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Retrieval, Restoration and Maintenance of Old Radioactive Waste Inventory Records

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FOREWORD

A records management system constitutes an important and integral component of a radioactive waste management programme and it is normally developed and implemented at the earliest stage of waste generation. The IAEA has identified the importance of a reliable and internationally acceptable records management system and, in particular, the need to ensure that information associated with long-term storage and disposal facilities is preserved in accordance with appropriate quality management requirements for future generations. However, there are many cases, for both existing storage and disposal facilities, where the records are either missing or inadequate. Based on input from various Member States, it appears that this is a recurring problem encountered in their waste management programmes.

A specific area of concern is the safety of some of the existing disposal facilities for low and intermediate level waste established around the world in the 1950s to early 1960s, long before current regulatory, safety and quality management requirements, as well as more recent disposal technologies, took effect. In many of these near surface facilities, long lived and/or high-activity disused radioactive sources were disposed of along with other institutional waste.

A recently established binding international regime on radioactive waste management The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management makes specific reference to the need for enhancing safety of existing waste management facilities and to reporting on the inventories of radioactive waste either in storage or already disposed of. In response to the recommendations made in the above-referenced Joint Convention, many Member States are either planning or have already implemented upgrading measures at a number of existing waste management facilities. An issue of particular importance, directly related to the upgrading of these facilities, is the retrieval and restoration of the historical waste inventory records. The loss or inadequacy of waste inventory records is a recurring problem for many of the existing facilities, in particular for the facilities, established in the 1950s to early 1960s, where the intent for future retrieval of the waste was not clearly defined or specified.

The availability of and accessibility to a set of complete records on the contents of a storage or a disposal facility, in particular its waste inventory, is a pre-requisite for establishing the safety of any waste management facility or for planning or implementing an upgrading programme. As a result of various upgrading programmes implemented at a number of storage and disposal facilities in many Member States, some valuable experience has been gained and relevant information is now available on actions and procedures that may be employed for the retrieval and restoration of waste inventory records for existing storage and disposal facilities. This publication draws on such international experience.

It is in this context that this report was developed to provide generic guidance to Member States on developing a methodology for the retrieval, assessment, verification and restoration of waste inventory records for waste management facilities where the records are either lost or inadequate. The subsequent transfer of the revised and improved inventory records into a reliable and internationally acceptable records management system is another important issue that is addressed in this report.

It is anticipated that this publication will be useful to regulators and managers of waste management facilities directly involved in the retrieval and restoration of waste inventory records for facilities where the records are either lost or inadequate, and also to others who need a revised and adequate waste inventory to carry out safety re-assessments and/or undertake upgrading programmes on such facilities.

The report was developed with the help of consultants and through a technical meeting in Vienna, June 2005. The IAEA officer responsible for this publication was A. Kahraman of the Division of Nuclear Fuel Cycle and Waste Technology.

CONTENTS

1. INTRODUCTION

1.1. Summary

This TECDOC was developed to provide guidance on a methodology to retrieve, assess, verify and restore the historical radioactive waste inventory records for those storage and disposal facilities where adequate records are not available. The document presents a comprehensive assessment on waste inventory records system. A variety of circumstances that may require the records to be re-assessed or retrieved is discussed. The role of a quality management system (QMS), which may impose corrective actions, including revision of waste records as part of an overall facility upgrading programme is introduced.

The general guidance provided on the waste inventory data retrieval process integrates, in a systematic way, various methods and technical issues, including conversion of old activity and radiation units, and prioritization of data retrieval activities. These technical and methodological issues have been introduced in this publication based on the experience gained and approaches employed in some Member States, as part of the overall upgrading programme at their storage or disposal facilities.

The implementation of the waste inventory data retrieval process will vary depending on the specific situation in each country, but the basic approach described in this publication will be applicable for those facilities where the loss or inadequacy of inventory records are observed.

The discussions and information given by this document cover both unconditioned and conditioned low and intermediate level radioactive waste and waste packages, including disused sealed sources.

It is anticipated that the methodology presented in this publication will be useful to operators, regulatory bodies and others who are planning to restore and verify waste inventory records, according to the international recommendations, conventions and experience as well as to national regulatory requirements.

