GOV/2000/34-GC(44)/7
Attachment 3
Annex

Categorization of Radiation Sources

10 JULY 2000

CONTENTS

INTRODUCTION

BACKGROUND

On 25 September 1998, in resolution GC(42)/RES/12, the General Conference - inter alia - welcomed a Secretariat report on the International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials held in Dijon, France, from 14 to 18 September 1998, noted with interest the major findings of the Conference, encouraged all governments

> *"to take steps to ensure the existence within their territories of effective national systems of control for ensuring the safety of radiation sources and the security of radioactive materials"*, requested the Secretariat *"to prepare for the consideration of the Board of Governors a report on (i) how national systems for ensuring the safety of radiation sources and the security of radioactive materials can be operated at a high level of effectiveness and (ii) whether international undertakings concerned with the effective operation of such systems and attracting broad adherence could be formulated"*

and requested the Director General to report to it at its next (1999) regular session on the implementation of that resolution.

The Secretariat submitted to the Board of Governors at its meeting in March, 1999, a report with a number of proposed actions. One proposed action was a request to the Secretariat to prepare an action plan that took account of the conclusions and recommendations in and the Board's discussion of the report. The report of the Chairman stated that

> *"...there had been general support for the conclusions and recommendations in the ... report prepared on the basis of advice from a group of experts ... and noted that the action plan would come before the Board before being transmitted to the General Conference"*.

The Board of Governors at its meeting on 20 to 24 September, 1999, approved the Action Plan and requested the Secretariat to implement it. The General Conference, which took place from 27 September to 1 October 1999, endorsed the decision of the Board and urged the Secretariat to implement it.

The Action Plan contains a number of activities. One of the activities identified is the need for a system of source categorization.

The action on categorization of sources is given high priority because it is a prerequisite for other actions of the plan. Such a categorization is seen as necessary in view of the wide variety of uses of radiation sources and radioactive materials so that the controls to be applied will be commensurate with the radiological risks that the sources and materials present. Of particular concern are those radiation sources containing substantial levels of radioactivity which have the potential for causing significant harm to persons in the short term. Consideration may also need to be given to the potential for contamination.

OBJECTIVES

The objective is to develop a categorization scheme for radiation sources that could be relevant to decisions both in a retrospective application to bring sources under control and in a prospective sense to guide the application of the regulatory infrastructure. The Action Plan envisages that the preparation of guidance on national strategies and programmes for the detection and location of orphan sources and their subsequent management should commence after the categorization of sources has been carried out. In the prospective application of the system of notification, registration, and licensing, the categorization is relevant to prioritize a regulatory authority's resources and training activities; to guide the degree of detail necessary for a safety assessment; and to serve as a measure of the intensity of effort which a regulatory authority should apply to the safety and security of a particular type of source.

Issues of safety and security for radiation sources may arise during each stage of the life of a source, including, for example, manufacture, supply, transport, use, storage, transfer, repair, and decommissioning or disposal. The categorization scheme for sources is based on a number of factors including the potential for causing serious injury or contamination and the probability of such accidents occurring. The categorization scheme would also be relevant to any future international databases of lost and found sources and of incidents and accidents involving radiation sources.

SCOPE

This report is concerned with radioactive sources that may be used in industry, research and teaching, agriculture, medical practice and military applications. It is not concerned with the nuclear fuel cycle as such, although it is concerned with any uses of radioactive sources within establishments of the nuclear fuel cycle, such as industrial radiography. In addition, issues associated with the non-proliferation of nuclear materials are not taken into account in the development of this categorization scheme.

The focus of this report is upon sealed sources containing radioactive material. Other radiation sources, including unsealed uses of radioactive material and radiation producing equipment such as x-ray machines and particle accelerators, may also induce radiation injury, but are not included in this categorization. Consumer products and other exempted devices have not been included due to the small quantities of radioactive material involved.

All sources, however, exhibit radiological and practice attributes, many of which are similar to the attributes described in this document on sealed sources. Thus, *all* sources need to be managed and maintained safely and securely, to prevent theft or damage and to prevent any unauthorized person from obtaining or misusing them. The methods used to develop the categorization of sealed sources are easily extended to other types of sources in order to develop a set of comprehensive and coherent regulatory structures.

