioactive material. Devices capable of generating radiation electrically include particle accelerators and X-ray machines. When the electrical power supply is disconnected, however, these devices produce no radiation.

Other devices contain materials that are radioactive. The sources inside these devices always produce radiation, but the intensity of the radiation will decrease gradually over time.

Devices containing sealed radioactive sources, when used as intended, are designed to limit radiation exposure to users to inconsequential levels. Despite their design safety features, some sealed radioactive source devices may produce a potentially lethal amount of radiation if used improperly. People using devices containing sealed radioactive sources must be trained and knowledgeable about proper use from both a safety and security perspective in accordance with relevant regulatory requirements. When used improperly or maliciously, such devices can cause injury or death. Acquisition and malevolent use of radioactive sources may cause radiation exposure or dispersal of radioactive material into the environment. Such an event could also cause significant social, psychological and economic impacts.

If a source becomes too weak for its intended use, it does not mean that the source is harmless. Many accidents have resulted from sources that are no longer being used for their original purpose, but which still emit a significant amount of radiation.

Physical protection and proper security measures should be implemented for all sources to avoid the possibility of theft. However, a graded approach needs to be applied in which the most dangerous sources are defined so as to provide higher security and more stringent safety measures than is done for less dangerous sources.

ACCIDENTS INVOLVING LOSS OF CONTROL OF SEALED RADIOACTIVE SOURCES

Numerous accidents, where sealed radioactive sources have been lost or abandoned, illustrate the potential danger from sealed radioactive sources when proper precautions for safe and secure storage are not followed. Without an effective regulatory authority to inspect the facilities where radioactive sources are used, there is a risk of accident, loss, theft, inadvertent misuse, or malicious use harming people and the environment with radioactive contamination. Some examples of accidents are listed below.

Sources Abandoned in Turkey

Exchange container (IAEA).

A company stored two packages containing cobalt-60 radiotherapy sources in their general purpose warehouse in Istanbul, Turkey. When the warehouse was full, the packages were moved to an adjoining empty storage space that was later transferred to new owners who did not realize what was in the packages. In December 1998 and January 1999, both were sold as scrap metal, after which the purchasers broke open the shielded containers in a residential area.

Ten persons who had spent time in proximity to the dismantled containers became ill. Although they sought medical assistance, the cause of the illness was not recognized until almost four weeks after the symptoms appeared. A total of 18 persons (including seven children) were admitted to hospitals, with ten adults exhibiting symptoms of radiation sickness. When the injuries were eventually suspected as having been caused by radiation exposure, the doctor immediately alerted national authorities.

When the authorities responded, one unshielded source was quickly discovered at the scrapyard and safely recovered, preventing further radiation exposure. The source capsule had not been damaged and there had been no leakage of radioactive material. The source that had supposedly been in the second container was never found. After thorough investigation, it appears that there had been no source in the second container, but this could not be demonstrated unequivocally.

Investigations found that there were several contributing factors to the accident, including inadequate security and inadequate inventory control that allowed unauthorized sale of the packages to take place. Lack of recognition of the radiation symbol was also an important factor. Furthermore, transfer of the sources to a qualified and licensed waste operator would have prevented the accident.

Source Melted with Scrap Metal in Spain

In May of 1998, an unnoticed caesium-137 source was melted in an electric furnace of a stainless steel factory in Spain. The vapours were collected in a filter system, resulting in contamination of the collected dust, which was removed and sent to two factories for processing as a part of routine maintenance. One factory used the contaminated dust in a marsh stabilization process, resulting in contamination being spread throughout the marsh. The first warning of the event was from a gate monitor that alarmed on an empty truck returning from delivering the dust. Several days later elevated levels of caesium-137 were also detected in air samples in Southern France and Northern Italy. The radiological consequences of this event were minimal, with six people having slight levels of caesium-137 contamination. However, the economic, political and social consequences were significant. The estimated total costs for clean-up, waste storage, and interruption of business exceeded $25 million US dollars.

Source Lost in Honduras

On 28 October 2010, elevated radiation levels were detected from an underground source in a courtyard in a Honduras medical facility. Initial actions were taken to shield the area and install appropriate barricades and warning signs. The facility owners conducted an inventory of sealed radioactive sources that were in storage and found that a caesium-137 brachytherapy source was missing. The source was safely recovered from a depth of approximately 2 cm below the soil surface. Source encapsulation remained intact, so the retrieved source was placed in a dedicated shielding facility with other brachytherapy sources. Although neither the source nor the area in which it was found was controlled, individual overexposure was extremely unlikely, based on the location and measured radiation levels.

PREVENTING LOSS OF CONTROL OF SEALED RADIOACTIVE SOURCES

Government programs can minimize the chance that sealed radioactive sources will be lost, stolen, or improperly discarded. Governments should also be able to respond to accidents or incidents when there has been a loss of control of sealed radioactive sources.

Government Infrastructure

Devices containing sealed radioactive sources are used in virtually all countries of the world. Governments must ensure that the use of radioactive sources within their jurisdiction is performed according to laws and regulations. If requirements do not exist, radioactive sources might be imported and used without any type of regulatory control over safety, security or plans for appropriate disposal. To prevent such occurrences, national authorities should establish an infrastructure with laws and regulations and governmental organizations with responsibility for safe and secure importation, use and disposal of sealed radioactive sources, as well as provide emergency planning and response for accidents or incidents involving such sources. Users are responsible for complying with the laws and regulations governing safe and secure use and storage of sources.

Laws and Regulations

Comprehensive national laws and regulations need to be in place to establish requirements for the safe and secure use of sealed radioactive sources. Laws provide for the establishment of the legal authority through which a national regulatory authority can be established to authorize, inspect and enforce compliance with regulations that control the sale, import, export, use and disposal of sealed radioactive sources. These regulations may specify the type of facility or individual permitted to possess and use a sealed radioactive source and may require all users to obtain an authorization, usually called a license, for possession and use of a source. The authorization process specifies the education and training required for those responsible for the proper use of the source and the requirements that a facility must meet with respect to physical protection to prevent its loss, theft, or unauthorized transfer. Procedures must also be in place for monitoring radiation when the source is stored, used or transported. The user must notify the regulatory authority of any changes in use of sources at the facility (including when sources are removed from active use).

Regulatory Authority

A regulatory authority is usually empowered to authorize and inspect regulated activities and to enforce laws and regulations. The regulatory authority needs to have adequate legal authority for its activities (either through laws or regulations), properly trained staff, and a sufficient budget to undertake its duties, including regular inspection of facilities using radioactive sources and review of applications for permits or licenses to use sealed radioactive sources. The size of the staff required is dependent on the number and types of sealed radioactive sources that are in use. Most countries in the world will have several facilities using sources in medical and industrial applications. Inspections are the primary means to verify safe practices and adequate security measures.

National Register of Radioactive Sources

In order to ensure that radioactive sources can be tracked throughout their lifetime, a national register of sealed radioactive sources, covering all sources should be established (See side box). Each facility using a sealed radioactive source should be required to maintain an inventory of sealed radioactive sources on its premises, and a national register of sources should also be maintained by the regulatory authority to ensure that sources can be traced if ownership changes. Such an inventory can help maintain regulatory control of a source throughout its lifetime and help to identify any sources for which control has been lost.

Emergency Preparedness and Response

National authorities must be prepared to deal with emergencies that can arise when control over sealed radioactive sources is lost. Regulatory authorities must not only have procedures in place to respond to such

The relative risk for sources, attributable to hazards associated with radiation emission, has been categorized by the IAEA according to potential to cause serious health effects. The lower category number indicates a greater potential hazard, if the source is not used properly. That is, Category 1 sources are considered the most dangerous, while Category 2 sources present a lesser danger, Category 3 lesser than Category 2, and so on.

CATEGORY 1 sources could lead to the death or permanent injury of individuals who are in close proximity to the source for a short period of time (minutes to hours). Category 1 sources include: radioisotope thermoelectric generators, irradiators, teletherapy machines, and fixed multi-beam teletherapy machines.

CATEGORY 2 sources could lead to the death or permanent injury of individuals who are in close proximity to the source for a longer period of time than for Category 1 sources. Category 2 sources include: industrial gamma radiography equipment and high/medium dose-rate brachytherapy sources.

CATEGORY 3 sources could lead to the permanent injury of individuals who are in close proximity to the source for a longer period of time than Category 2 sources. Sources in Category 3 could, but are unlikely to, lead to fatalities. Category 3 sources include: fixed industrial gauges (level gauges, dredger gauges, conveyor gauges, and spinning pipe gauges) and well logging gauges.

CATEGORY 4 sources could lead to the temporary injury of individuals who may be in close proximity to the source for a longer period of time than Category 3 sources. Permanent injuries are unlikely. Category 4 sources include: low dose-rate brachytherapy sources, thickness gauges, portable gauges, and bone densitometers.

CATEGORY 5 sources could, but are unlikely to, cause minor temporary injury of individuals. Category 5 sources include X ray fluorescence devices, static eliminators, and electron capture devices.

emergencies, but must require all users and facilities to have appropriate emergency plans and emergency reporting mechanisms in place. Depending on the nature and activity of the source involved, such accidents or incidents could have fatal or life-threatening consequences and cause widespread radioactive contamination and panic as well as financial losses to businesses and people. Clean up and monitoring of exposed persons requires significant resources, careful planning, and coordination between a variety of government agencies such as environmental protection, health and social services. Prevention is far more cost effective.

