Radioactive Material in Scrap Metal

How to manage the risk

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Introduction

How prevalent are radioactive sources?

In current times, the use of radioactive sources and substances is widespread worldwide.

Radioactive sources can be found pretty much in every sector: health, industry, agriculture, research and in some cases in everyday life. A lot of these sources, having a high activity, are a serious health issue for workers and population. When a source is stolen, misplaced or simply lost due to negligence, accidents or fortuities, the risk of radiation exposure can become a dramatic reality. In the UK, around 10 sources a year per shredder site are found and the cost of their disposal is not only expensive but it slows down on site operation causing more money loss and unsafe situations.

In the last couple of decades, the history of accidents caused by lost sealed radioactive sources indicates a mean value of two persons per tear deceased due to these events and a high number of individuals with issues caused by radiation over exposure or internal contamination.

For these reasons, international organisations have long been concerned about this problem, producing a large number of publications and information material, both for the public and for users. In particular the IAEA, the International Atomic Energy Agency (widely known also as the world's Atom for Peace and Development organisation) works closely with the countries in the United Nations to promote a safe and secure handling of radioactive sources used both in industrial and nuclear applications. On the IAEA website it is possible to find a large number of guides, notes and accident reports regarding radioactive material found in scrap metal, its handling and the liability consequences of finding such sources. [3]

Figure 1. Example of radiopharmaceutical involved in a car accident and recovered by the emergency teams.

Figure 2. Level indicators found in a scrap yard.

IAEA

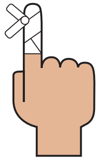
Incidents involving lost sources

How easy is it for an incident to occur?

Scrap metal is an important source material for the metal production industry, contributing a proportion of the final product (in the case of steel, about 50%). Most cities have several scrap yards, ranging from small operations involving a few individuals through medium sized facilities to, in industrialised states, large scrap yards handling between a hundred thousand and some ten million tonnes of scrap metal each year. The number of metal works and foundries worldwide that buy scrap to melt and refine or cast to shape is in the tens of thousands. Furthermore, there is a substantial transboundary movement of scrap metal and other products of the metal recycling and production industries. As a consequence, radioactive material mixed with scrap metal may inadvertently be transported across national borders. In view of this international dimension, a harmonised approach to dealing with radioactive material incorporated into scrap metal is clearly desirable. [1]

The consequences of a radiological accident can be grouped in five major areas: human health related, environmental, psychological, economic and legal. [6]

Injuries

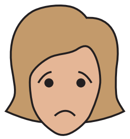


Acute radiation burns and other related effects usually affect a few to tens of people depending on the scenario.

Reputational harm

Melting a radioactive source can cause major reputational harm and the public and customers can heavily criticise a scrap metal dealer if an accident occurs when it could have been avoided.

Psychological harm

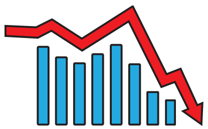


Radiological accidents may affect large numbers of people.

Death

Death may occur but experience suggests usually only a few. Only those close to the source are likely to receive fatal exposure levels. But families and communities will clearly react strongly to deaths.

Economic harm



After a melting or contamination accident, a company has to face huge decontamination and recovery costs. This can lead to close the plant for a while during the decontamination operation losing the income.

2018 and 2012 – Outokumpu, Finland

In 2012 at Outokumpu's Tornio site a source of Am-241 was melted during normal operations. The mill radiological security system revealed the radiation source and standard security actions were carried out according to the company processes. Four meltshop employees were exposed to radiation as they entered the melting furnace during maintenance work.

In 2018, four Am-241 sources were melted in four months.

All the accidents cost the company £4 - 6 million in decontamination costs.

2010 – Mayapury, India

The Chemistry Department at the University of Delhi sold a machine containing cobalt-60 sealed radioactive sources (SRS) to a scrap metal dealer as part of a campus-wide project to get rid of outdated laboratory machinery. No one realised that it contained some sealed radiaoctive sources (SRSs).

The machine was dismantled by the dealer and several scrap yard workers who were unaware of the hazards within this device. One of the SRSs was cut into pieces for testing and one of the pieces was given to a second dealer who put it in his wallet. Eight people were hospitalised, one of whom died later.

A few weeks later, the first dealer developed skin lesions and diarrhoea, and was hospitalised with radiation sickness, prompting an investigation that resulted in authorities confirming the presence of sealed radioactive sources at the scrap yard. The second dealer developed radiation burns on his buttocks and later collapsed. A total of eight individuals were hospitalised with radiation injuries. One of the individuals died from multiple organ failures due to exposure to very high levels of radiation.

Authorities recovered the intact sources and fragments at the original shop and a nearby shop as well as the fragment from the dealer's wallet. Authorities also removed some contaminated soil.

The whole operation cost millions to the Indian government.