1.2. Background

A specific area of radioactive waste management of current concern that requires special attention is the safety of some of the existing near surface repositories established around the world in the 1950s to early 1960s, long before international consensus for their safety had emerged [1]. Although having operated safely for more than 40 to 50 years, some of these facilities, either closed or still in operation, are now considered to be unsuitable for certain types of waste, including some categories of disused sealed radioactive source(s) (disused SRS) [2-7]. An issue of particular concern is that, in many of these facilities, long lived and/or high-activity disused SRS were disposed of separately or together with other institutional waste. This obviously poses a serious health hazard for hundreds and thousands of years because the residual activity of the disused SRS is likely to be still quite high at the end of the institutional control period [8-13]. Various Member States have ongoing programmes both to upgrade these facilities and/or to develop new near surface disposal facilities [2].

Recently, a binding international regime for radioactive waste management was established through Article 12 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [14]. This Article states that, “each contracting party shall in due course take the appropriate steps to review the results of past practices in order to determine whether any intervention is needed for reasons of radiation protection”. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management makes specific reference to the need for enhancing safety of existing waste management facilities (Article 12), safe management of disused SRS (Article 28) and to reporting on the inventories of radioactive waste that is either currently in storage or has been disposed of (Article 32). It is anticipated that the implementation of the Joint Convention is likely to result in safety re-assessments of certain repositories and that corrective actions, including retrieval and restoration of historical waste inventory records, will be pursued.

The IAEA Safety Standards on near surface disposal [15-18] and the ICRP recommendations, as applied to the disposal of long lived radioactive waste [19], have been elaborated as more experience with radioactive waste management has been gained. On this basis, it is recommended that national authorities review the safety of operational and closed repositories to decide whether specific upgrading measures are required to improve their performance and safety. Planning and implementation of a repository upgrading programme would require information on the contents of the repository, specifically adequate waste inventory records.

A QMS also plays an important role in the development, management and operation of disposal facilities for low and intermediate level radioactive waste [20–21]. The programmes for establishing a QMS can vary from country to country, and have undergone substantial changes in recent years, reflecting increased adoption of ISO 9000 and 14000 standards [20]. The QMS components generally include controls for management organization, design, procurement, procedures and processes, documentation and record management system, inventory, inspections, tests, equipment calibration, improvements in the event of non-conformance, and audits. The effective application of a QMS at every stage of repository development and operation is essential to providing assurance that the requirements and objectives for repository performance and safety, as well as environmental and quality goals, will be complied with. It should be mentioned that some of the existing waste management facilities were initially planned, sited, designed, constructed, operated and closed (in many cases) without a formal quality management plan in place. The application of improved QMS principles and requirements to existing storage and disposal facilities may indicate a series of deficiencies, requiring a variety of corrective actions, including retrieval and revision of waste inventory records as part of the overall repository upgrading programme [2], [6].

A number of existing waste management facilities has already been upgraded to improve their performance and safety [2], [6]. Irrespective of the nature and extent of the upgrading measures implemented at these facilities, it is important to recognize that the availability of adequate waste inventory records is a pre-requisite for any corrective action(s) to be planned or implemented, thus making the retrieval of waste inventory records, if not available or adequate, an essential and high-priority component of the facility upgrading programme. Furthermore, to comply with current regulatory and QMS requirements and to ensure that disposal and storage operations are allowed to continue at some of the problematic facilities, it is important that a modern waste inventory records-keeping system is developed and implemented, taking into account the entire life cycle of the facility from the initial planning phase to the final post-closure phase.

Waste inventory records for the disposal facilities established in the 1950s to early 1960s reflect regulatory requirements and methods of records keeping at that time, such as hand-written records, as well as inappropriate conditions for long term storage of records. Some previous studies have shown that, for some facilities, a number of the records were lost due to fires and other accidents; some records were subject to transcription and typographical errors. The absence or inadequacy of waste inventory records makes the issue of restoring records and transferring them to a modern records management system a rather complex and cumbersome task, if at all practical. In cases, when data restoration and verification using administrative methods are not feasible, or available records are not adequate, the actual retrieval of the waste or waste packages may need to be undertaken to generate relevant data on the waste inventory.