With the recent rise in terrorist activity, the possibility that a terrorist group will use a source for malicious purposes such as in a radioactive dispersal or exposure device must be included in emergency preparedness both by the regulatory authority and the facilities where sources are used or stored. High activity industrial radiography, irradiators, thermoelectric generators and teletherapy machines all use sealed radioactive sources that may be the target of terrorist activity. The extent of the provisions to protect sources from those with malicious intent should be applied according to a graded approach commensurate with the hazard of the source. Some provisions are intended to prevent the theft a source, to detect any unauthorized access, and to delay thieves until law enforcement agencies respond. Other provisions are intended to facilitate locating and recovering a lost or stolen source. Sealed radio-active sources may be smuggled across national borders; therefore, customs officers should be given clear guidance on how to respond when sealed radioactive sources are identified at a border control point. Similarly, national regulatory and police authorities should be prepared to respond to such situations.

Management of Disused Sources

Although many sealed radioactive sources have a relatively long life, at some point they must be replaced. Most countries with nuclear power facilities have some capacity for long term storage of radioactive waste that could also be used for sources that are no longer being used (disused sources).

One of the major challenges facing countries without waste facilities is how to safely and securely manage disused sources. National governments must ensure that disused sources can be kept secure without risk of loss, theft or accident, while also preventing radioactive contamination, over very long time periods. Effective source management includes conditioning the source, checking the status of the source regularly, providing proper security measures, and keeping records of all transactions by the waste operator.

Importing a radioactive source creates a long term obligation to manage the source when it no longer has a useful purpose. If the source cannot be returned to the supplier or recycled, it will need to be stored in a dedicated storage facility. National governments will require a strategy for safe and secure storage under such conditions. Final disposal of sources in a licensed disposal site is the preferred and recommended solution, although options for permanent disposal are limited at this time.

IN CONCLUSION

The most effective means to prevent accidents and incidents with sealed radioactive sources is to adopt work habits and measures that reduce the likelihood of a source becoming lost or stolen. Organizations and companies using sources are responsible for taking the necessary steps to protect the public, the environment, and themselves every time they work with a sealed radioactive source. Sources no longer in use should be returned to the manufacturer, recycled, disposed of as radioactive waste if possible, or conditioned for secure long term storage with the consent of the national regulator.

To balance the risks and benefits of sealed radioactive sources from social, health and economic perspectives, national governments will require an adequate policy and infrastructure to effectively control the use and final disposal of sealed radioactive sources.

Devices containing sealed radioactive sources in a storage facility operated by a government agency / Credit: E. Reber (IAEA).

REDUCING RISKS FROM SOURCES IN INDUSTRIAL USES

Typical gamma radiography setup for testing concrete / Credit: HSQE.

COMMON INDUSTRIAL USES OF SEALED RADIOACTIVE SOURCES

Sealed radioactive sources are used in a wide variety of industrial applications, commonly to measure some property of the material under consideration such as thickness, moisture content, or density; to conduct nondestructive tests during construction; or to control a manufacturing process, such as monitoring the level of liquid in a tank or eliminating static electricity during manufacturing. Many industrial uses of sealed radioactive sources involve mobile equipment, with the sources, and devices containing them, transported by small vehicles to various remote job sites.

One of the most common industrial uses of radioactive sources is gamma radiography for nondestructive testing, using the penetrating ability of gamma radiation to inspect welds, such as those in gas and water pipelines, to look inside the weld for flaws that cannot be seen with the naked eye. In most gamma radiography devices, the source is housed in a shielded device and moved out of the device by a drive cable, which pushes the source through a guide tube to the object being inspected. In some device designs, the source is exposed by a rotating collimator rather than a drive cable. Radiation emitted from the source (usually iridium-192) passes through the weld to expose photographic film. The resulting photo image, called a radiograph, will show any flaws in the weld similarly to medical diagnostic radiographs.

Sealed radioactive sources are also used in a variety of portable gauges. Portable nuclear gauges can be used to measure density, thickness, or moisture, or to identify materials, all based on how the radiation emitted from the source interacts with the material under study. They all use a source in a shielded container to emit radiation that is then measured by at least one detector. Such gauges are commonly used in measuring the uniformity in road construction materials. Another use of sealed radioactive sources in portable devices is inspection of geologic formations and properties, such as the potential presence of oil, gas, or water.

Typical modern lightweight gamma radiography projector (for ^{75}Se) / Credit: MDS Nordion.

Nuclear gauge containing a gamma source installed in an industrial setting / Credit: E. Reber (IAEA).

Portable moisture/density gauge / Credit: Troxler Electronic Laboratories, Inc.

Some industrial uses of sealed radioactive sources are for controlling manufacturing processes by using interactions between radiation and materials in the manufacturing process. Examples include use of sealed radioactive sources to eliminate static electricity, which is important in manufacturing films, to measure the thickness of sheets of material in rolling mills, and to measure the level of liquid in reaction vessels at chemical manufacturing facilities. These gauges are typically permanently attached to pipes, vessels, or some other structure in the manufacturing facility.

Sealed radioactive sources are also used in industry in irradiators, where an object is placed in a high-intensity radiation field to inactivate or kill microorganisms. These irradiators include a high-activity source of cobalt-60 or caesium-137 inside a heavily shielded vessel of approximately one meter diameter by one and a half meters tall, although the dimensions vary by manufacturer. The object to be irradiated is placed inside a chamber designed for that purpose, the chamber secured, and the sources exposed inside the chamber for the length of time necessary to achieve a sterilization dose. The irradiator may contain several individual sources in an array designed to give a uniform irradiation field in the chamber. After some years, it is usually necessary to replace the sources. Such source exchanges must be performed only by trained and authorized manufacturer's agents, with the removed sources returned to the manufacturer for disposal.

ACCIDENTS INVOLVING LOSS OF CONTROL OF INDUSTRIAL SEALED RADIOACTIVE SOURCES

Source Lost in Russia

In 2000, three radiographers were working in a remote location in Samara, Russia. When the source was being retracted into the shielded container following the last radiograph of the day, it became disconnected from the cable and lodged in the guide tube. This was not detected by the radiographers because they did not perform a survey to verify the source was shielded. After storing the equipment in the back of their truck, the three workers slept in bunks in the same truck.

The following morning, all three workers reported nausea and vomiting. They returned the truck to the company base, went home, and recovered over the next few days. The truck was unused until the same three workers went back to the job site eight days later. While preparing for the first radiograph of the day, the loose source was discovered. One man picked the source up with his bare hands and returned it to the shielded container.

One month passed before the workers sought medical help for the continuing symptoms of overexposure to radiation. One worker had developed infections, which ultimately became pneumonia, due to lowered disease resistance from reduced white blood cell counts that resulted from the radiation exposure. The man who handled the source developed severe burns on both hands. All three workers were treated in a Moscow hospital and eventually released from care.

Source Lost in Egypt

In 2000, workers in Abu Rawash, Egypt, lost several radioactive iridium-192 sealed radioactive sources used for industrial radiography. Workers looked for, but did not find the lost sources, and did not report the loss to the regulatory authorities. An individual later found one source on 5 May and took it home, believing it to be a precious metal. On 5 June, a nine-year-old boy in the family died of radiation exposure. Within a week, other family members presented similar symptoms and were hospitalized. The 61-year old father died the following

Typical static eliminator air gun / Credit: Oak Ridge Associated Universities.

Beta gauge in place on a web processing mill / Credit: Betarem.

Pipeline density gauges in position.

Typical sample irradiator.

week, while five others in the household suffered from symptoms of high radiation exposure. Up to 200 neighbours and friends were estimated to have received lower levels of radiation exposure, which did not result in illness. The sources were recovered by authorities in late June and early July following extensive searches with radiation detection instruments.

Source Lost in Chile

In 2005 in Nueva Aldea, Chile, an iridium-192 source being used for industrial radiography at a construction site became disconnected from the device and fell to a platform. The operators continued working without realizing the source was missing. About twelve hours later, a worker found the source and handled it without safety equipment. Two other workers were also in contact with the source for several minutes. The workers brought the source to the site office, not knowing what it was. The radioactive emissions from the source were discovered later in the day when an alarm sounded on a radiation monitor carried by another worker. The three exposed workers were hospitalized with radiation burns. A fourth worker who was exposed was identified two weeks later.

PREVENTING LOSS OF CONTROL OVER RADIOACTIVE SOURCES

The loss of control over sealed radioactive sources in industrial applications has led to a number of serious accidents. While proper training and experience will reduce the risk of radiation exposure when sealed radioactive sources are used, the vast majority of serious accidents and incidents in industrial use are due to a source that has been lost or stolen.

Industrial gamma radiography sources are at a higher risk of loss because they are mobile and are used at temporary work sites, where proper control is dependent on a person (the radiographer) and not on engineered control systems, as would be the case in a dedicated facility. However, proper maintenance of equipment and good operational practices and procedures can reduce the risk of a source being lost or stolen. When it is no longer in use, a source should be disposed of in accordance with regulatory requirements.

Industrial Radiography

A "typical" industrial radiography accident involves a high radiation dose to the radiographer, which usually occurs when the source does not return to the shielded position because it became disconnected from the drive cable or jammed in the guide tube. The discovery of these types of malfunctions is dependent on the radiographer using a radiation detection instrument to verify that the source is safely shielded after each operation, as well as the radiographer understanding the instrument, knowing what readings would indicate that the source had been dislodged, and taking appropriate emergency response actions.