RATIONALE FOR THE CATEGORIZATION OF SOURCES

Sources containing radioactive materials are used throughout the world for a wide variety of peaceful purposes in industry, medicine, research and education, and are also used in military applications. Many uses involve sealed sources with the radioactive materials firmly contained or bound within a suitable capsule or housing.

Because of the wide variety of uses of radiation sources, some sort of categorization is necessary so that the controls that are applied are commensurate with the radiological risks the sources and materials present. Those radiation sources containing substantial levels of activity, and which have the potential for causing significant harm to individuals within a short time or widespread contamination, are of particular concern.

DESCRIPTION OF SOURCES AND USES

Teletherapy units are commonly found in medical institutions, such as hospitals or clinics. The physical dimensions of the source are relatively small, with generally a cylindrical (few cm in diameter by several cm long) shape. The source is contained inside a large shielding device. The facilities within which the unit is located are generally specifically designed and include thick shield walls and have other protective equipment, due to the high activity source strength.

Irradiator facilities are relatively few in number, and contain very high activity sources to sterilize foodstuffs, medical products and supplies, and for other specialized applications. The sources used in performing the irradiation of the material vary in physical size, some being large or others being pencil-sized, and each facility will contain many such sources.

The facilities that contain the irradiation sources are specially designed, often including thick shield walls, interlocks, and other protective equipment.

Portable industrial radiography sources and their devices are generally small in terms of physical size, although the devices are usually heavy due to the shielding contained in them. The sources themselves are very small, less than 1 cm in diameter, and only a few cm long, and are attached to specially designed cables for their proper operation. The use of radiography sources and devices are very common, and their portability may make them susceptible to theft or loss. The small size of the source allows for unauthorized removal by an individual, and such a source may be placed into a pocket of a garment. Industrial radiography may also be performed in fixed installations, either using the same small portable devices, or using larger machines which may appear to be similar to teletherapy units.

Brachytherapy applications are of two slightly different varieties. These are generally referred to as Low Dose Rate (LDR) brachytherapy and High Dose Rate (HDR) brachytherapy. Both applications use sources that may be small physically (less than 1 cm in diameter, only a few cm long), and thus are susceptible to being lost or misplaced. HDR sources, and some LDR sources, may be in the form of a long wire attached to a device (a remote afterloading device). The afterloading device may be heavy, due to the shielding for the sources when not in use, and the device may be on wheels for transport within a facility. The remote afterloading device may also contain electrical and electronic components for its operation. Brachytherapy sources are located in hospitals, clinics and similar medical institutions, and such facilities may have a large number of sources. Brachytherapy is less commonly used than teletherapy, but use of the modality is increasing.

Well logging sources and devices are generally found in areas where exploration for minerals is occurring, such as searching for coal, oil, natural gas, or similar uses. The sources are usually contained in long (1-2 m, typically) but thin (< 10 cm in diameter) devices which also contain detectors and various electronic components. The actual size of the sources inside the devices is generally small. The devices are heavy, due to the ruggedness needed for the environments in which they are to be used.

Industrial gauges are of various shapes and sizes, and are either fixed or portable. These devices are generally designed for many years of operation with little or no special tending. They may be used for control over a process, for measurement of flow, volume, density, material presence, and may be placed in locations unsuitable for continuous human presence. Consequently, they may accumulate layers of dirt, grime, grease, oil, material, etc., covering any warning labels that may have been present. Depending upon the specific application, industrial gauges may contain relatively small quantities of radioactive material, or may contain sources with activities approaching 1 TBq. The devices generally are not large, but may be located some distance from the radiation detector, which may have electrical or electronic components located within the detector. A facility may have a large number of these gauges. The locations of such devices or sources within a facility may not be recognized, since the devices may be connected to process control equipment. This lack of recognition may result in a loss of control if the facility decides to modernize or terminate operations.

Moisture/density devices are a type of industrial gauges which are small and portable. These devices contain the sources, detectors and electronic gear necessary for the measurement undertaken. The source is physically small in size, typically a few cm long by a few cm in diameter, and may be located either completely within the device or at the end of a rod/handle assembly. The small size of the device makes it susceptible to loss of control or theft.

Figure 1 presents the typical ranges of source activity for various uses of radioactive sealed sources.