It is important to mention here that, while many repositories have encountered problems with regard to loss or inadequacy of records, there are many other facilities where the waste inventory records are satisfactory and adequate.

Given this background, the main thrust of this report is to establish a generic methodology for the retrieval, restoration, assessment and verification of waste inventory records, especially for many of the existing facilities where the available records are inadequate. In the context of this publication, this activity has been termed as “retrieval of waste inventory records”. Transferring revised waste inventory records into a modern records-keeping system requires thorough knowledge and awareness of the requirements for the maintenance of records for long term usage [22-25]. This is another important issue that is addressed in this report.

According to IAEA terminology [26], waste inventory is defined as “quantity, radionuclides, activity and waste form characteristics”. In this publication, the emphasis is on the radiological properties of the waste inventory. However, other information relating to the waste and/or the storage or disposal facility may be required to carry out safety re-assessments or planning upgrading measures, in general.

1.3. Objectives

The main objective of this publication is to provide generic guidance on developing a methodology for the retrieval, assessment, verification and restoration of waste inventory records for some of the existing storage or disposal facilities where the inventory records are either lost or inadequate.

The primary audience of this publication are the operators of storage or disposal facilities, where the existing waste inventory records need restoration and revision to develop an improved waste inventory, which can then be used for the safety re-assessments of the facility or for undertaking any corrective action(s), planned in response to the recommendations of the Joint Convention [14] and/or national regulatory requirements. In addition, it is anticipated that the information presented in this publication will be useful to regulatory bodies and others who are planning to restore and verify waste inventory records for such storage or disposal facilities.

The publication is also expected to assist the IAEA experts on their technical missions to Member States in advising the various regulatory bodies and operational staff in related repository issues and waste inventory records management.

1.4. Scope

In the context of this publication, the terms “disposal facility” or “repository” refer to those facilities defined as such in the IAEA Radioactive Waste Management Glossary [26], and facilities that may have been designated as storage facilities but where the intent for future retrieval of the waste was not clearly established or specified. In this report, the terms "older" or "earlier" disposal facilities or repositories are used interchangeably and frequently to refer to those facilities, either still in operation or closed, which were established in the 1950s to early 1960s. In addition, the scope of the report also covers interim storage facilities where the waste is in a storage mode, awaiting further processing for disposal.

This publication discusses a methodology for the retrieval, assessment and verification of waste inventory records for facilities where the available waste inventory records are inadequate. The publication covers both unconditioned and conditioned low and intermediate level waste and waste packages, including disused SRS. Issues dealing with uranium mining and milling waste are beyond the scope of this publication. Similarly, this publication does not address waste inventory issues related to the remediation of contaminated sites, or facilities designed specifically for discharge of radioactive effluents.

Specific technical issues related to the upgrading of disposal facilities, such as application of specific corrective actions, waste characterization procedures, technologies and methodologies for retrieval and repackaging of the retrieved waste, are beyond the scope of this publication. These topics are covered in companion IAEA publications [2–3].

1.5. Structure

Section 2 presents, in the context of a waste inventory records system, some problems encountered in the waste inventory records for many of the existing storage and/or disposal facilities, the need for improved waste inventory records and considerations for the development and maintenance of a modern records management system.

Section 3 describes a methodology for the retrieval, assessment and verification of historical waste inventory records, including a discussion of an approach to data retrieval, prioritization of data retrieval steps, assessment of the reliability of the retrieved records, implementation of data retrieval and assessment methodology, and data verification and validation.

Section 4 contains the conclusions of the report.

2. WASTE INVENTORY RECORDS SYSTEM

Records are defined [26] as “a set of documents, such as instrument charts, certificates, logbooks, computer printouts and magnetic tapes for each nuclear facility, organized in such a way that it provides past and present representations of facility operations and activities, including all phases from design through closure and decommissioning (if the facility has been decommissioned)”. Records management and control are an integral part of a QMS programme, which in turn is an essential component of the development and operation of any waste management facility.