Loss of control of sealed radioactive sources can occur if the dislodged source is not discovered and retrieved. In addition to radiographers, members of the public have been injured or killed as a result of such accidents. To minimize the chances of such an accident, radiation measurements need to be performed (a) when devices are removed from storage to ensure that the source is properly secured and safely shielded, (b) during operations to ensure that the source is moving out of and into the shielded exposure device as intended, (c) immediately after each operation, upon locking the exposure device to prevent the source from coming out unintentionally, to ensure that the source is secured in the shielded position, and (d) when placing the device back into storage to ensure that the source has not become dislodged during transportation.

Accidents in industrial radiography can be prevented by proper training, adequate maintenance of equipment, and following established procedures and practices. Maintaining equipment in good working condition and providing secure transportation and storage of the sealed radioactive sources are preventive steps that must be taken to minimize accidents. Sources no longer in use must be disposed of according to the applicable regulations in order to prevent accidents from an uncontrolled source.

Nuclear Gauges and Well Logging

While the source activity, and consequently the radiation level, is lower in gauges and well logging devices than in industrial radiography devices, loss of control accidents and incidents can lead to exposure of the public directly from the sealed radioactive source or, if the source is inadvertently melted as scrap metal, through the use of radioactively contaminated metal products. Properly maintaining devices and following established procedures and practices help to ensure that loss of control of the sealed radioactive source does not occur. Particularly for portable or mobile devices, safe and secure transportation and storage is critical to maintaining control of the sources. Surveys are also important to verify safe radiation levels and to ensure that the sources are properly shielded when not in use.

Labels on industrial gauges and inventory records are important safety and security considerations, particularly for gauges that are installed in fixed locations in manufacturing facilities. Over periods of several years, personnel working in and around the gauge will change, with new workers perhaps not being aware of the presence of the sealed radioactive source. Maintaining proper inventory records (source, activity, location), securing the gauge from unauthorized or inadvertent removal, and ensuring that warning signs remain intact and legible helps to ensure that the sealed radioactive sources do not get released into the public.

For sealed radioactive sources used in well logging, there is a danger of losing the source down the well (i.e., the source becomes disconnected underground from the cable during use). There are accepted industry practices for recovery and retrieval attempts, but it is important that the source not be damaged during such efforts.

Monitoring for uncontained radioactivity must be done during recovery attempts, as the presence of such material would indicate that the source has been damaged. If retrieval efforts fail, it may become necessary to abandon the source down a well. The well owner and regulatory authority must takes steps to ensure that the source is permanently sealed in place and the well head marked to indicate that a sealed radioactive source is present in the well.

IN CONCLUSION

The most effective means to prevent accidents and incidents with sealed radioactive sources is to adopt work habits and adequate measures that reduce the likelihood of a source becoming lost or stolen. Organizations and companies using sources are responsible for taking the necessary steps to protect the public, the environment, and themselves every time they work with a sealed radioactive source.

Sources no longer in use should be returned to the manufacturer, disposed of as radioactive waste if possible, or conditioned for long term secure storage with the consent of the national regulator.

Pipeline crawler being loaded into an open pipeline / Credit: MDS Nordion.

REDUCING RISKS FROM SOURCES IN MEDICAL USES

Teletherapy machine in operation / Credit: IAEA.

COMMON MEDICAL USES OF SEALED RADIOACTIVE SOURCES

Sealed radioactive sources are commonly used in a variety of medical applications for both diagnosis and therapy. The sources used in medical applications are usually very powerful and, therefore, have the potential to cause serious and life threatening injuries if used improperly or maliciously, become lost, or are stolen.

Sealed radioactive sources used in treatment of diseases include teletherapy sources, which deliver precise doses of radiation from a source outside the patient's body to a well-defined area of the body in order to treat cancer. Teletherapy with sealed radioactive sources commonly uses cobalt-60 as the source of radiation, although some older equipment may use caesium-137. Teletherapy equipment can be used safely and effectively to treat cancerous tumours, but to be effective, it must be properly installed, calibrated, and maintained and should only be used by skilled personnel under appropriate medical supervision. Cobalt-60 sources will also need to be replaced regularly, which can be performed only by a licensed source supplier. The preferred option to manage disused sources properly is to return such sources to the supplier after replacement. If this is not possible, disused sources should be disposed of in accordance with regulatory requirements.

Another common medical use of sealed radioactive sources is brachytherapy, where the sealed radioactive source is placed in direct contact with the patient. It is inserted into a tumour either manually or remotely using special equipment. Remote loading has become much more frequently used, as it provides lower risk of radiation exposure to the medical staff and reduces the risk to patients. Because brachytherapy sources are implanted and subsequently removed, care must be taken to ensure that no source is left implanted following treatment. Depending on the manufacturers' specifications, some brachytherapy sources need to be replaced every 10 to 15 years. This necessitates not just appropriate procedures for radiation protection

High dose rate brachytherapy source wire with source located at the end of the wire /
Credit: Varian Medical Systems, Inc. All rights reserved.

Modern brachytherapy remote afterloading machine / Credit: Varian Medical Systems, Inc. All rights reserved.

during replacement and transfer, but also appropriate procedures and facilities to dispose of all disused brachytherapy sources permanently.

In recent years, sealed radioactive sources have also been used to perform stereotactic radiosurgery, using a device called a Gamma Knife® to perform noninvasive treatment of tumours and other abnormalities in the brain. The technology has not been widely deployed, with only about 200 devices installed world-wide in 2012. In the device, multiple sealed radioactive sources of cobalt-60 are arranged in a circular array in order to focus numerous tiny radiation beams to a defined point inside the brain. These sealed radioactive sources must be replaced periodically and this procedure can only be performed by trained and authorized manufacturer's agents. Following the replacement of radioactive sources, the spent sources that have been removed should be returned to the supplier or manufacturer.

Sealed radioactive sources are also used in a medical setting for sterilization, where an object placed in the beam is irradiated at levels that inactivate or kill microorganisms in the irradiated material. This process is done routinely for human blood used for transfusions and may be used for a variety of other purposes. These irradiators include a high-activity source of cobalt-60 or caesium-137 inside a heavily shielded vessel of approximately one meter diameter by one and a half meters tall, although the dimensions vary by manufacturer. The object to be irradiated is placed inside a chamber designed for that purpose, the chamber secured, and the sources exposed inside the chamber for the length of time necessary to achieve a sterilization dose. The irradiator may contain several individual sources in an array designed to give a uniform irradiation field in the chamber. After some years, it is usually necessary to replace the sources. Such source exchanges may only be performed by trained and authorized manufacturer's agents, with the removed sources returned to the manufacturer for disposal.

ACCIDENTS INVOLVING LOSS OF CONTROL OF MEDICAL SEALED RADIOACTIVE SOURCES

Source Abandoned in Brazil

In 1987, a cancer therapy facility in Goiânia, Brazil, was being demolished. Inside the facility, a teletherapy machine containing a source of caesium-137 had been abandoned. Two individuals dismantled the unit to sell as scrap metal, removing the radioactive sealed radioactive source in the process. Both men started vomiting within one day. The source was taken to one of their homes, where the steel encapsulation was opened two days later. The source was sold to a junkyard, where the owner noticed a blue glow from the source container that night. He and his wife examined the material closely, also inviting a number of people to view the capsule. The source material was removed and distributed among several people, some of whom spread it on their skin. That day, the owner's wife became ill and was cared for by her mother, who also spread contamination to her home. About ten days after the source was first found, junkyard employees were exposed to the source while further dismantling parts of the unit. One took

Typical gamma knife / Credit: Elekta.

Typical gamma knife reloading system / Credit: Elekta.

Blood irradiator / Credit: BRIT.

Older style blood irradiator.

some source material home and set it on a table during a meal. Several family members, including his 6-year old daughter handled the material while eating. Some unit components were sold to a second junkyard.

The symptoms were not initially recognized as being due to radiation. However, one of the persons irradiated connected the illnesses with the source capsule and took the remnants to the public health department in the city. This action began a chain of events which led to the discovery of the accident. The authorities were alerted and initiated a response, including identification of contaminated areas and treatment of injured people in facilities set up in the city's Olympic stadium. About 112,800 people were examined at the stadium of which 129 were found to be contaminated; 20 were hospitalized.

Three weeks after the source was first removed from the machine, some injured people had been sent to Rio de Janeiro for treatment, while others were treated in a special wing of the Goiânia General Hospital. Four people died from the effects of radiation exposure, including the 6-year old girl. A fifth person was hospitalized and subsequently died of liver failure related to his radiation injury. Others who were exposed suffered radiation injury to hands and radiation sickness. In addition to the five who died, 23 suffered localized radiation burns, several requiring amputation of fingers. The 23 injured survivors included 9 showing bone marrow depression of whom 3 displayed acute radiation sickness.

Sources Abandoned in Turkey

A company stored two packages containing cobalt-60 radiotherapy sources in their general purpose warehouse in Istanbul, Turkey. When the warehouse was full, the packages were moved to an adjoining empty storage space that was later transferred to new owners who did not realize what was in the packages. In December 1998 and January 1999, both were sold as scrap metal, after which the purchasers broke open the shielded containers in a residential area.

Ten persons who had spent time in proximity to the dismantled containers became ill. Although they sought medical assistance, the cause of the illness was not recognized until almost four weeks after the symptoms appeared. A total of 18 persons (including seven children) were admitted to hospitals, with ten adults exhibiting symptoms of radiation sickness. When the injuries were eventually suspected as having been caused by radiation exposure, the doctor immediately alerted national authorities.