Figure 3. A typical scrap yard.

Figure 4. Sifting through the scrap.

2010 – Genoa, Italy

During a routine inspection at the Port of Genoa, on Italy's northwest coast, a cargo container from Saudi Arabia containing nearly 23,000 kg of scrap copper was detected to be emitting gamma radiation at a rate of around 500 mSv/h.

After spending over a year in quarantine on Port grounds, Italian officials dissected the container using robots and discovered a rod of cobalt-60 23 cm long and 0.8 cm in diameter intermingled with the scrap. Officials suspected its provenance to be inappropriately disposed of medical or food-processing equipment. The rod was sent to Germany for further analysis, after which it was likely to be recycled. Overall, the operation cost around £500 k to the italian government.

Figure 5. Scrap copper in a shipping container.

Incidents involving lost sources

2000 – UK

A cardiac pacemaker containing PU-238 was melted inadvertently during normal operations.

Doses to workers and population were negligible, however, clean-up and disposal costs were believed to be around several million pounds.

1998 – The Acerinox event, Spain

A stainless steel factory inadvertently melted a source of Cs-137. The factory used the contaminated dust in a marsh stabilisation process, resulting into 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 Cs-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 Cs-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 £10 - 15 million.

This event triggered the idea at IAEA that a Metal Recycling Code of Conduct is an important initiative for establishing control over radioactive material that may have been inadvertently incorporated into scrap metal.

1997 – Alfa Acciai, Italy

In May 1997 the firm which collects the furnace dust of the Alfa Acciai for disposal rejected a shipment due to a radiation anomaly, identified as some Cs-137 present in the dust, also Co-60 was detected in the final product of the mill. The most contaminated products were still at the firm, whereas part of the rods from two successive castings had already left the plant. They were heading for several Italian localities, therefore exposing drivers, workers of other firms and possibly the population to irradiation risk. This material was brought back (16 - 20th May) and stored safely in an area of the plant, together with other more contaminated products.

Recovery of the plant took place from the 3rd June to the 1st July. After a partial and new start, under surveillance, on the 11th July, the plant returned to routine conditions on the 22nd July. At the end it was concluded that the source was melted in the period from the 6th May to the 13th May and that the source of Co-60 was of the order of 7 GBq (assessed by means of steel contamination), whereas that of Cs-137 of the order of 150 GBq (assessed by means of dust contamination). It was not possible to determine in which way the sources arrived at the firm. Since no national radioactive waste deposit has ever been approved or set up in Italy, the contaminated mild steel rods, together with the wastes of the recovery of the plant (mainly Cs-137 contaminated dust), are still deposited in an area of the plant. In conclusion, the consequences of the accident were rather limited.

Figure 6. Plutonium pacemaker.

Indeed, part of the final product was contaminated by Co-60, but the system to settle fumes had been effective in avoiding release of radionuclides in the surrounding environment (8). Nevertheless, the total cost of the accident was much more than 10 billion lira (> £300/400 k), including the recovery of the plant and the fixed expenses during plant shutdown. this event led italy towards a strict regulation about radiological checks in srcap metal loads. [10]

1987 – Goiania, Brazil

This accident is considered the worst radiological* event in history.

When the Goiania Institute of Radiotherapy relocated, they left behind many old hospital machines and supplies that would not play a role at their new location. An old teletherapy unit containing Cs-137 was one of the machines left in the abandoned building. Rummaging through the abandoned building, two men found the machine and sold it to a local scrap yard.

When employees at the junkyard dismantled the machine, the remaining Cs-137 was released. Employees at the junkyard were fascinated by the blue light that glowed in the dark that was hiding in the machine and unaware of its many dangers and its repercussions, they distributed it to family and friends.

Consequences of the Goyania accident:

Population affected: 1 million

Persons monitored: 112,800

Persons contaminated: 271

Radiation injuries: 28

Hospitalised: 20

Bone marrow depression: 14

Acute radiation syndrome: 8

Fatalities within 1 month: 4

Recovery costs: £10 million

**According to the INES a tool developed by IAEA for communicating the safety significance of nuclear and radiological events to the public.*

INES covers events at facilities and activities involving radiation sources. It is used for the rating of events that result in a release of radioactive material into the environment and in the radiation exposure of workers and the public. It is also used for events that have no actual consequences but where the measures put in place to prevent them did not function as intended. The scale is also applied to events involving the loss or theft of radioactive sources and the discovery of uncontrolled radioactive sources in scrap metal.

Figure 7. An abandoned teletherapy unit.

Figure 8. Decontaminating the site.

The cost

Radiological accidents result in both direct and indirect costs. [6]

Direct costs

Direct costs tend to be the ones that we think of first: Injury, ill-health and damage.

Indirect costs

Indirect costs may be these that are less obvious but they account for more of the overall cost of an accident than the direct costs.