As discussed in the previous section, many of the earlier disposal facilities were established in the period from the 1950s to early 1960s. Some of these facilities are still in operation and some have already been shut down. Consequently, various kinds of records management have been practised. For a given disposal facility, the actual logistics of generation, collection and interim storage of record files are normally determined through arrangements among the various parties involved in the process. These are discussed in detail in a recent IAEA publication [24].

An important issue directly relevant to the retrieval and revision of waste inventory records is to identify any changes or substitutions in radiation and measurement units over time. Currently, establishing and managing waste inventory records systems for disposal facilities is an important regulatory requirement. Accordingly, a set of records must be available, covering the entire life cycle of the facility. Detailed records of waste transported to a repository, received and subsequently disposed of, together with all relevant records of operational procedures, must be documented and readily available, when needed. The site characteristics and as-built facility features are as important as the characteristics of the waste inventory.

The requirement for an adequate waste inventory records system is supported by a good scientific and technical basis and is currently being implemented in many Member States. Considerations for establishing and maintenance of such a system are discussed in this Section of the report. Detailed information about the structure and contents of a modern waste inventory records management system can be found in IAEA publications [9], [22–25].

2.1. Problems with historical waste inventory records

The experience with the management of records for many of the earlier repositories, especially during their initial operational periods, is quite varied. The problems with historical waste inventory records arise for a number of reasons. Some problems, perhaps the minor ones, are associated e.g. with the application of the old radiation units. More serious problems arise from changes with time of measurement equipment and methods. Such changes make it sometimes difficult, if at all possible, to compare some of the original waste inventory data, which were based, e.g. on the total alpha or beta activity, with more recent detailed data, based, e.g. on the measurement of individual nuclides. Another problem is the loss of data accessibility, attributable to recent advances in information technology related to storage of information on electronic media and/or discarding old (original) records.

The major problems stem, however, from inadequacy of past regulatory infrastructure and from organizational changes related to radioactive waste management in many Member States. Because of regulatory deficiencies, many of the earlier repositories started their operations with no or inadequate QMS and inadequate requirements for developing and maintaining a proper waste inventory records system.

Inadequacy of waste inventory records is a recurring problem for many of the earlier disposal facilities, in particular for some facilities in the USA and countries of the former USSR. As part of repository upgrading activities in some Member States, for example France, United Kingdom, Norway, the USA and some countries of the former USSR and Eastern Europe [2], [6], the repository operators have been able to restore the waste inventory records, focusing on radionuclide inventory, using the methodology based on both archive searches and application of advanced waste characterization technologies.

The changes that have evolved over time in the waste management organizational structure in some Member States have contributed to loss and misplacement of information related to waste inventory records. Some of the organizational changes include:

- transfer of responsibilities
- lack of awareness, on part of the operator, of the relevance and importance of waste inventory records; or
- recipient organization operates a different records management system.

The examples given below illustrate some specific problems encountered with waste inventory records at many of the older disposal facilities and clearly portray inadequate regulatory, infrastructural and records management systems. Lack of enforcement or availability of an appropriate QMS is another deficiency that is evident in the examples.

2.1.1. Incompleteness of data

At the Maxey Flats disposal facility, USA, uncertainties have been reported in the waste inventory records, particularly with regard to the activity levels, because much of the waste sent to the disposal facility was labelled simply as 'mixed fission products'; in some trenches, up to 50% of the waste inventory was designated as 'mixed fission products' [27].

Another example is the Sheffield disposal facility in the USA. In this particular case, the operator was not required to keep a precise inventory of the waste disposed of in each trench. However, at a later date, in order to carry out a safety assessment for repository closure, it was necessary to conduct a series of investigations to estimate the radionuclide inventory at this disposal facility [27].

Similar problems were encountered at the West Valley disposal facility, USA, where waste inventory records were reviewed and revised to develop improved radionuclide inventory records for four waste trenches at the facility [27].