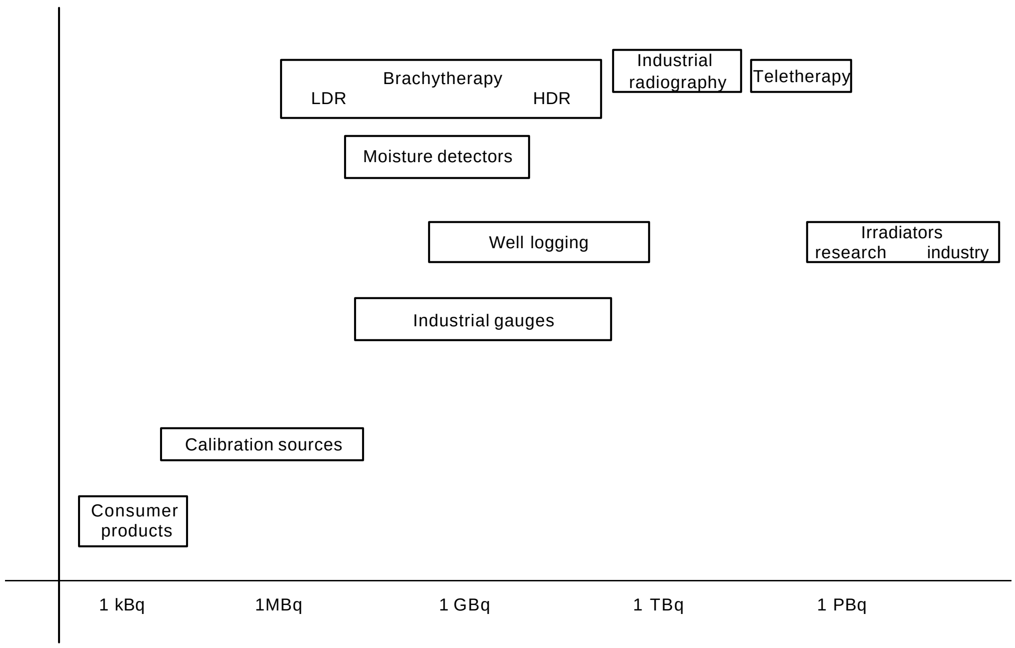

Figure 1. Activity ranges for some important applications of sealed sources

REVIEW OF ACCIDENTS

The potential for accidents as a result of loss of control of radioactive sources depends on the probability of such loss of control, the exposures that might result and the ability to detect the source after control is lost but before it causes further damage.

A part of this information could be derived from an examination of past experience of actual accidents, another part from dosimetric consideration of exposure scenarios, and a further part from known sensitivity of detection instruments.

An examination of the accidents recorded in various databases illustrates that a variety of situations can arise. Two types of situations have presented serious consequences for the regulatory authorities. First are those situations which have resulted in doses sufficient to cause deterministic effects in one or more individuals[1]. The second situation is where the individual doses resulting from the accident were not significant to cause deterministic effects, but contamination of materials, property, and individuals resulted in the need for significant actions to rectify and control the situation. An analysis of this data in the light of information available on the circumstances, causes, resulting exposure and damages produced by each accident leads to the following observations:

a) ^{192}Ir sources are the most common sources involved in accidents causing deterministic effects, followed by ^{60}Co sources. ^{137}Cs sources are the third most important but accidents involving them are significantly less probable.

b) The sources causing most accidents are industrial radiography sources and teletherapy sources. Industrial radiography sources have also contributed more than teletherapy sources in the number of accidents. Although industrial radiography accidents are more frequent, medical teletherapy sources cause a greater fraction of the reported deaths of exposed people, since teletherapy sources contain larger amounts of radioactivity and expose greater numbers of people.

c) For the main contributor to loss of control accidents (industrial radiography sources) the causes of the accidents are 75% operator errors or failure to follow procedures and 25% equipment errors.

d) Military sources also can cause injury[2] or death, but the number of cases is not as high as events in the commercial area.

e) Radium-226 is still used in medical and non-medical applications in some countries. It has contributed minimally to accidents. In medical applications, losses dominate the accidents (90%), with theft accounting for the remaining 10%. In non-medical applications (accounting for less than 10% of the radium accidents) losses and theft are equally probable (50% each).

f) Many additional accidents result in lower individual doses but significant property damage as a result of contamination of material or equipment. This has been the case in the large number of situations where a source was inadvertently melted in the recycling of scrap for new metal. Depending on the type of source, this has resulted in contamination of the metal product or the by-products of the metal-making process, or of the dust collection system associated with the melting process, or the release of material to the environment.