When the authorities responded, one unshielded source was quickly discovered at the scrapyard and safely recovered, preventing further radiation exposure. The source capsule had not been damaged and there had been

Disused teletherapy source stored without proper control / Credit: E. Reber (IAEA).

no leakage of radioactive material. The source that had supposedly been in the second container was never found. After thorough investigation, it appears that there had been no source in the second container, but this could not be demonstrated unequivocally.

Investigations found that there were several contributing factors to the accident, including inadequate security and inadequate inventory control that allowed unauthorized sale of the packages to take place. Lack of recognition of the radiation symbol was also an important factor. Furthermore, transfer of the sources to a qualified and licensed waste operator would have prevented the accident.

Source Left in Cremated Patient in the United States

In 2000, a patient in New Jersey in the United States died five days after having iodine-125 brachytherapy sources implanted for cancer treatment. There was no autopsy on the body, which was cremated approximately one week later. The hospital that had performed the implant procedure conducted radiation surveys of the crematory and found no elevated radiation levels, except in the ash after the cremation. This was shielded by placing the ashes into an urn. With the increased use of radioactive seeds for brachytherapy, it is likely that crematory operators are already handling some bodies that have sealed radioactive sources implanted. The risk to the public is usually through handling ash following cremation, as crematory temperatures are generally lower than the melting point of the metal used to encapsulate brachytherapy sources.

Source Abandoned in Thailand

In 2000, an individual in Samut Prakarn, Thailand, purchased scrap metal and took it home for dismantling and recycling. The scrap metal included part of a cobalt-60 teletherapy unit that, unknown to the buyer or seller, still contained a sealed radioactive source. After unsuccessfully attempting to dismantle the unit, two persons carried the metal to a junkyard approximately 30 minutes away, where other workers used an oxy-acetylene torch to cut the unit open. This caused the source to fall to the ground. Still not knowing this metal object was radioactive, the original purchaser took the cylinder containing cobalt-60 back to his residence.

Over the course of several days, ten persons involved in the process developed symptoms of radiation poisoning, including nausea, vomiting, diarrhoea, hair loss, and burns. Three persons died and about 1,870 people living near the junkyard were exposed to some elevated level of radiation.

PREVENTING LOSS AND THEFT OF SOURCES

While proper training and experience will reduce the risk of radiation exposure when sealed radioactive sources are used, the vast majority of serious accidents and incidents are due to a source that has been lost or stolen. Good operational practices and procedures can reduce such occurrences by preventing a source from becoming lost or stolen in the first place.

Brachytherapy sources' small size and portability are required for them to perform their intended function, which also makes them more susceptible to being lost, misplaced, or stolen. Teletherapy machines and irradiators are significantly larger devices, such that it is unlikely the entire device would be inadvertently lost. However, after years of not being used at a facility, these devices have been sold to metal recyclers without first having the sealed radioactive source removed. Loss of control in these situations is generally a result of inadequate recordkeeping and inventory management, such that workers forget that there is a sealed radioactive source inside the device. The devices are required to be labelled as to their radioactive contents, but such labels may be inadvertently removed or become illegibly worn or damaged.

IN CONCLUSION

The most effective means to prevent accidents or incidents with sealed radioactive sources is to adopt work habits and adequate measures that reduce the likelihood of a source becoming lost or stolen. Organizations and companies using sources are responsible for taking the necessary steps to protect the public, the environment, and themselves every time they work with a sealed radioactive source. Sources no longer in use should be returned to the manufacturer, disposed of as radioactive waste if possible, or conditioned for secure long term storage with the consent of the national regulator.

REDUCING RISKS IN THE METAL RECYCLING INDUSTRY

Scrap metal at the Acerinox foundry in Los Barrios, Spain / Credit: ACERINOX, S.A.

COMMONLY ENCOUNTERED SEALED RADIOACTIVE SOURCES IN METAL RECYCLING

While sealed radioactive sources are not commonly used in the metal recycling industry, it is not uncommon for radioactive materials to be inadvertently incorporated into scrap metal and encounter in the normal course of business in the metal recycling industry. The sources themselves are typically small and not usually found alone in metals destined for recycling. However, sealed radioactive sources are often stored inside large, heavy devices constructed of metal, making these devices ideal candidates for recycling. Examples of the types of devices that may be encountered are discussed below.

Some sealed radioactive sources are used in gauges to control manufacturing processes. Examples include eliminating static electricity, which is important in manufacturing films, measuring the thickness of sheets of material in rolling mills, and measuring the level of liquid in reaction vessels at chemical manufacturing facilities. These gauges are typically permanently attached to pipes, vessels, or some other structure in the manufacturing facility. In metal recycling, these devices may not be found as separate units, but could be attached to other metal pieces being recycled.

Sealed radioactive sources are used in medicine to treat cancer patients. One form of this treatment is teletherapy, which involves a large machine containing a sealed radioactive source emitting radiation that is directed to a tumour inside the patient. These machines contain enough metal to make them economically attractive for recycling and have been found in various recycling facilities worldwide. Teletherapy machines often contain lead or depleted uranium as shielding and have a distinctive shape that should warn recyclers of the possible presence of a sealed radioactive source. With the source removed, teletherapy machines present no radiation hazard to recyclers, but caution is required to be certain that the source is not present.

Device containing a 2 Curie Cs-137 source discovered in scrap metal / Credit: Turner Nuclear Consulting Services, LLC.

Radiography projector discovered in scrap metal / Credit: Turner Nuclear Consulting Services, LLC.

Scrap metal bale containing Cs-137 source / Credit: Turner Nuclear Consulting Services, LLC.

Cs-137 source from demolition site / Credit: Turner Nuclear Consulting Services, LLC.

Irradiators are used in medicine and industry primarily to treat small objects for sterilization or disinfestation. These irradiators include high-activity sources of cobalt-60 or caesium-137 inside a heavily shielded vessel of approximately one meter diameter by one and a half meters tall, although the dimensions vary by manufacturer. As with teletherapy machines, when the source is removed, irradiators present no radiation hazard to recyclers, but caution is required to be certain that the source is not present.

Some sealed radioactive sources may not be contained in devices, but packaged in storage or shipping containers such as drums or crates. These containers may be in a variety of sizes, but will typically use heavy metals such as lead, tungsten, or uranium as shielding materials, giving the container a relatively high weight for its size.

ACCIDENTS AT METAL RECYCLING FACILITIES RESULTING FROM LOSS OF CONTROL OF SEALED RADIOACTIVE SOURCES

Sources Melted with Scrap Metal

Numerous accidents have occurred where sealed radioactive sources were inadvertently melted with scrap metals, causing contamination spread throughout the batch of metal, which was ultimately distributed to the general public. Examples where radioactive materials in recycled metals have been distributed to the public include:

- In 1983, a foundry in Ciudad Juarez, Mexico, melted cobalt-60 from a medical teletherapy, which was incorporated into products that included construction rebar and table bases.
- In 2008, an equipment manufacturer discovered that buttons installed in elevators in France contained cobalt-60, most likely due to contamination from a medical sealed radioactive source that had been melted with scrap metal that was used to cast the buttons.
- In 2012, a retail company in the United States discovered that cobalt-60 had been incorporated into metal facial tissue boxes distributed to more than 200 stores nationwide.
- In 2012, customs officials stopped a shipment of contaminated goods from India entering Belgium. It was confirmed that about 60 small stools were contaminated with cobalt-60. As of early 2013, the origin of the contamination had not been determined, but it is likely that a sealed radioactive source was melted with scrap metal, which was eventually made into stools.

The most noteworthy accidents involving sealed radioactive sources at metal recycling facilities have usually affected persons at the facility more significantly than members of the general public. In some situations, members of facility workers' families were also involved. Three recent significant accidents are discussed below.

Source in Scrap Metal in China

In 1999, a teletherapy unit in Henan, People's Republic of China, was sold as scrap metal to a waste disposal company, where the cobalt-60 source was removed from the unit. The source was sold separately to another scrap metal dealer, who took it home and placed it in a bedroom shared by his wife and son. Both of them began vomiting overnight, which prompted the scrap metal dealer to stay with and care for them, until he also began vomiting. The family sought treatment the next morning, initially believing they were afflicted by food poisoning. A physician noted the possibility that their symptoms were due to radiation exposure and referred them to a hospital for diagnosis and treatment. On the basis of the diagnosis, the presence of the source was eventually verified and it was safely recovered. All three individuals were treated and survived, beginning to recover approximately 30 days after the exposure.

Source Abandoned in Thailand

In 2000, an individual in Samut Prakarn, Thailand, purchased scrap metal and took it home for dismantling and recycling. This included part of a cobalt-60 teletherapy unit that, unknown to the buyer or seller, still contained a sealed radioactive source. After unsuccessfully attempting to dismantle the unit, two persons carried the metal to a junkyard approximately 30 minutes away, where other workers used an oxyacetylene torch to cut the unit open. This caused the source to fall to the ground. Still not knowing this metal object was radioactive, the original purchaser took the cylinder containing cobalt-60 back to his residence. Over the course of several days, ten persons involved in the process developed symptoms of radiation poisoning, including nausea, vomiting, diarrhoea, hair loss, and burns. Three persons died and about 1870 people living near the junkyard were exposed to some elevated level of radiation.