At most of the Radon-type repositories in the former USSR and East European countries, there are a few common problems relating to waste inventory records [28]. One specific problem relates to the uncertainty associated with insufficient information on the waste inventory, e.g. the waste is commonly labelled as 'mixed fission products' or simply 'radioactive waste'. Another recurring problem at all of these facilities is the uncertainty associated with the inventory of plutonium isotopes, reported as ^{239}Pu. As reported in [28], the inventory data for ^{239}Pu registered in waste receipt records of the disposal facilities is probably a sum of ^{238}Pu, ^{239}Pu and ^{241}Pu nuclides, because for pure ^{239}Pu the indicated inventory was considered to be suspiciously high. Similar problems with plutonium inventory may be encountered in other countries that have imported plutonium sources of Russian origin. Furthermore, the inventory records of the disused SRS placed in a particular disposal unit are not always available.

In India, a user of radioactive sources placed disused SRS in their original containers for long-term storage, but did not make a proper record. Subsequently, when the regulatory body audited the inventory of the disused SRS, the user was not able to account for the sources that were in storage. The disused SRS sources could only be traced and retrieved by conducting an elaborate survey using ultra-sensitive monitoring equipment [5].

2.1.2. Inappropriate record keeping

As a result of inappropriate records-keeping conditions, a number of records have been lost due to fires and other accidents (for instance, at the Oak Ridge disposal facility, USA, a building fire destroyed many waste inventory records of past disposal operations). Some records had deteriorated to such an extent that they could not be salvaged, while others, though well preserved, could not be used because of transcription and typographical errors [27].

Another specific example of inappropriate records keeping is the waste inventory records at the Chisenau disposal facility in Moldova. In this particular case, the operator of the facility made an erroneous entry (~10 Ci of ^{239}Pu, instead of 10 mCi) in the waste inventory records, resulting in an error in the ^{239}Pu inventory for the facility [29–30].

2.1.3. Data storage media

Paper is the most common medium on which waste inventory data was recorded for many of the earlier disposal facilities. However, there a few, if any, waste inventory records on 'permanent' or 'archival' grade paper. In most cases, low-quality paper was used with an unpredictable long term performance. Magnetic disks or tapes were other principal storage media employed until the mid-1980s and much of the information stored in this manner is currently used by repository operators. Recent advances in information technology, in particular rapid development of computer-operating systems, have further contributed to a wide variety of options available for the storage and maintenance of waste inventory records.

2.1.4. Accessibility of data records sources

The archived waste inventory records consist essentially of two categories: data records directly related to waste characterization, conditioning and packaging procedures and 'supporting and enabling' information. The first category of information is to be found in logbooks, process log-sheets, container manufacturing and inspection records and package store records. The second category comprises research and development reports, process drawings, specifications for waste immobilization processes, materials, etc. Altogether, these data records provide the sources of information from which the missing or deficient inventory data could be retrieved to arrive at a revised and adequate waste inventory for the facility.

A problem with the archived historical information is that pieces of it may be scattered in various places, some of which may not exist any longer. At a disposal facility, at least two types of records are usually maintained: records submitted by the waste transportation organization and waste receipt records. While waste transportation and receipt records are normally kept solely by the repository operator in a safe location, some records may be temporarily stored, for one reason or another, in various locations (e.g. by the regulatory body, by contractors, etc.), while others (or the duplicates, as appropriate) may be archived in a central location. Thus, in the case of disused SRS, the original information on SRS typically resides with the manufacturer, distributor of the sources, or with the SRS users and owners. Some of them may also have closed their business.

2.1.5. Radiation units

Radioactivity is the phenomenon of spontaneous random nuclear disintegration, usually accompanied by emission of radiation; hence a radioactive substance is a substance of which the nuclei are subject to spontaneous disintegration. The rate at which nuclear transformations occur in radioactive substances (materials) is defined as *activity*. The current system international (SI) unit of activity (i.e. the unit of radioactive decay rate) is the reciprocal second (s^{-1}), termed the *becquerel (Bq)*. The *specific activity* is defined as the decay rate per unit mass of a radionuclide (for materials, per unit mass or volume of the material in which the radionuclides are essentially uniformly distributed). The SI unit of specific activity is $Bq.kg^{-1}$. When reported per unit volume ($Bq.m^{-3}$, $Bq.l^{-1}$) it is termed *activity concentration* [31, [32].