In each of the above cases, the principal initiating event was the loss of control over a source, and its movement into the public domain where it was not recognized as a source. It

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[1] A whole body dose in excess of 0.25 Gy is used to define such accidents.
[2] Cf., the incident in Tbilisi, Georgia,1997, "The Radiological Accident in Tbilisi," IAEA, Vienna, 1999

should be noted that some accidents occurred despite the presence of an ISO radiation symbol on the radioactive device, thus indicating that the ISO trefoil is generally not perceived as a hazard warning. Additional warning statements are almost always needed to increase the likelihood that a radioactive source or device will be recognized. In many situations, damage may be limited and additional damage prevented by prompt location, identification and control of the source.

Although adequately sensitive instrumentation is often available, the presence of radiation shielding significantly reduces the radiation intensity, and hence the possibility that the source will be detected. Similarly, the presence of other material, such as what would be found in a shipment of metal intended to be recycled, also reduces the radiation level, and challenges the ability of instrumentation to detect a radioactive source. Some types of radioactive sources, such as pure alpha emitters, cannot be detected unless the instrument is very close to the source, and could escape detection entirely.

It should be noted, however, that the ability to detect a source presumes that one has knowledge of its approximate location and that the radiation source is not shielded, either by a protective housing or other intervening material. It also assumes that the source is reasonably intact and that there is no wide-spread contamination. IAEA-TECDOC-804, "Methods to identify and locate spent radiation sources (July, 1995)" provides additional guidance.

EXPOSURE SCENARIOS

From the review of accidents presented above, it is clear that there are a number of different situations which can lead to the loss of control of sources and a number of different event scenarios which may result in radiation exposures occurring. The following are three generic exposure scenarios involving radiation injury to an individual which are typical of many situations. These generic scenarios may be used to estimate potential radiation exposures which may occur if control of sources is lost. Other scenarios which do not involve radiation injury but can have great economic, social or political consequences may also occur.

The generic radiation injury scenarios are, as follows:

1. External exposure to an individual from a source in very close proximity
2. External exposure from unshielded source (involving several individuals)
3. Exposures following rupture of source casing

A detailed description of each scenario is presented below:

External exposure to an individual from a source in very close proximity. One scenario that has occurred a number of times is that an individual has put a radiation source into a pocket. This may be for a number of reasons, including theft, interest in an unknown object or ease of transfer to another location. The individual involved may be another worker at the facility or may be a member of the public. In either case, that individual would not recognize the typical size or appearance of a radiation source, but see a small, shiny metallic object, and perceive that this object has some value. For this generic scenario it is assumed that the source is picked up and put in a pocket[3] and carried.

External exposure from unshielded source (involving several individuals). It is possible that once control of a source has been lost, it may irradiate workers or members of the public without the knowledge of those involved. This scenario may occur, for example, if faulty equipment is left in a facility or a stolen, spent or disused source is present in a house or other location. In a recent situation, the source was removed from its shielding and left in a room or area where other individuals work, resulting in significant doses to several persons.

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[3] The following exposure rates are provided for a 37 GBq (1 Ci) source: ^{137}Cs - ~5 Gy per minute @ contact; ^{60}Co: ~20 Gy/min @ contact; ^{192}Ir: ~8 Gy/min @ contact; ^{226}Ra: ~13 Gy/min @ contact.

Exposures following rupture of source casing. If a source which is not controlled becomes ruptured, it may then result in contamination of equipment or individuals, exposures from inhalation of radioactive material, inadvertent ingestion of radioactive material, contamination of the skin and external exposure from the spillage.

These three generic exposure scenarios were developed from actual incidents. For example, the external exposure to a single individual from an unshielded source occurred in Georgia in 1997, and in Peru in 1999. The exposure of multiple individuals from an unshielded source occurred in Estonia[4] in 1994, in Algeria in 1978, in Mexico City in 1962, in China in 1996, in Turkey in 1998, in Thailand in 2000, and in Egypt in 2000. Several of those incidents resulted in the deaths of members of the public. The exposure following the rupture of a source occurred in Juarez, Mexico, in 1983, and in Goiania, Brazil, in 1987[5].