Source Inadvertently Sold in India

In 2010, the University of Delhi in India instituted a campus-wide project to remove unused and unwanted objects. One of the objects identified for removal and disposal was an instrument that had been unused since 1985. It was auctioned in February to a scrap metal dealer and was delivered to the dealer in Mayapuri. No one realized that it contained sealed radioactive sources. Sometime in March, the owner cut off a sample of a source for testing as the metal had not been identified, and gave it to another dealer who put it in his wallet. By late March, the shop owner developed diarrhoea and skin lesions. In early April, the shop's owner was hospitalized with radiation sickness, which prompted an investigation that resulted in authorities confirming the presence of sealed radioactive sources. The dealer who had taken the sample developed radiation burns on his buttock and later collapsed. By mid-April, a total of seven individuals were hospitalized with radiation injuries, with one more hospitalized and released. One individual was transferred to another hospital where he died from multiple organ failures due to the high radiation exposure. Authorities recovered eight sources at the original shop, two at a nearby shop, and one from the dealer's wallet. Many of these were fragments of the original cobalt-60 source. Authorities also removed some contaminated soil.

PREVENTING ACCIDENTS INVOLVING SOURCES AT METAL RECYCLING FACILITIES

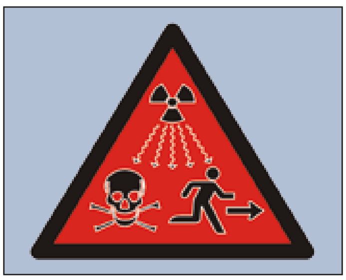
Assessment of past accidents demonstrates that it is important to be aware of the potential hazards from radioactive materials and recognize materials that may be radioactive. Smaller companies and independent scrap dealers are particularly at risk, if they do not have adequate detection systems and if their workers are not trained to recognize radiation warning symbols. Those working with scrap metal should be aware of the labelling used to indicate the presence of radiation.

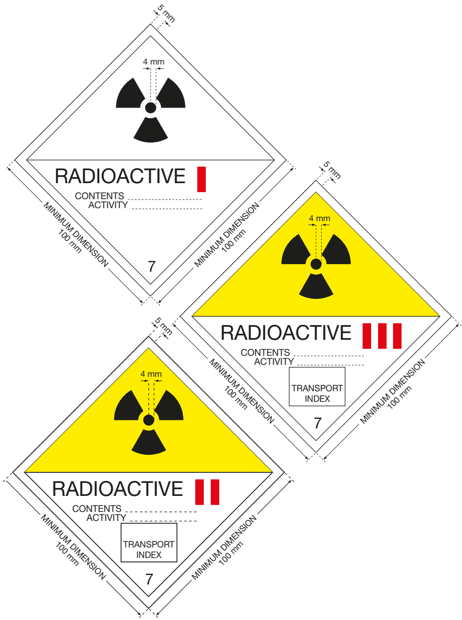
In addition to the exposure risks, melting down a radioactive source can contaminate equipment, requiring very costly clean-up, long term waste management, and interruption of business. It is in the best interest of operators at foundries and steel factories to have procedures in place to detect radioactive material.

Portal monitor for detecting radioactive material in scrap metal / Credit: Turner Nuclear Consulting Services, LLC.

Basic ionizing radiation symbol: to signify the presence of ionizing radiation and to identify sources and devices that emit ionizing radiation.

Ionizing-radiation warning — Supplementary symbol: to warn of the presence of a dangerous level of ionizing radiation from a high-level sealed radioactive source.





Examples of the types of labels required for packages containing radioactive sources.

Grapple with installed radiation detector / Credit: Turner Nuclear Consulting Services, LLC.

Unusually heavy metal objects may contain radioactive sources

High activity sealed radioactive sources are usually stored in heavy metal containers with shielding that is often constructed of lead, tungsten, or depleted uranium, materials that are selected because of their ability to shield the radiation emitted from radioactive sources. Unfortunately, such metal objects often enter the scrap metal supply chain inadvertently, with their radioactive contents unknown. Abnormally dense containers should be treated cautiously, as their weight may indicate the container was designed for shielding a radioactive source.

Radioactive sources have labels

The "trefoil" is the official international radiation symbol used to label sources, containers, or devices. In addition to the trefoil symbol, the word "radioactive" may also appear. Some containers used for transporting sources will have other information on the amount of radioactivity or the type of protective container. Some sources, such as fine needles used for treating cancer, are too small to have any symbols. However, their containers are required to be labelled.

Monitoring incoming scrap for radioactivity

Many countries have set up monitoring equipment at ports of entry to detect radioactive materials that may be present in goods or shipments, including scrap metal, before they enter the country. Many large scrapyards and foundries also use radiation detectors to check loads of incoming scrap metal for signs of radioactivity. Improved record keeping on the origins of scrap metal may also help reduce the risk of undetected radioactive materials.

Procedures and instructions

In the event that radioactive material is found or suspected, workers need to know what to do and whom to contact. Operators of metal recycling facilities should develop procedures to follow and make sure workers understand the procedures. Emergency numbers for relevant agencies should be posted and updated regularly.

Training

All staff responsible for collecting, transporting and processing scrap metal should be provided with on-going training on the procedures in place to monitor for radiation and check for radioactive materials. This training should include how to recognize radiation symbols and the procedures to follow should they encounter such a label or material.

3 and 4 — Sealed radioactive sources/M. Al-Mughrabi (IAEA).

1 — Device containing 2 Curie Cs-137 source discovered in scrap metal / Credit: Turner Nuclear Consulting Services, LLC.
2 — Device containing Co-60 source discovered in scrap metal / Credit: Turner Nuclear Consulting Services, LLC.

IN THE EVENT SUSPICIOUS MATERIAL IS FOUND

Call for help

If suspicious materials (i.e., suspected of being radioactive or containing a radioactive source) are found, immediately contact emergency personnel or the responsible regulatory authority. Protect those in the vicinity from being exposed to radiation. There are three important things to remember to reduce risk from radiation:

- time,
- distance, and
- shielding.

Limit time near a source of radiation

Limiting the time spent near any radioactive material will reduce the amount of radiation exposure.

Keep well away from radioactive materials

The intensity of radiation and its effects drop off sharply with distance from the source, so always maximize distance. As a general rule, stay at least 30 meters away until more is known about the source.

Shielding reduces radiation exposure

High density materials, such as cement blocks, lead, steel, and other metals, will block the radiation produced by radioactive materials. Properly trained personnel use shielding to reduce the amount of radiation to which they are exposed.

IN CONCLUSION

The most effective means to prevent accidents with sealed radioactive sources in the metal recycling industry is to adopt work habits and adequate measures that increase the probability that a radioactive source can be identified and handled safely. Organizations and companies discovering sources are responsible for taking the necessary steps to protect the public, the environment, and themselves every time they work with a sealed radioactive source. Sources no longer in use should be returned to the manufacturer, disposed of as radioactive waste if possible, or conditioned for secure long term storage with the consent of the national regulator.

Surveying for radioactive material at metal recycling facility.

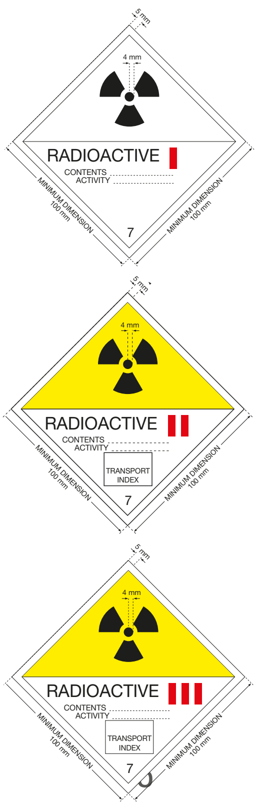
Decontamination efforts at a metal recycling facility.

Credit: Turner Nuclear Consulting Services, LLC.

REDUCING RISKS FROM SOURCES DURING EMERGENCY RESPONSE

IAEA training course on searching for orphan radioactive sources / Credit: E. Reber (IAEA).

Monitoring illicit trafficking.



Examples of the types of labels required for packages containing radioactive sources.

ISSUES FOR FIRST RESPONDERS, CUSTOMS AND BORDER PATROL

SEALED RADIOACTIVE SOURCES

Sealed radioactive sources are used for a variety of purposes in medicine, industry, and construction. Responding to an emergency or inspecting a shipment crossing borders can potentially lead to the discovery of radioactive sources. In these situations, it is critical that responders can recognize sources and the devices or containers that may hold them, take the necessary precautions to protect themselves against radiation hazards, and still respond appropriately to the emergency situation.

Sealed radioactive sources may be contained inside large, heavy devices constructed out of metal that shields the radiation they emit. The sealed radioactive sources themselves are typically small, on the order of several centimetres in length and not usually found outside of devices that provide shielding.

Sealed radioactive sources are routinely transported worldwide on public roads, railways and ships. These legitimate shipments occur with the sources inside specially-designed shipping containers that shield the radiation from the source and protect the source during transport. Such shipments can be recognized by radiation symbols affixed as labels to the shipping containers and are specifically noted on manifests. These not only indicate that the material is radioactive, by including a radiation symbol, but also give an indication of the radiation field in the vicinity of the package.

INCIDENTS RESULTING FROM LOSS OF CONTROL OF SEALED RADIOACTIVE SOURCES RELEVANT TO FIRST RESPONDERS

Theft, loss, and malicious misuse of sealed radioactive sources present a significant threat to persons responding to an emergency. Discovery of radioactive sources in locations where they are not intended can also present hazards to customs inspectors who do not recognize the danger.