The act or condition of being subject to radiation is termed *exposure*. The exposure is the energy flux of the unperturbed photon radiation hitting matter. The unit used to measure charge is *coulomb* (C). The SI unit for exposure is the unit of electrical charge per unit of mass ($C.kg^{-1}$). The smallest subdivision of the amount of charge that a particle can have is the charge of one proton ($+1.602x10^{-19}$C) or of one electron ($-1.602x10^{-19}$C). The exposure rate is expressed as $C.kg^{-1}s^{-1}$.

Energy deposited by any ionizing radiation in matter is termed *dose*. The dose unit is $J.kg^{-1}$, termed the *gray (Gy)* and the SI unit for *dose rate* is, correspondingly, $Gy.s^{-1}$. Also the SI unit for the equivalent dose, used for the risk assessment in radiation protection, is $J.kg^{-1}$. The special name for this dose equivalent unit is *sievert (Sv)*.

(a) Old activity and exposure units

In the past, a variety of activity units were used in the applications of radioactive isotopes (*the curie, the rutherford, the eman, the mache, the equivalent concentration of radium, the uranium unit, the thorium unit*, etc.) [33-36]. However, only two of them, the curie (Ci) and the radium-equivalent (Ra_{eqv}) units, are currently relevant in respect of radioactive waste management and revision of historical waste inventory records.

The curie unit was originally adopted for measuring the amount of radon: 1 Ci corresponds to $6.51x10^{-6}$ g of ^{222}Rn which is found in radioactive equilibrium with 1 gram of ^{226}Ra. Hence, assuming that the ^{226}Ra half life is 1,580 y, the curie unit was defined as $3.7x10^{10}$ s^{-1} (Bq). Soon after, the curie unit was applied also to other radium daughter products and later to all other radionuclides. The value of $3.7x10^{10}$ s^{-1} was introduced as a universal unit of activity (Ci), independent of the half-life of radium. With the present day value of the half life of 1,599 y, the specific activity per gram of ^{226}Ra is $3.65x10^{10}$ Bq, or 0.988 Ci. The specific activities of two other naturally-occurring radioactive isotopes are: ^{232}Th-4.05 $MBq.kg^{-1}$ and ^{238}U-12.4 $MBq.kg^{-1}$ [37], which are also important in radioactive waste management.

Since 1911, the radium-equivalent unit has been used as a supplement to the curie unit, after a radium preparation was distributed as an international measuring (calibration) standard for radioactive materials. For example, the term “gamma-gram-radium-equivalent” has been used widely in measuring activities of gamma emitters. The term refers to the amount of a gamma emitting radionuclide such that its activity is equivalent to the gamma radiation from 1 g of radium.

In the past, in measuring total activities of some materials (e.g. soils, rocks, etc.), gram-radium-equivalent per gram of material (*$gRa_{eqv}.g^{-1}$*) was taken as the unit of radium-equivalent concentration. In this case, gram-radium-equivalent equals the sum of the activity concentrations of radioactive elements (radionuclides) where as many disintegrations ($3.7x10^{10}$) occur per second in 1 g of the matter as in 1 g of radium. Thus, in present day interpretations of historical waste inventory data, it is safe to accept that gram-radium-equivalent units (both gamma-gram-radium-equivalent and gram-radium-equivalent concentration in 1 g of matter) correspond to the activity of 1 curie.

One of the oldest radiation units, still in use, is the *roentgen (R).* It applies only to photons and is defined as exposure. 1 R is the exposure that in air produces ion pairs with total charge per unit mass of $2.58x10^{-4}$ $C.kg^{-1}$. The corresponding exposure rate is expressed in *$R.s^{-1}$*. The *roentgen* has been in use for more than 60 years and is still used in many places.

(b) Unit conversion methods

As discussed above, there are simple numerical relationships between the principal non-SI system (old) units and the SI units, therefore, at least formally, the conversion of old units into SI units does not represent a problem. For example, for the conversion of activity A (Ci) to activity N (Bq), the following relationship is used:

$$N = 3.7x10^{10}A \qquad (1)$$

The conversion of exposure expressed in roentgen units (R) to the SI unit ($C.kg^{-1}$) and vice versa is made using following relationships:

$$1\ R = 2.58x10^{-4}\ C.kg^{-1} \qquad (2)$$

$$1\ C.kg^{-1} = 3.87x10^{3}\ R \qquad (3)$$

For some radioactive substances, such as ^{232}Th, ^{235}U, ^{238}U, etc., their inventories are often given in mass units. The relationship between the mass G (g) and the activity N (s^{-1}) of a radionuclide is the following:

$$G = (NxMxT_{1/2})/(0.693xL_A), \qquad (4)$$

Where: M is atomic weight, $T_{1/2}$ - half life (s), and L_A – Avogadro’s number.