In addition to incidents where radiation injury occurred, other events can also occur. In the absence of adequate regulatory control, devices containing radioactive sources may be discarded with other scrap from a facility, or may be stolen from an abandoned or unused facility and either enter the recycling stream or enter the public domain. In either case, the possibility of radiation exposure from the device itself, or of potential contamination from breaching the encapsulation of a radiation source, may cause radiation injury to individuals or radioactive contamination of individuals and the environment.

A source may be accidentally melted if a device containing radioactive materials were introduced into the scrap metal intended for recycling, following, for example, loss or theft of a device. The resulting potential exposures will depend upon the partitioning of the

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Assuming a threshold erythema dose of 3 Gy, exposure time is thus ~ 35 sec for 37 GBq of ^{137}Cs, ~12 seconds for ^{60}Co, ~25 sec for ^{192}Ir and ~15 sec for ^{226}Ra.

[4] "The Radiological Accident in Tammiku," IAEA, Vienna, 1998

[5] "The Radiological Accident in Goiania," IAEA, Vienna, 1988

radionuclide into the product or to the various waste streams (i.e., the furnace gases and slags or drosses) generated in the recycling process.

The implications of this scenario of melting a radioactive source in a metal manufacturing facility may be less in terms of doses to individuals than those for the three scenarios discussed above, but the financial implications for the metal manufacturing company may be considerable as a result of contamination of equipment, products and by-products. Once the incident is discovered, any clean up activity will also result in exposures to workers remediating the facility, and necessitate effective radioactive waste management. There may be significant social, political, and economic consequences associated with the return to normality of the affected facility and its local environment. There may also be considerable media interest in the event.

SOURCE ATTRIBUTES

Ranking radiation sources on the basis of their radioactivity content is not sufficient to classify the threat or hazard posed by their presence or use. Other attributes relative to the construction and use of the source need to be considered. For purposes of developing a source categorization, two broad groups were identified. These were attributes related to the *properties* of the source being used, and attributes related to the *use* of the source in a particular practice. In relation to the properties of the source, the radiological properties and the form of the material serve as groups for consideration. In relation to the use of the source in a practice, the characteristics of the practice or use activity, the exposure scenarios that may arise, the accident history, and the considerations present at end of life serve as useful attributes for consideration. An effective categorization will take into account a number of attributes of the source, device and application, although rarely will one attribute be the single determining factor. The following is an expansion of each of the groups of attributes.

A. Radiological Properties

The attributes considered under this heading include the types of radiation emitted, the half-life of the radioisotope, the energy of the radiation, and the source activity. Within this heading, the source activity and the half-life of the material are the properties usually considered as the most important.

The radiological properties of the material directly dictate the hazard from external and internal exposure. In general, these can be directly expressed by the gamma constant and energy for external radiation, and by the inhalation and ingestion dose conversion coefficients for internal exposure. For some radioactive materials, such as tritium, the external and internal exposure hazards are generally low. However, if the material poses significant hazards from both internal and external exposure (such as radium), it would be ranked higher than for radioactive material which contributes significantly in only one method of exposure.

Source activity and the half-life are a critical set of attributes. In general terms a higher category would be indicated for sources with a greater level of activity. The influence of the half-life is to rank radioactive materials with a longer half-life higher than those with shorter half-lives, simply due to the fact that they will present a hazard over a longer period of time.

B. Form of the material

The attributes considered under this heading include the physical and chemical form of the material in the source, whether the source is sealed or unsealed, the (chemical) toxicity of the material, and the risk of contamination posed by the source in the event of an accident. In particular, the form of the material will have an influence in the exposure scenarios in accident situations. Material that is dispersible, or in a dispersible form within a sealed source, poses a greater hazard than material that is not dispersible in situations where the source integrity is breached.

Some devices, exemplified by tritium self-luminous signs, may have a relatively high quantity of radioactive material, but the physical form of the material, coupled with its low toxicity (on the basis of either an external or internal exposure hazard) makes devices like these relatively safe.

C. The Practice or Conditions of Use

The attributes considered under this heading include the characteristics of use for the source, including whether the situation is in a fixed facility or is mobile, the type of application (e.g. industrial, medical, research or military), the design and construction of the source and equipment, the source size, the presence of other equipment such as shielding and interlocks, and operational factors such as whether the source is removed from its shielding in order to accomplish the type of use. In many instances, the key attributes within this heading are whether the device is fixed or mobile, and the operational factors associated with using the source.