Lost time, damage to product, plant, buildings, tools and equipment, sick pay, clearing the site, investigation time, loss of business/industry reputation, excess on insurance claims, fines, loss of contracts, legal costs, production delays, extra wages/overtime.

- Global experience is that the costs of recovery from a radiological incident are rising.
- Cost can be easily be more than the company affected can pay – this forces them into bankruptcy.
- Costs vary according to the State affected and the nature of the incident £1 million to £10 million (£100 million possible and could be £1 billion in worst cases).
- A large part of the cost of recovery will be radioactive waste management and radioactive waste disposal. Incidents generate proportionately large volumes of radioactive waste (low activity concentrations and lots of secondary wastes) compared to planned operations involving similar quantities of radioactive materials. [6]

Reducing the risk

How is it possible to reduce the risk of melting or rupturing a radioactive source? Everyone has their own role in reducing the risk.

Role of the state

Every state should encourage the metal recycling industries and national authorities to cooperate to meet the objectives of:

- Protecting people, property and the environment.
- Harmonising the approach to discovering the presence and handling and managing in a safe manner radioactive material that may inadvertently be present in scrap metal.

Therefore every State has:

- General role regarding the possibility of scrap metal being inadvertently incorporated into scrap metal.
- Specific roles for the management of radioactive material, once it has been discovered in a consignment. [6]

Role of the metal and recycling industries

- It is the responsibility of the metal recycling industries to ensure that their own safety policies give an appropriately high priority to radiation safety.
- The metal recycling industries should ensure, where appropriate, that a radiation monitoring report is provided per each consignment.
- The metal recycling industries should perform a visual inspection of the consignment by an appropriately trained person.
- The metal recycling industries should perform radiation monitoring at appropriate stages in the movement and processing of scrap metal and the manufacture of semi-finished products where radioactive material might be detected, including entrances and exits of facilities up to and within the melting facility. [6]

How can industries protect themselves?

The metal recycling industries should perform radiation monitoring at appropriate stages in the movement and processing of scrap metal and the manufacturers of semi finished products where radioactive material might be detected, should perform checks as well including at entrances and exits of facilities.

Radioactive material can be detected in scrap metal by monitoring in the following ways:

1. **Business information:** knowledge about scrap metal suppliers.
2. **Visual monitoring:** to check the presence of typical radiation warnings signs and source housings.
3. **Radiation Monitoring:** check radiation levels in the vicinity of the scrap with suitable equipment.

Business Information

Scrap metal facilities should:

- Know the scrap metal supplier.
- Review incoming shipments in relation to arrival.
  - Without evidence of radiation monitoring having been performed,
  - From a supplier with previous history of supplying radioactive scrap metal, and
  - From a supplier not previously known to the recipient company or the regulatory authorities.

Visual Monitoring

In view of the wide range of facilities within the metal recycling and production industries, a graded approach to monitoring should be adopted. It may not be reasonable to expect operators of small and medium sized facilities to undertake comprehensive radiation monitoring. However, as a minimum, operators of such facilities should be provided with a basic knowledge and awareness of the following, through leaflets and posters:

(a) The visual appearance of devices and containers that might contain radioactive sources;

(b) The radiation symbol (trefoil) and the ionizing radiation supplementary warning symbol;

(c) The labels and placards used in the transport of radioactive material;

(d) The possibility that heavy metal containers or shielding blocks may be constructed of depleted uranium rather than lead.

These leaflets and posters should provide instructions to the effect that any material, device or container that on visual examination appears suspect should be isolated, and should summarise the steps to be taken to manage correctly the source.

While such information should also be made available to operators of large metal recycling and production facilities, as visual observation is still important, the primary means of identifying radioactive material in such facilities should be by means of radiation detectors.

If you see a label or device similar to those illustrated, or you see suspected or actual presence of radioactive material in scrap metal, metal products or wastes, notify your H&S Department or whoever is responsible for radioactive findings

Radiation Monitoring

Ideally, for a consignment suspected to contain radioactive material, we would want to know:

1. **Does it contain radioactivity?**
   It can often be determined, but not always.
2. **Where in the consignment?**
   If radiation is detected we may be able to localise it.
3. **What is the nature of radioactivity?**
   Once detected, establish the dose rate and, if possible, the radionuclide(s) present.
4. **How much is there present?**
   It is usually quite straightforward in a scientific laboratory, but it is time consuming and not easy for operators to perform these kind of evaluations.

Figure 9. Examining cargo with the FLIR R500, a digital hand-held gamma radionuclide identification device (RIID).

Does it contain radioactivity?