Source Stolen in Estonia

In 1994, a caesium-137 source was stolen from a radioactive waste facility in Estonia by three brothers. One of them had picked up the source when it fell out of a metal block and placed it in his jacket pocket. He took the source to his home and hung his jacket, containing the source, in a hallway, already feeling ill. Three days later, he was hospitalized. He died after one more week, with the cause of death given as kidney failure. No radiation injury was recognized at this time. One month later, the man's stepson found the source in the jacket and moved it to a kitchen drawer. One week later, the child was hospitalized with burns recognized as radiation burns by hospital staff. The staff notified authorities, who found the source in the house. Of the other perpetrators, one received a dose to his hands, causing injury, and the other a dose causing mild radiation sickness. The three other residents of the house were injured: a radiation dose to the hands of the child required amputation of the fingers on one hand; the man's mother developed radiation sickness, and the man's wife received a lower dose. A dog that slept near the source indoors also died.

Sources Stolen in the United States

A man was arrested in Michigan in the United States in 2001 for stealing smoke detectors, apparently to collect radioactive sources from them. He was charged with stealing at least 13 smoke detectors containing americium-241 from several buildings in his apartment complex. At the time of his arrest, his face was covered with open sores reported related to exposure to radioactive materials. The same individual, around 1993 at age 17, had accumulated large amounts of commercial radioactive sources including americium, thorium, radium, and tritium, in an effort to build a homemade breeder reactor. The effort was accidentally discovered by local authorities and the radioactive materials were later disposed of by federal authorities.

Sources Abandoned in Republic of Georgia

Three men found two radioisotope thermoelectric generators (RTG, a device that uses heat from radioactive decay to generate electricity) in the woods of western Georgia during the winter of 2001–2002. They removed the shielding, apparently to obtain scrap metal. In early December 2001, they removed both strontium-90 sources and took them back to their campsite where the sources were used as heat sources. All three became sick from radiation exposure within hours. After they sought medical treatment, Georgian authorities requested assistance in securing the sources. Heavy snow and rugged terrain prevented access to the area initially, but the recovery team successfully reached the sources in February 2002 after which they were secured.

Source Use in Murder Attempt in China

An attempt to murder an associate using a gamma emitter occurred in China in 2002 when a disgruntled hospital worker placed iridium-192 pellets in the ceiling panels above a business rival. This incident caused symptoms of



Training courses on emergency response and searching for orphan radioactive sources / Credit: IAEA.

radiation sickness in 74 staff members. Symptoms experienced by the intended victim were severe and included memory loss, fatigue, loss of appetite, headaches, vomiting, and bleeding gums.

Radioactivity Found in Import Shipment

In September 2012, customs officials stopped a shipment of contaminated goods from India entering the country of Belgium. It was confirmed that about 60 small stools were contaminated with cobalt-60. The origin of the contamination has not been determined, but it is likely that a sealed radioactive source was melted with scrap metal, which was eventually made into stools. It should be noted that a small about of radioactive material can contaminate a large amount of scrap metal during recycling.

PREVENTING ACCIDENTAL EXPOSURE TO SOURCES IN EMERGENCY RESPONSE AND FOR CUSTOMS INSPECTORS

Assessment of past accidents and incidents demonstrates that it is important to be aware of the potential hazards from radioactive materials and recognize materials that may be radioactive.

Unusually heavy metal objects may contain radioactive sources

High activity sealed radioactive sources are usually stored in heavy metal containers with shielding usually constructed of lead, tungsten, or depleted uranium because of their ability to shield the radiation emitted from radioactive sources. Abnormally dense containers should be treated cautiously, as their weight may indicate the container was designed for shielding a radioactive source.

Labelling of radioactive sources

The "trefoil" is the official international radiation symbol used to label sources, containers, or devices. In addition to the trefoil symbol, the word "radioactive" may also appear. Some containers used for transporting sources will have other information on the amount of radio-activity or the type of protective container. Some sources, such as fine needles used for treating cancer, are too small to have any symbols. However, their containers are required to be labelled.

Monitoring for radioactivity

Many countries have set up monitoring equipment at ports of entry to detect radioactive materials that may be present in goods or shipments before they enter the country. Emergency response personnel may be provided with portable radiation detection instruments to alert them to dangerous levels of radiation when responding to alarms.

Training

All emergency response staff should be provided with on-going training on the procedures in place to monitor for radiation and check for radioactive materials. This training should include how to recognize radiation symbols and the procedures to follow if such a label or material is encountered.

IN THE EVENT SUSPICIOUS MATERIAL IS FOUND

Responding to emergencies involving radioactive materials will usually require obtaining assistance from specially-trained and qualified personnel familiar with radiation hazards and how to control them. First responders and customs or border patrol officials should establish contact with government radiation experts as part of emergency preparedness, before any emergencies are encountered. Technical experts can assist with procedures and methods to assess hazardous situations and provide guidance on proper response.

Call for help

If suspicious materials (i.e., suspected of being radioactive or containing a radioactive source) are found, immediately contact emergency personnel or the responsible regulatory authority. Protect those in the vicinity from being exposed to radiation. There are three important things to remember to reduce risk from radiation:

- time,
- distance, and
- shielding.

Limit time near a source of radiation

Limiting the time spent near any radioactive material will reduce the amount of radiation exposure.

Keep well away from radioactive materials

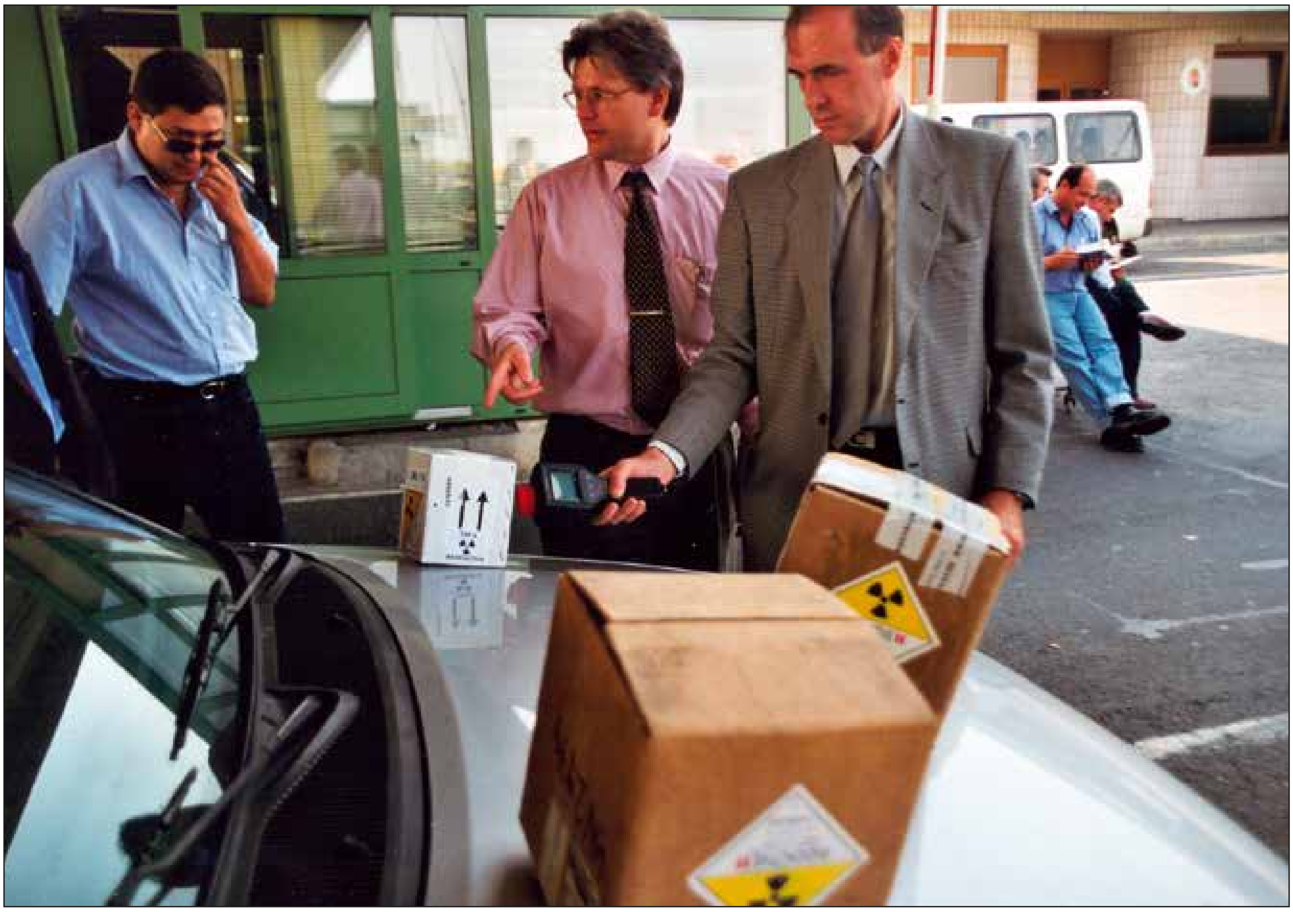
The intensity of radiation and its effects drop off sharply with distance from the source, so always maximize your distance. If you discover an unknown source you should stay at least 30 meters away until more is known about the source.