Within the operational factors associated with using the source, it is recognized that a number of human factors come into play. For example, experience shows that practices where commercial or other pressures exist can create impossible targets. This may result in using inappropriate procedures, short cuts, or other arrangements which reduce the safety and security of the source or device.

The accessibility of the source is a significant influence in the operational hazards posed by the material and application. In general, sources which are moved out of, and in to, their shielding pose greater risks than sources which remain within their shielding during use. Thus, for example, radiographic and brachytherapy sources pose greater operational hazards due to source wire breakage, disconnection, and their unshielded condition than do fixed gauges. In addition, the size of the source may make it more or less prone to removal or loss. In general, small devices are more likely to be removed or misplaced than larger devices, which would be difficult to move.

Whether the device is portable or fixed influences whether other individuals might have or gain access to the device or to the radiation source. For example, teletherapy units are installed in specially designed rooms in medical institutions. Food or product irradiators are also installed in specially designed and equipped facilities to ensure the safety of the device during normal operation. High dose rate brachytherapy units, although they are movable, are designed for use in medical institutions, and are generally housed and used in rooms shielded to reduce radiation levels to areas on their outside. The sources in those latter devices, however, are designed to be moved from their shielded and safe storage location, and such movement may lead to the breakage of the cable containing the source. Devices used in well-logging are meant to be moved from location to location. Likewise, portable gauges are moved, often frequently, in order to make the needed measurements. Fixed gauges are not generally moved to locations different from the location of use unless certain maintenance or facility requirements dictate their removal.

D. Exposure Scenarios

The attributes considered under this heading include the types of exposure scenarios that are available in operation and if control is lost, the presence of stochastic or deterministic exposure outcomes, the ability to detect a source if control is lost, and the historical record of accidents with the type of source and practice. In many cases the previous history of accidents, including the outcomes of those accidents, is the principal attribute considered. This report does not concern the deliberate exposure of patients for medical purposes.

E. End of Life

The attributes considered under this heading include the disposition options which may be available for the source, the costs and availability of those options, the traceability of sources, the frequency with which there may be disused sources (sources that are no longer in use or intended to be used) or spent sources (sources which are no longer useful for their intended purpose), and the net probability that the source will be lost from the regulatory control regime. In this group, the presence of reasonable disposition options[6], and in particular whether arrangements are made for return or exchange of the sources to the manufacturer, play a key role in the hazard presented.

The availability and costs of disposition options have a strong influence on the user's willingness and ability to dispose of the source properly at the end of its use. In situations where disposition options are few, or where the costs associated with those options are high, the user is more likely to remove the source or device from use and simply store it. This has, in many situations, resulted in the gradual degradation of controls and accountability, and has led eventually to situations where the material was lost or stolen. In some cases, or some locations, there may not exist an authorized disposal location, and the source/device could become abandoned. Transportation of a source for return or disposal may also be difficult to arrange and be costly, and the user may store the source or device or try to transfer it to another person without sufficient or adequate approval from the regulatory authority. Storage of a device presents a situation where continuing oversight may be reduced, resulting in an increased likelihood of intrusion, and the possibility of loss of control. A fixed gauge may have been in industrial use, and labels and warning signs may have become obscured or obliterated due to their proximal environment in the facility. In such cases, accountability may be lost, and the device may be disposed as scrap for recycling. The introduction of a radioactive device into the recycling stream could lead to radiation exposure or contamination of the recycling facilities, their workers, and the

[6] Disposition includes return of source/device to vendor; transfer for use by another authorized recipient; reuse upon device refurbishment; as well as the intentional burial of a source/device in a regulated radioactive waste disposal facility.

potential contamination of new products and by-products of the recycling process.

CATEGORIES

The source attributes can be considered in a matrix type of arrangement to determine general categories of sources and uses. For purposes of a general categorization, the source attributes were ranked according to the potential harm the sources may cause. The resulting categories are as follows:

Category 1.	Industrial Radiography
	Teletherapy
	Irradiators
Category 2.	HDR Brachytherapy
	Fixed industrial gauges involving high activity sources
	Well Logging
	LDR Brachytherapy
Category 3.	Fixed industrial gauges involving lower activity sources

The categorization scheme represented above does not rank practices within a category. Practices within each category were broadly considered to be of equivalent hazard to warrant sufficient and appropriate regulatory control.