It is relatively easy to say that something has been detected, i.e. that there is radioactivity present in the consignment. However, it is much more difficult to say that a shipment does not contain any radioactivity. There are several possible reasons for this:

- Some types of radiation are shielded out very easily: they will not penetrate the steel (or even canvas) side of the vehicle.
- The selection and use of the correct type of detector is key to establishing if there is radioactivity in the scrap. If the wrong type is used, or it is used incorrectly, then the probability of success may be very low, or even zero. So there is a need for skilled personnel and / or very good guidance to people undertaking the measurements.
- If the consignment emits gamma radiation, it is likely to be detectable. However, the scrap can shield out the radiation, reducing the number of counts. If the time interval for counting is too short, the instrument may not be able to detect the radiation.
- Some types of radiation are hard to detect and may get through the detectors.
  - Beta radiation may be detectable, but not through some centimetres of steel.
  - Alpha radiation will be undetectable in bulk – it will only be detectable only under laboratory conditions.
  - Neutrons are generally readily detectable, but only if the right detector is being used.
- It is really important to appreciate that no radiation detection system is 100% reliable.
- Portal monitors are commonly used for checking vehicles (road and rail; sometimes, vehicles unloading ships alongside a quay).
- Grapple monitors are used for monitoring scrap during loading and unloading operations.

How do you check for radiation?

Radiation portal monitors were originally developed for screening individuals and vehicles at secure facilities such as weapons laboratories. They were then deployed at scrap metal facilities to detect radiation sources mixed among scrap that could contaminate a facility and result in a costly clean up.

There are different types of radiation portal monitors. The most popular ones use large volume plastic detectors to increase the sensitivity to low counting rates. Spectroscopic and neutron capabilities are also available on the market, but the cost can significantly increase. Regardless of the type of portal used there are a number of factors to be considered.

Portal Monitors

- Vehicle geometry is important.
- the presence of a vehicle and its load between the detectors will suppress significantly the background counts.
- It has been known that drivers under certain medical treatments have caused an alarm.
- There are many different lay-outs of these systems but in general they all have large surface detectors facing the sides of the vehicle facilitating fast measurements on large vehicles.
- Portal detectors are used commonly, mainly because most movements are done by truck, rail or by containers.
- Portal detectors are also used for outgoing transports to verify that they do not contain radioactive material.
- At metal melting facilities these portal detectors are mainly used to scan incoming material. Owners of facilities do not want to receive radioactive material on their sites and they do not want to inadvertently melt a radioactive source contaminating their plants.
- Usually a portal detector gives an audible and/or visual alarm when an alarm threshold is reached. Electronic and paper records are also generated and stored to assist in more detailed investigations of suspicious consignments.
- An infrared sensor detects the presence and speed of the vehicle.

Figure 10. A portal monitor from Nucsafe, installed at a scrapyard.

Portal monitor features

- Usually large volume plastic scintillation detectors.
- Should be highly sensitive to detect small increases in gamma radiation levels.
- Are not sensitive at large distances (maximum distance of 6 meters between opposite portals).
- Provide speed alarms when the speed of the vehicle is over 10 km/h.
- Usually an infrared sensor detects a vehicle and then starts a measurement.
- Should have an audible and/or visual alarm.
- Should be robust e.g. an anti-crash bar.
- Should have a stop sign or barrier to control traffic.

Figure 11. A portal monitor installed by Nucsafe at a dockside freight terminal.

Other causes of alarms

Radiation detectors can be very sensitive devices and trigger a warning for reasons other than radioactive material in the consignment of scrap metal. Every alarm should be investigated. Other reasons for alarms may include:

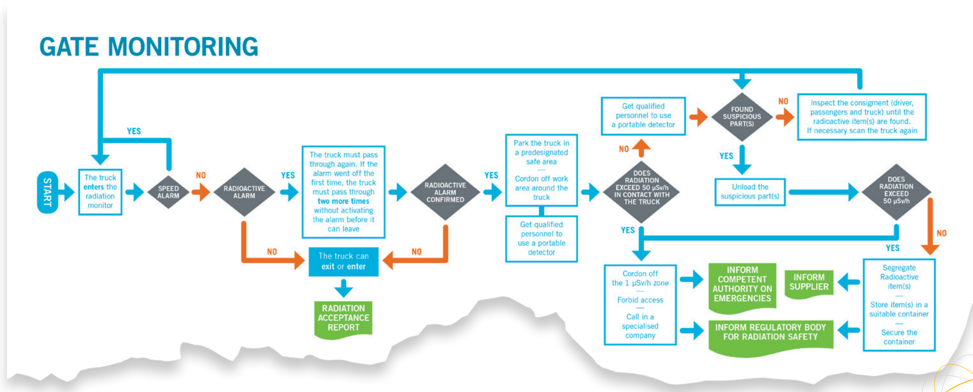
- Is there NDT in the neighbourhood (gamma radiography)?
- Was the driver examined or treated with radioactive material recently?
- Are Normally Radioactive Occurring Materials (NORMs) (bricks, gypsum, ceramics, minerals etc) present?
- Could there be enhanced background radiation, e.g. due to slag used in road building or heavy rain?
- The magnetism of pipes can interfere with the performance of hand-held radiation detectors.