Shielding reduces radiation exposure

High density materials, such as cement blocks, lead, steel, and other metals, will block the radiation produced by radioactive materials. Properly trained personnel use shielding to reduce the amount of radiation to which they are exposed.

IN CONCLUSION

The most effective means to prevent accidental exposure to sealed radioactive sources is to be observant so that such sources can be identified and handled safely. Organizations and companies using sources are responsible for taking the necessary steps to protect the public, the environment, and themselves every time they work with a sealed radioactive source.



Trainees are shown how to use a radiation counter during a training course for customs and police officials organized by the IAEA with the World Customs Organization and Interpol. (Austro-Hungarian border, Nickelsdorf, Austria, October 1999)/ V. Mouchkin (IAEA)

IAEA ACTIVITIES

IAEA training course on searching for orphan radioactive sources / Credit: E. Reber (IAEA).

IMPROVING THE SAFETY AND SECURITY OF SEALED RADIOACTIVE SOURCES

Radioactive sources are used widely throughout the world in medicine, industry, and agriculture. Unfortunately, the International Atomic Energy Agency (IAEA) receives reports regularly of serious injuries or deaths due to misuse or accidents involving sealed radioactive sources. The IAEA offers a wide range of guidance, activities and services to assist its Member States to improve the safety and security of their sealed radioactive sources.

Accident prevention requires a comprehensive approach to protecting and controlling sealed radioactive sources: applying standards for manufacturing and use; establishing regulatory control, physical protection, and inventories; training users on good practices and procedures; and properly disposing of the source when it is no longer in use.

Since the terrorist attacks of September 2001, the security of sealed radioactive sources has become a growing concern, particularly the potential that such a source could be used as a radioactive dispersal device or "dirty bomb". Preventing the loss or theft of sealed radioactive sources reduces both the risk of accidents and the risk that such sources could become an instrument of misuse.

KEY ACTIVITIES

INTERNATIONALLY RECOGNIZED SAFETY STANDARDS

The IAEA has developed safety standards on a wide range of topics related to radiation safety. These safety standards establish an international consensus on provisions that are necessary to protect people and the environment from the harmful effects of radiation. Member States use these standards as the basis for national standards and regulations in areas such as: radiation protection, manufacture and design, transport, waste disposal, and emergency preparedness.

Radiation Protection and Safety of Radiation Sources: The International Basic Safety Standards (Interim Edition), General Safety Requirements Part 3 (2011), is a comprehensive standard for radiation protection for all activities that involve radiation. Examples of safety standards that address the control of sealed radioactive sources include:

- Governmental, Legal and Regulatory Framework for Safety, General Safety Requirements Part 1(2010)
- Regulations for the Safe Transport of Radioactive Material, 2012 Edition, Specific Safety Requirements No. SSR-6 (2012)
- Control of Orphan Sources and Other Radioactive Material in the Metal Recycling and Production Industries, Specific Safety Guide No. SSG-17 (2012)

- National Strategy for Regaining Control over Orphan Sources and Improving Control over Vulnerable Sources, Specific Safety Guide No. SSG-19 (2011)
- Preparedness and Response for a Nuclear or Radiological Emergency, Safety Standards Series No. GS-R-2 (2002)
- Safety of Radiation Generators and Sealed Radioactive Sources, Safety Guide No. RS-G-1.10 (2006)

INTERNATIONALLY RECOGNIZED SECURITY GUIDANCE

The IAEA has developed the "Nuclear Security Series" (NSS), a set of publications which address nuclear security issues relating to the prevention and detection of, and response to, theft, sabotage, unauthorized access and illegal transfer or other malicious acts involving nuclear material and other radioactive substances and their associated facilities. The primary publication of the NSS is a fundamentals-level document which provides the objective and essential elements for a State's nuclear security regime. Several publications in the NSS deal with the security of sealed radioactive sources in particular. These include:

- Identification of radioactive sources and devices, Nuclear Security Series No. 5 (2007)
- Combating illicit trafficking in nuclear and other radioactive material, Nuclear Security Series No. 6 (2007)
- Security in the transport of radioactive material, Nuclear Security Series No. 9 (2008)
- Security of radioactive sources, Nuclear Security Series No. 11 (2009)
- Nuclear Security Recommendations on Radioactive Material and Associated Facilities, Nuclear Security Series No. 14 (2011)

ADVICE THROUGH SAFETY REPORTS, TECHNICAL DOCUMENTS AND SERVICES

In addition to formal safety standards, the Agency also provides advice through safety reports, technical documents and services. Safety Reports and technical documents (TECDOCs) are produced on a wide range of topics, such as: management of disused sources, procedures for conditioning and storing long lived sealed radioactive sources, and borehole disposal. Prepared in consultation with leading experts, these documents provide detailed guidance at the technical level for those working in the relevant area.

The IAEA provides a wide range of services to assist Member States improve safety and security of radioactive sources, such as training courses to help guide strategies for regaining control over sealed radioactive sources and the Emergency Preparedness Review (EPREV) to independently appraise the emergency preparedness and response capabilities in Member States.

The Agency also facilitates information exchange through international conferences, symposia, and technical meetings.

DISUSED SEALED RADIOACTIVE SOURCE MANAGEMENT ASSISTANCE

The IAEA assists Member States in implementing safe and cost effective technologies for recovering, conditioning, storing, and disposing of disused sealed radioactive sources (DSRS), which pose unique safety and security threats. Direct assistance includes:

- Recovering, characterizing, and conditioning DSRS for long term storage;
- Repatriation and/or recycling of higher activity DSRS; and
- Consolidation of DSRS within countries to safe and secure storage where available.

In addition, the IAEA helps to improve national capabilities to manage DSRS by advising on designs for facilities to condition and store DSRS, providing technical procedures on sealed radioactive source handling, conditioning, and storage, and providing training on DSRS management techniques. The Agency has also developed specialized shielded mobile equipment for use in conditioning high-activity sources in the field. The Agency has also established a searchable database of sealed radioactive sources and devices, the International Catalogue of Sealed Radioactive Sources and Devices (ICSRS), for use in identifying sources and devices that may be found and assisting source managers with characterization.

Contact Waste Technology Section, Division of Nuclear Fuel Cycle and Waste Technology

http://www.iaea.org/OurWork/ST/NE/NEFW/Technical_Areas/WTS/sealedsources.html

Contact International Catalogue of Sealed Radioactive Sources and Devices

http://nucleus.iaea.org/CIR/CIR/ICSRS.html

IMPROVING REGULATORY FRAMEWORK FOR SAFETY

A regulatory framework is essential for protecting people and the environment from the harmful effects of radiation. The IAEA offers a wide range of assistance with regard to the development and maintenance of the regulatory framework for safety including:

- international review missions that assess and provide recommendations on, the national framework for safety;
- a self-assessment tool;
- a software management tool for regulatory bodies; and
- training for regulators.

Contact: Department of Nuclear Safety and Security

http://www-ns.iaea.org/tech-areas/radiation-safety/source.asp?s=3&l=22

IMPROVING REGULATORY FRAMEWORK FOR SECURITY

A robust nuclear security regime is required to achieve worldwide, effective security wherever radioactive material is in use, storage or transport. The IAEA offers a wide range of assistance with regard to the establishment and maintenance of a country's security regime, including:

- International advisory missions to review and assess security needs;
- Training for regulators and first responders;
- Development of nuclear security recommendations and guidance, and support for their implementation

The Incident and Trafficking Database (ITDB) is the IAEA's information system, on incidents of illicit trafficking and other unauthorized activities and events, involving nuclear and other radioactive material outside of regulatory control. It helps to combat illicit nuclear trafficking and to strengthen nuclear security, by facilitating the exchange of authoritative information on incidents among States. As of 31 December 2012, 120 States participate in the ITDB programme and more than 2330 incidents have been confirmed.

Contact Illicit Trafficking: The Office of Nuclear Security

http://www-ns.iaea.org/security/default.asp?s=4&l=33

CODE OF CONDUCT ON THE SAFETY AND SECURITY OF RADIOACTIVE SOURCES

The Code of Conduct on the Safety and Security of Radioactive Sources and its supporting guidance document, Guidance on the Import and Export of Radioactive Sources – 2012 Edition, were established to help national authorities ensure that radioactive sources that may pose a significant risk are used within an appropriate framework of radiation safety and security. These non-binding legal instruments provide the basis for a range of IAEA safety and security activities.

Contact: Department of Nuclear Safety and Security

http://www-ns.iaea.org/tech-areas/radiation-safety/code-of-conduct.asp?s=2&l=9

International experts meeting at IAEA Headquarters to develop guidance on improving the control of sealed radioactive sources.

EMERGENCY ASSISTANCE DURING ACCIDENTS AND INCIDENTS OR IN RECOVERY OF A RADIOACTIVE SOURCE

Under the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, Member States party to the Convention may request assistance through the IAEA to deal with an emergency involving a radioactive source. This assistance may be in the form of technical advice or direct assistance in safely recovering and securing a source or treating persons exposed to radiation.

All Member States that are party to the Convention have designated contact points in their country that are knowledgeable and have the authority to deal with radioactive sources. These contact points have been trained and understand how to contact the IAEA to report events and/or to request assistance.

The IAEA Incident and Emergency Centre (IEC) maintains the Response and Assistance Network (RANET) to provide assistance and advice, and/or to co-ordinate the provision of assistance as specified within the framework of the Assistance Convention, and to promote emergency preparedness and response capabilities for nuclear or radiological emergencies among IAEA Member States.