The use of unsealed radioactive materials, for any purpose, was excluded from consideration in this report. The Regulatory Authority should apply the principles developed here in this categorization scheme when performing its assessment of the practice, and the need for appropriate regulatory control over the radioactive materials.

Table 1 presents a more detailed description of types of sealed sources and uses, including the typical amounts of material.

CONTROL MEASURES FOR SOURCES IN EACH CATEGORY

The general categorization of sources provides an indication of the priority which a regulatory authority should attach to establishing a regulatory infrastructure and bringing sources under regulatory control. In this situation, where sources are already present, the first priority would be to locate and bring under appropriate controls those sources and devices that are in Category 1. Following this would be efforts to capture those sources in Category 2, and so forth until control had been established over all sources.

The responsibilities of principal parties[7] include developing and implementing a protection and safety programme commensurate with the nature and extent of the risks associated with the practices and interventions under their responsibility. One of the technical requirements of the principal party is to maintain security of sources so that theft or damage or actions by unauthorized legal persons is prevented[8]. The legal person responsible for the radiation source shall have an authorization from the appropriate Regulatory Authority. This authorization may take the form of either a registration or a license. Practices that are amenable to registration include those for which (a) safety can largely be ensured by the design of the facilities and equipment; (b) the operating procedures are simple to follow; (c) the safety training requirements are minimal; and (d) there is a history of few problems with

[7] "International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources," Safety Series No. 115, IAEA, Vienna, 1996. Principal Requirements 1.6

[8] "International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources," Safety Series No. 115, IAEA, Vienna, 1996. Principal Requirements 2. 34

safety in operations[9]. These will generally be sources which are in Category 3, although some types of sources within this category may also be appropriate for licensing.

The (draft) IAEA safety guides on regulatory infrastructures, the safety of sources, and the security of sources provide guidance for implementing the requirements of the Basic Safety Standards. These provide protocols for appropriate notification, registration, licensing, and inspection for uses of radioactive materials. The Code of Conduct presents the basic expectations for implementing the Basic Safety Standards and for interactions between member states of the IAEA.

When a Regulatory Authority is faced with decisions regarding the application of the regulatory infrastructure to a particular source, this source categorization may serve as an indication of the level of intensity and detail that needs to be applied to have confidence that safety and security is being respected. Regulatory Authorities should consider each of the headings of source attributes in determining the hazards presented by a given source, and the level of detail needed to assure proper implementation of the regulatory infrastructure. In some cases, the Regulatory Authority may wish to consider additional measures to assure itself of appropriate safety and security until experience is gained with new types of activities being authorized for the first time. In addition, the frequency and level of detail utilized in inspection of the practices can be considered on the basis of the source categorization.

For sources and devices in Category 1, it would be expected that Regulatory Authorities would expect a great level of detail in the information submitted for the authorization for use. Sources in this category present significant hazards which require examination of the conditions of use, the construction and operation of the facility, the training and competence of users, and the control mechanisms that the user will apply to assure safety and security.

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[9] "International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources," Safety Series No. 115, IAEA, Vienna, 1996. Principal Requirements 2.11 [footnote]

In general, a detailed safety assessment would be expected to support the authorization of the source or device, and also of the facility when the use is in a fixed location.

For sources and devices in Category 2, the level of intensity applied to the review and assessment of an application for authorization might be somewhat less than that expected for Category 1. Sources in Category 2 may present significant hazards which will require examination, and the Regulatory Authority needs to be aware of issues such as patient protection which have not been considered in this Categorization. Although the quantities of radioactive material may be lower for sources in Category 2, other source attributes, such as portability and accessibility will remain critical, including the potential loss of accountability and presence of reasonable options for the disposition of disused or spent sources.

Sources and devices in Category 3 will require less effort on the part of the Regulatory Authority. In many cases, safety and security during operations is a function of the device construction, and a detailed review of a particular application for use will not be needed. However, the Regulatory Authority will need to remain mindful of end of life issues where there may be the potential for a loss of regulatory control if accountability is not maintained.

Table 1.