Key aspects for effective monitoring

- Detector placement, configuration and vehicle speed are critical for effective monitoring.
- The recommended vehicle speed varies from 5 to 9 km/h depending on the standard that applies. The purpose of the monitoring and specification and sensitivity of the portals.
- If the vehicle moves too fast, there will be a speed alarm.

BIR has been active in working groups at the United Nations level for over ten years on the issue of control and management of inadvertent radioactive material in scrap metal. Several guidelines have been written and discussed and all of them have common themes to control and manage inadvertent radioactive material in scrap metal, amongst which is the need for companies in the business of scrap metal collection and/or sorting and/or processing and/or melting to provide their employees with basic advise on radioactivity in scrap. Therefore, BIR has employed radioactivity experts, graphic designers and translators to produce an informative poster which can be used by companies throughout the metal recycling sector, throughout the world.

An example of gate monitoring with a radiation portal monitor is reported in the poster below (reference BIR website: https://www.bir.org/publications/posters)



Monitoring of radioactive material

Handheld devices

Hand-held detectors can be placed close to the scrap metal to be monitored and therefore can facilitate determination of the location of a discrete radioactive source or other radioactive material. Another advantage of hand-held detectors is that they can be taken to all parts of the facility. However, they are not suitable for routine monitoring of large consignments of scrap metal. Routine monitoring of such consignments should be undertaken with stationary detectors, which tend to be larger and more sensitive. Stationary radiation detectors are fixed in place and are generally not used for radiation surveys. Instead, these devices should be used as 'pass - fail' indicators, i.e. if the radiation level reaches a preset level, the instrument triggers an alarm.

- An instrument that is hand-held can be used to try to localise where the signal is coming from in the consignment.
- These devices can offer measurements as a dose rate, as a count rate or as a total number of counts over a set period (an integrated total).

Handheld detectors with large NaI crystals can be used as an alternative to RPMs to scan trucks in cps mode

or

they can be used once the RPM triggers an alarm to find the location of the source inside the emptied consignment.

Figure 12. A handheld radiation monitor.

Handheld gamma spectrometers

Gamma spectrometers are useful tools to identify the nuclide. It is important to identify the radionuclide found as each isotope has different characteristics such as the half life.* According to the type of isotope, half life and activity involved in the route for disposal can be evaluated.

** Half-life, in radioactivity, the interval of time required for one-half of the atomic nuclei of a radioactive sample to decay (change spontaneously into other nuclear species by emitting particles and energy), or, equivalently, the time interval required for the number of disintegrations per second of a radioactive material to decrease by one-half.*

Figure 13. A handheld gamma spectrometer.

Purposes of Handheld detectors

1. **To verify an alarm of a portal detector.**
   a. Can be used for scanning a consignment in cps mode (the frequency and intensity of a sound increases when a higher radiation level is detected), or
   b. Searching through an emptied consignment.
2. **To locate the radioactive material in a consignment.**
   a. The radioactive material (source) can be located at one or more spots or can be spread over a volume of the scrap (contaminated scrap) or combinations of these.
3. **To measure the radiation level caused by the radioactive material in nSv/hr, uSv/h or mSv/hr.**
   a. To check if direct measures are necessary to protect staff, the driver, and other people such as the public.
4. **To analyse the radio nuclides present.**
   a. Can help identify the radionuclide found. it is important to identify the nulide as this needs to be disposed correctly.
5. **To assess if further transport of the consignment is legally possible.**
   a. Need to comply with national regulations for safe transport.

Figure 14. Examining cargo with a detector.

Figure 15. Examining an object with a detector.

Identifying a radioactive source, device or transport package

Radioactive sources, devices and transport packages vary a great deal in their appearance, depending on the specific application for which they may be used. The primary method of recognising a radioactive device, source or transport package is by its identification labelling. The following sections provide a brief description of radioactive devices, sources and transport packages and their labelling.

The machine, instrument or shielded package in which a radioactive source is located during use is referred to as the 'device'. Devices vary widely in their appearance according to the amount, type and energy of the radiation from the internal radioactive source, as well as the specific application for which the device is intended. In general, most devices contain gamma emitting radioactive sources, which are most efficiently shielded by dense metals, such as lead, tungsten or depleted uranium. Therefore, many devices can be characterised as being heavy in relation to their size. Devices may be intentionally portable, such as radiography cameras and road gauges, or they may also be loaded with a source at a dedicated facility and then transported to a permanent place of use. The transport of devices is well regulated by each country in the world but as already mentioned a few times in this guide there are several reasons why a device or a source might be stolen, lost, misplaced, etc., and become orphan.