Contact: Incident and Emergency Centre
http://www-ns.iaea.org/tech-areas/emergency/default.asp?s=1&l=5

KEY IAEA PUBLICATIONS

KEY IAEA PUBLICATIONS RELATED TO SAFETY AND SECURITY OF RADIOACTIVE SOURCES

IAEA Safety Publications

- Governmental, Legal and Regulatory Framework for Safety, General Safety Requirements Part 1, No. GSR Part 1 (2010)
- Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (Interim Edition), General Safety Requirements Part 3, No. GSR Part 3 (Interim) (2011)
- Regulations for the Safe Transport of Radioactive Material, 2012 Edition, Specific Safety Requirements No. SSR-6 (2012)
- Preparedness and Response for a Nuclear or Radiological Emergency (FAO, IAEA, ILO, OCHA, OECD/NEA, PAHO, WHO), General Safety Requirements GS-R-2 (2002)
- Borehole Disposal Facilities for Radioactive Waste, Specific Safety Guide No. SSG-1 (2009)
- Radiation Safety of Gamma, Electron and X Ray Irradiation Facilities, Specific Safety Guide No. SSG-8 (2010)
- Radiation Safety in Industrial Radiography, Specific Safety Guide No. SSG-11 (2011)
- Control of Orphan Sources and Other Radioactive Material in the Metal Recycling and Production Industries, Specific Safety Guide No. SSG-17 (2012)
- National Strategy for Regaining Control over Orphan Sources and Improving Control over Vulnerable Sources, Specific Safety Guide No. SSG-19 (2011)
- Building Competence in Radiation Protection and the Safe Use of Radiation Sources: Safety Guide, Safety Standards Series No. RS-G-1.4 (2001)
- Radiological Protection for Medical Exposure to Ionizing Radiation (2002). Co-sponsorship: PAHO, WHO, Safety Standards Series No. RS-G-1.5 (2002)

- Categorization of Radioactive Sources, Safety Standards Series No. RS-G-1.9 (2005)
- Safety of Radiation Generators and Sealed Radioactive Sources, Safety Guide No. RS-G-1.10 (2006)
- Recommendations for the Safe Use and Regulation of Radiation Sources in Industry, Medicine, Research and Teaching, Safety Series No. 102 (1991)
- Radiation Protection and the Safety of Radiation Sources: A Safety Fundamental, Safety Series No. 120 (1996)
- Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency (Jointly sponsored by the FAO, IAEA, ILO, PAHO, WHO), General Safety Guide GSG-2 (2011)
- Arrangements for Preparedness and Response for a Nuclear or Radiological Emergency (Jointly sponsored by the FAO, OCHA, ILO, PAHO and WHO), Safety Guide GS-G-2.1 (2007)

IAEA Security Publications

- Identification of radioactive sources and devices, Nuclear Security Series No. 5 (2007)
- Combating illicit trafficking in nuclear and other radioactive material, Nuclear Security Series No. 6 (2007)
- Security in the transport of radioactive material, Nuclear Security Series No. 9 (2008)
- Security of radioactive sources, Nuclear Security Series No. 11 (2009)
- Nuclear Security Recommendations on Radioactive Material and Associated Facilities, Nuclear Security Series No. 14 (2011)

Technical Documents, Operational Manuals, Reports, and Conference Proceedings

- Nature and Magnitude of the Problem of Spent Radiation Sources, IAEA TECDOC-620 (1991)
- Methods to Identify and Locate Spent Radiation Sources, IAEA TECDOC-804 (1995)
- Conditioning and Interim Storage of Spent Radium Sources , IAEA TECDOC No. 886 (1996)
- Management of Small Quantities of Radioactive Waste, IAEA TECDOC Series No. 1041 (1998)
- Organization and Implementation of a National Regulatory Infrastructure Governing Protection against Ionizing Radiation and the Safety of Radiation Sources. Interim report for comment, IAEA-TECDOC-1067 (1999)
- Safety Assessment Plans for Authorization and Inspection of Radiation Sources, IAEA-TECDOC-1113 (1999)
- Safety of Radiation Sources and Security of Radioactive Materials, Proceedings of 1998 IAEA international conference in Dijon, France (1999)
- Handling, Conditioning and Storage of Spent Sealed Radioactive Sources, IAEA-TECDOC-1145 (2000)
- Generic procedures for assessment and response during a Radiological Emergency IAEA-TECDOC-1162 (2000)
- Management for the Prevention of Accidents from Disused Sealed Radioactive Sources, I AEA-TECDOC-1205 (2001)
- Management of Spent High Activity Radioactive Sources (SHARS), IAEA-TECDOC 1301 (2002)
- Management of Disused Long Lived Sealed Radioactive Sources (LLSRS), IAEA-TECDOC 1357 (2003)
- Disposal Options for Disused Radioactive Sources, Technical Reports Series No. 436 (2005)
- Review of Sealed Source Design and Manufacturing Techniques Affecting Disused Source Management, IAEA-TECDOC-1690 (2012)
- Control and Management of Radioactive Material Inadvertently Incorporated into Scrap Metal, Proceedings of an International Conference in Tarragona, Spain (2009)
- Locating and Characterizing Disused Sealed Radioactive Sources in Historical Waste, IAEA NE Series No. NW-T-1.17 (2009)
- Lessons Learned from Accidents in Industrial Radiography, Safety Reports Series No. 7 (1998)
- Training in Radiation Protection and the Safe Use of Radiation Sources, Safety Reports Series No. 20 (2001)
- Manual for First Responders to a Radiological Emergency, EPR-First Responders (2006)
- Communication with the Public in a Nuclear or Radiological Emergency,EPR-Public Communications (2012)

- Manual for Official Communication in Incidents and Emergencies, EPR-IEComm (2012)
- Lessons Learned from the Response to Radiation Emergencies (1945-2010), EPR-Lessons Learned, (2012)
- Method for Developing Arrangements for Response to a Nuclear or Radiological Emergency, EPR-METHOD (2003)
- Preparation, Conduct and Evaluation of Exercises to Test Preparedness for a Nuclear or Radiological Emergency, EPR-Exercise (2005)
- Preparation, Conduct and Evaluation of Exercises to Test Preparedness for a Nuclear or Radiological Emergency — Training Materials, EPR-Exercise/T (2006)
- Dangerous quantities of radioactive material (D-values), EPR-D-Values (2006)
- Training Material for First Responders to a Radiological Emergency, EPR-First Responders/T (2009)
- Portable Digital Assistant for First Responders to a Radiological Emergency, EPR-First Responders/PDA (2009)
- E-Learning Tools for First Response to a Radiological Emergency, EPR-First Responders/E-learning (2009)
- Generic Procedures for Medical Response During a Nuclear or Radiological Emergency (IAEA/WHO), EPR-Medical (2005)
- Training material for medical preparedness and response to a nuclear or radiological emergency (IAEA/WHO), EPR-Medical/T (2002)
- Training Material on Public Communications in a Nuclear or Radiological Emergency, EPR-Public Communications/T (2012)
- Cytogenetic Dosimetry: Applications in Preparedness for and Response to Radiation Emergencies, EPR-Biodosimetry (2011)
- Generic procedures for monitoring in a nuclear or radiological emergency, IAEA TECDOC-1092 (1999)
- Dosimetric and Medical Aspects of the Radiological Accident in Goiânia in 1987, IAEA TECDOC-1009 (1998)
- Joint Radiation Emergency Management Plan of the International Organisations, EPR-Joint Plan (2010)
- IAEA Response and Assistance Network, EPR-RANET (2010)

Reports on Radiological Accidents

- The Radiological Accident in Goiânia (1988)
- The Radiological Accident in San Salvador (1990)
- The Radiological Accident in Soreq (1993)
- The Radiological Accident at the Irradiation Facility in Nesvizh (1996)
- An Electron Accelerator Accident in Hanoi, Viet Nam (1996)
- Accidental Overexposure of Radiotherapy Patients in San Jose, Costa Rica (1998)
- The Radiological Accident in the Reprocessing Plant at Tomsk (1998)
- The Radiological Accident in Tammiku (1998)
- The Radiological Accident in Istanbul (2000)
- The Radiological Accident in Yanango (2000)
- The Radiological Accident in Lilo (2000)
- The Criticality Accident in Sarov (2001)
- The Radiological Accident in Gilan (2002)
- The Radiological Accident in Samut Pakarn (2002)
- The Radiological Accident in Cochabamba (2004)
- Accidental Overexposure of Radiotherapy Patients in Bialystok (2004)
- The Radiological Accident in Nueva Aldea (2009)

Other

- Security of Material, Measures to Prevent, Intercept and Respond to Illicit Uses of Nuclear Material and Radioactive Sources, C&S Papers Series No. 12 (2002)
- Code of Conduct on the Safety and Security of Radioactive Sources, IAEA/CODEOC/2004
- Guidance on the Import and Export of Radioactive Sources – 2012 Edition, IAEA/CODEOC/IMP-EXP/2012

THE IAEA IS WORKING TO IMPROVE THE SAFETY AND SECURITY OF SEALED RADIOACTIVE SOURCES

For **more** information:

Contact your national regulatory authority or

The International Atomic Energy Agency
Vienna International Centre
PO Box 100, 1400 Vienna, Austria
E-Mail: info@iaea.org

Printed by the IAEA in Austria, October 2013
IAEA/PI/A.98 / 13-32051

VISIT www.iaea.org

IAEA
International Atomic Energy Agency