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

Category 1

Practice or application	Radionuclide	Decay energy [keV] half-life	Typical activity	Dose rate at 1m[a,b,c] [mSv/h]	Time at 1m[a,b,c] to exceed 1mSv
Teletherapy	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	50-1000 TBq	3.E+05	< 1 s
	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	500 TBq	3.E+04	< 1 s
Blood irradiation	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	2-100 TBq	6.E+03	< 1 s
Industrial Radiography	Ir-192	γ (317) β (max.: 675) e (303) $T_{1/2}$ = 74 d	0.1-5 TBq	4.E+02	9 s
	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	0.1-5 TBq	1.E+03	3 s
	(Cs-137) (rare)	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y			
	(Tm-170) (rare)	γ (84) β (max.: 968) $T_{1/2}$ = 129 d			
Sterilization and food preservation (Irradiators)	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	0.1 - 400 PBq	1.E+08	< 1 s
	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	0.1 - 400 PBq	2.E+07	< 1 s
Other Irradiators	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	1-1000 TBq	3.E+05	< 1 s
	(Cs-137) (rare)	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y			< 1 s

Category 2

Practice or application	Radionuclide	Decay energy [keV] half-life	Typical activity	Dose rate at 1m[a,b,c] [mSv/h]	Time at 1m[a,b,c] to exceed 1mSv
High Dose Rate Remote afterloading brachytherapy	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	≈ 10 GBq	3.E+00	20 min
	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	0.03-10 MBq	6.E-04	70 d
	Ir-192	γ (317) β (max.: 675) e (303) $T_{1/2}$ = 74 d	≈ 400 GBq	3.E+01	2 min
Low Dose Rate brachytherapy (manual or remote)	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	50-500 MBq	3.E-02	30 h
	Ra-226	γ (186) α (4784) $T_{1/2}$ = 1600 y	30-300 MBq	2.E-04	200 d
	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	50-500 MBq	1.E-01	8 h
	Sr-90	β (max.: 196) $T_{1/2}$ = 29 y	50-1500 MBq	0	N/A
	Pd-103	X (20) $T_{1/2}$ = 17 d	50-1500 MBq	0	N/A
Well logging	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	1-100 GBq	6.E+00	10 s
	Am-241/Be	γ (60) α (5486) neutrons $T_{1/2}$ = 432.2 y	1-800 GBq	2.E+00	20 s
	(Cf-252)	α (6118) X (15) $T_{1/2}$ = 2.6 y	50 GBq	6.E-04	70 d
Level gauge Thickness gauge Conveyor gauge	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	10 GBq-1TBq	6.0 E +01	1 min
	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	1-10 GBq	3.E+00	20 min
	Am-241	γ (60) α (5486) $T_{1/2}$ = 432.2 y	10-40 GBq	1.E-02	3 d
Moisture/density detector (portable, mobile units)	Am-241/Be	γ (60) α (5486) neutrons $T_{1/2}$ = 432.2 y	0.1-2 GBq	6.E-03	7 d

Practice or application	Radionuclide	Decay energy [keV] half-life	Typical activity	Dose rate at 1m[a,b,c] [mSv/h]	Time at 1m[a,b,c] to exceed 1mSv
	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	to 400 MBq	2.E-02	2 d
	Ra-226/Be	γ (60) α (5486) neutrons $T_{1/2}$ = 1600 y	~1500 MBq		
	(Cf-252)	α (6118) X (15) $T_{1/2}$ = 2.6 y	3GBq	6.E-04	70 d

Category 3

Practice or application	Radionuclide	Decay energy [keV] half-life	Typical activity	Dose rate at 1m[a,b,c] [mSv/h]	Time at 1m[a,b,c] to exceed 1mSv
Level gauge[d] Density gauge[d]	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	0.1-20 GBq	1.E+00	50 min
	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	0.1-1 GBq	3.E+00	20 min
Thickness gauge[d]	Kr-85	β (max.: 687) $T_{1/2}$ = 10.8 y	0.1-50 GBq	1.E-02	4 d
	Am-241	γ (60) α (5486) $T_{1/2}$ = 432.2 y	1-10 GBq	1.E-02	3 d
	Sr-90	β (max.: 546) $T_{1/2}$ = 29 y	0.1-4 GBq	0	
	Tl-204	γ (69) β (max.: 763) $T_{1/2}$ = 3.8 y	40 GBq	4.E-03	10 d

Notes:

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

b Bremsstrahlung radiation was not taken into account.

c Times were calculated assuming total loss of shielding.

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