Medical equipment

Just a few years after the discovery of X-rays and radioactive substances, medical science began to use the energy produced by radiation to try to cure diseases first and foremost cancer.

The radioactive sources used today in the health care sector can be divided into two main categories: the first refers to sources of therapeutic use while the second group is those used for clinical or laboratory diagnostics.

To the first category belong radionuclides of relatively high activity and relatively long half-life (of the order of months or years), capable of generating a high dose rate such as to kill cancer cells using radiotherapy techniques with external or internal beams (brachytherapy).

The second category includes short-lived radioisotopes, the use of which is partly reserved for both in vivo applications and in vitro analytical methods. In vivo investigations consist in the administration to patients of a known amount of radioisotopes, whose molecular structure exploits metabolic processes to reconstruct, with other detectors, morphological images or functional reconstructions of organs or anatomical structures. In the case of in vitro investigations, instead, the radioactive material is chemically bound to biological samples and treated in the laboratory, without the patient being subjected to any kind of exposure to ionizing radiation.

For obvious reasons, the sources used for in vivo diagnostics do not, in principle, constitute a significant radiation protection problem, also in consideration of the low intrinsic radiotoxicity of substances intended to be freely released into the body. On the contrary, sources of therapeutic use, and in particular sources of external radiotherapy, represent a serious safety issue, especially when such substances are lost, dispersed or otherwise excluded from the controls of the competent authority.

The table below shows the main radionuclides used as sealed sources in the medical field. [5]

Application	Radionuclide	Half-life	Source activity	Comments
Bone Densitometry	^{241}Am ^{153}Gd ^{125}I	433.0 a 244.0 d 60.1 d	1 - 10 GBq 1 - 40 GBq 1 - 10 GBq	Mobile units
Manual brachytherapy	^{137}Cs ^{226}Ra ^{60}Co ^{90}Sr ^{103}Pd ^{125}I ^{192}Ir ^{252}Cf	30.0 a 1600 a 5.3 a 29.1 a 17.0 d 60.1 d 74.0 d 2.6 a	50 - 500 MBq 30 - 300 MBq 50 - 500 MBq 50 - 1500 MBq 50 - 1500 MBq 30 - 1500 MBq 200 - 1500 MBq 50 - 1500 MBq	Small portable sources
Remote after loading brachytherapy	^{60}Co ^{137}Cs ^{192}Ir	5.3 a 30.0 a 74.0 d	~10 MBq 0.03 - 10 MBq ~400 MBq	Mobile units
Teletherapy	^{60}Co ^{137}Cs	5.3 a 74.0 d	50 - 1000 TBq 500 TBq	Fixed installations
Whole blood irradiation	^{137}Cs	74.0 d	500 TBq	Fixed installations

Identifying radioactive sources

Below are some examples of radioactive sources or devices used in the medical field and found either in scrap metal or just abandoned:

Radiotherapy Head

The source itself is usually contained inside the head and it is quite small (a few cm). Often the head is lined with depleted uranium (DU) whose aim is to shield radiation from the source. Even though the activity level of DU is much lower than the one of the source contained its presence represents a further issue.

Isotope	Activity
^{60}Co, ^{137}Cs, ^{192}Ir	0.1 MBq – 400 GBq

Brachytherapy Sources

Isotope	Activity
^{192}Ir, ^{137}Cs, ^{60}Co, ^{226}Ra, ^{90}Sr ^{103}Pd, ^{125}I, ^{131}I, ^{198}Au	50 kBq – 500 MBq

Old Bone Mineral Density Testing Devices

These kind of devices were widely used in the past but now they are less likely to be found in Europe, BUT some Chinese websites still sell them as an innovative device.

Isotope	Activity
^{125}I, ^{241}Am, ^{153}Gd	1 – 40 GBq

Plutonium Pacemakers

Before lithium batteries were implemented for these devices, in the 70's devices powered by thermo-electric batteries were put on the market whose operation was controlled by a plutonium source protected by a titanium container that had to guarantee the containment in case of accident or destructive event (e.g. Cremation).

Isotope	Activity
^{238}Pu	74 – 148 GBq

Figure 16. An abandoned radiotherapy head.

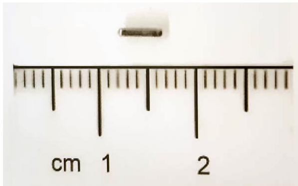


Figure 17. A brachytherapy source.

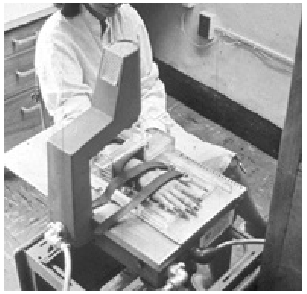


Figure 18. A bone mineral density testing device.

Figure 19. Plutonium pacemaker.

Sources for industry and research

There are numerous radioactive sources used in industry, related to a wide range of uses and consequently to an extremely wide range of activities. Alongside sources of modest hazard, it is possible to find radioisotopes with high energy and activity, which can pose a very serious hazard if left uncontrolled in the environment.

The most common uses of radioisotopes in the industrial field are:

- Industrial gammagraphy, which exploits the capacity of high-energy radiation to cross high thicknesses of solid material, allowing a radiographic view of the internal parts, in order to highlight discontinuities or structural anomalies;
- Irradiation systems, which allow the sterilisation of objects and food;
- Industrial radiometric measurements, (level measurements, interface systems, density and thickness measurements, process controls), which guarantee, for example, the verification of the filling of opaque containers;
- Electric current generators, which use the heat produced by radioactive decay to activate thermoelectric processes.

Industrial Gammagraphy

This is a modality of non-destructive testing that uses ionizing radiation to inspect materials and components with the objective of locating and quantifying defects and degradation in material properties that would lead to the failure of engineering structures.

Isotope	Activity
^{192}Ir, ^{60}Co, ^{137}Cs, ^{75}Se	0.1 ÷ 5 TBq

Level and Thickness Gauges

The sources are usually contained inside shielding containers of Lead or Depleted Uranium.

Isotope	Activity
^{60}Co, ^{192}Ir, ^{137}Cs, ^{241}Am	Few GBq

Figure 20. A gammagraphy device.

Figure 21. Level and thickness gauges.

Identifying radioactive sources

Radionuclide Thermoelectric Generator

Electricity generators mainly used in rural and isolated areas during the cold war by USSR and USA. Smaller generators are used since 1959 for space applications.

These devices were widely used in the former USSR as a power supply for lighthouses.

Isotope	Activity
^{90}Sr	1100 – 6600 TBq

Chemical Analysis Gas Chromatography

The external container is represented by a metal box with sides equal to a few tens of centimetres, in which the measuring system is inserted. Inside, there is the sealed source, which in turn is included inside a stainless steel container.

Isotope	Activity
^{3}H, ^{63}Ni	37 GBq @ 3H, 555 MBq @ 63Ni

Cyclotron Collimators

Beam collimators deactivated after years of usage can finish up in scrap metal long after a cyclotron has decommissioned.

Isotope	Activity
^{57}Co	Up to few MBq

Ballast for ships and aircraft

The high density and the relatively low cost of natural uranium and depleted uranium, has increased its use in various civilian areas, other than in military use (see paragraph xxx). The main risk arising from such uses is related to the dispersion due to uncontrolled abandonment and especially to the probability that the material is involved in an accident, for example following the crash of an aircraft.

Isotope	Activity
^{232}Th, ^{238}U, ^{235}U(DU)	Not known

Naturally Occurring Radioactive Materials (NORM)

Some industries related to the extraction and refining of fertilisers, handle large amounts of naturally radioactive products and also produce a considerable volume of production waste and slag containing significant percentages of radioactive elements of natural origin. Under particular conditions of accumulation, these substances may pose an undue risk to the workers involved and potentially to the environment and the population. It is often the case that a portion of pipeline from such industries is sent for recovery in a scrap metal site, thus generating an alarm.

Figure 22. Electricity generators.

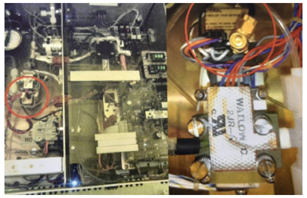


Figure 23. Gas chromatography devices.

Figure 24. A cyclotron beam collimator.

Figure 25. Examining NORM materials.

Radioactive sources in consumables

Smoke Detectors

Old home smoke contain a small amount of americium-241, a radioactive material. Smoke particles disrupt the low, steady electrical current produced by radioactive particles and trigger the detector's alarm. They react quickly to fires that give off little smoke.

Isotope	Activity
^{241}Am	37 kBq ÷ 3 MBq

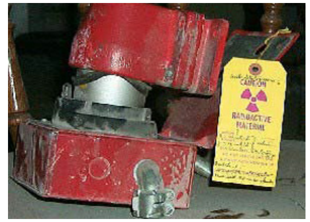


Figure 26. Smoke detector.

Lightning Preventers / Conductors

The radioactive lightning rod tips are covered with radioactive substances that ionize the surrounding air creating a plasma state and therefore a preferential way to the passage of current (less resistance) than the surrounding air, increasing the probability of discharge.

The main issue if these items are disposed in scrap metal is the contamination released throughout the load if the device is broken or smashed during transport or shredding operations.

Isotope	Activity
^{241}Am, ^{226}RA	Up to few kBq

Figure 27. Lightning rods.

Gas Mantles

During the production gas mantles are soaked in thorium nitrate becoming white hot when heated by the flame.

Isotope	Activity
^{232}Th	Up to 150 Bq

Figure 28. Gas mantles.

Valve and Vacuum Tubes

A wide variety of vacuum tubes used radioactive materials to ionize the filling gas and have instantaneous current flows when voltage is applied.

Isotope	Activity
^{3}H, ^{14}C, ^{60}Co, ^{63}Ni, ^{85}Kr, ^{137}Cs, ^{147}Pm, ^{210}Pb, ^{26}Ra, ^{232}Th	Few kBq

Identifying radioactive sources

Military devices and items

There is a large number of military equipment and instruments that, for different reasons, can be found randomly in the civil sector, especially in the market for the recovery of ferrous materials.

On-board Instrumentation

In the aeronautical field, and in older aircraft in particular, the need to make any instruments on board visible in all conditions required the use of radioactive sources to function as fluorescence activators. In general the sources are made up of fluorescent paints mixed with radioactive sources, which produce the shapes to be highlighted (letters, numbers, etc.).

Isotope	Activity
^{226}Ra, ^{3}H, ^{90}Sr	Up to few MBq

Conventional Weapons

A depleted uranium (DU) projectile of given mass has a smaller diameter than an equivalent lead projectile, with less aerodynamic drag and deeper penetration because of a higher pressure at point of impact. DU projectile ordnance is often inherently incendiary because uranium is flammable.

Because of its high density, depleted uranium can also be used in tank armour, sandwiched between sheets of steel armour plate. When a tank is decommissioned is likely that its metal is recycled and DU can easily be found in scrap metal yards.

Isotope	Activity
^{238}U	Unknown

Figure 29. Aircraft instrument and watch.

Figure 30. Ammunition.

Conversion Tables

Fractions and Multiples of Units

Multiple	Decimal Equivalent	Prefix	Symbol	Report Format
10^{6}	1,000,000	mega-	M	E+06
10^{3}	1,000	kilo-	k	E+03
10^{2}	100	hecto-	h	E+02
10	10	deka-	da	E+01
10^{-1}	0.1	deci-	d	E–01
10^{-2}	0.01	centi-	c	E–02
10^{-3}	0.001	milli-	m	E–03
10^{-6}	0.000001	micro-	µ	E–06
10^{-9}	0.000000001	nano-	n	E–09
10^{-12}	0.000000000001	pico-	p	E–12
10^{-15}	0.000000000000001	femto-	f	E–15
10^{-18}	0.000000000000000001	atto-	a	E–18

Conversion Table (Units of Radiation Measure)

Old System	International System	Conversion
Curie (Ci)	Becquerel (Bq)	1 Ci = 3.7 x 1010 Bq
Rad (radiation absorbed dose)	Gray (Gy)	1 rad = 0.01 Gy
Rem (roentgen equivalent man)	Sievert (Sv)	1 rem = 0.01 Sv

Conversion Table

Multiply	By	To Obtain
in.	2.54	cm
ft	0.305	mm
mi	1.61	km
lb	0.4536	kg
liq qt–U.S.	0.946	L
ft^2	0.093	m^2
mi^2	2.59	km^2
ft^3	0.028	m^3
d/m	0.450	pCi
pCi	10^{-6}	µCi
pCi/L (water)	10^{-9}	µCi/mL (water)
pCi/m^3 (air)	10^{-12}	µCi/mL (air)

Multiply	By	To Obtain
cm	0.394	in.
mm	3.28	ft
km	0.621	mi
kg	2.205	lb
L	1.057	liq qt–U.S.
m^2	10.764	ft^2
km^2	0.386	mi^2
m^3	35.31	ft^3
pCi	2.22	d/m
µCi	10^{6}	pCi
µCi/mL (water)	10^{9}	pCi/L (water)
µCi/mL (air)	10^{12}	pCi/m^3 (air)

How we can help

The Southern Scientific team can assist with your questions and queries about portal and detector placement to ensure total coverage of smelting, scrap and other industrial recycling sites. From site entrance portals for vehicles to reject contaminated loads before they are accepted to conveyor or grapple detector options we can provide a solution to maximise efficiency whilst reducing risk.

Contact our team for a free consultation appointment.

References

[1] IAEA SAFETY STANDARDS 'Control of Orphan Sources and Other Radioactive Material in the Metal Recycling and Production Industries', Specific Safety Guide SSG-17.

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[4] Santi Sparta' 'Atlante delle sorgenti radioattive in disuso e edelle sorgenti orfane, Dallo smaltomento incotrollato al terrorismo nucleare', Campoverde.

[5] IAEA TECHNICAL REPORT SERIES 114 'Decommissioning of small medical industrial and research facilities'.

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