According to eq. (4), the following mass amounts correspond to the activity of $3.7x10^{10}$ s^{-1} (1 Ci); ^{226}Ra: 1.01 g, ^{235}U: 465 kg, ^{238}U: 3000 kg and ^{232}Th: 9000kg.

(c) Unit conversion difficulties

It is often difficult and not always possible to convert the historical waste inventory units into modern SI units with a sufficient degree of confidence due to both deficiencies in the original data and changes over time of the calibration and measurement techniques and methods. In this respect, a particular problem could be to reliably convert old radium-equivalent and roentgen expressed data into corresponding SI units.

Though, for example, the gamma-gram-radium-equivalent unit is very convenient in many practical applications of gamma-emitting radioactive sources. However, the precise measurements of activity, expressed in this unit, encounter substantial experimental difficulties. This is because the measurement results are dependent on the spectral composition of the emitted gamma rays and design of the measuring device, as well as on the measuring procedures. This deficiency is inherent also in results of radiation measurements expressed in the roentgen (R) unit. For these reasons, to properly understand the measurement results, information is required on the measuring equipment and conditions of measurements (e.g. measurement detection limits, uncertainties, sample composition, etc.). This is often missing in the radioactive waste inventory records of many old disposal facilities.

In problematic cases, it is necessary, therefore, to retrieve the relevant information on measuring devices and calibration standards. Certificates for ^{226}Ra standards contain, in particular, information on the amount of radium and dose rate at the distance of 1 m with reference to an accompanying standard filter for radium gamma rays, and the probable error of the determination of the quantity of radium.

Thus, in cases, where radiation unit conversion is not possible for any of the reasons discussed above, information on the actual methods employed to obtain the waste inventory data is required in order to verify the historical waste inventory records.

2.2. Need for improved waste inventory records

As discussed in the previous section, the main driver for the restoration and revision of waste inventory records for many of the older repositories is the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [14], which makes specific reference to the need for enhancing the safety of existing waste management facilities and to reporting on the inventories of radioactive waste that is either currently in storage or has been disposed of. The availability of and accessibility to a set of complete records on the contents of a repository, including the waste inventory, is a pre-requisite for establishing the safety of any disposal facility. Specific reasons for the need for revised and adequate waste inventory records include the following:

- Compliance with current safety requirements
- Changes in government waste management policy
- Compliance with QMS requirements
- Compliance with revised waste acceptance criteria
- Changes in repository operational practices
- Selection of waste treatment and conditioning methods
- Improved records management system
- Control of fissile materials
- Security of disused SRS

2.2.1 Compliance with current safety requirements

During the past 60 years, extensive experience has been gained in many countries with the development and operation of near surface disposal facilities for radioactive waste. Such experience shows that, in many cases, near surface disposal has been a successful operation, achieving safe isolation of radioactive waste at a cost significantly lower than alternative disposal options. However, as shown by monitoring and surveillance of the disposal facilities, there are also a number of cases, particularly with some of the older facilities located in humid regions where near surface disposal has failed to meet anticipated performance and safety targets. The reasons for the poor performance include inadequate control of the inventory of some radionuclides and/or toxic substances introduced into the repository. In order to confirm the safety of a near surface repository or to make a decision on the retrieval of the waste (if needed) for characterization and repackaging, it is imperative that a revised and adequate waste inventory for the facility is available.

Regulatory authorities may also adopt more stringent regulations with regard to exposure to radioactive waste from disposal facilities. This situation may lead to intervention, including retrieval of the waste from the repository, in order to comply with current safety requirements.

2.2.2 Changes in government waste management policy

Changes in government waste management policy in Member States are likely to have a direct impact on existing or planned waste management facilities. For example, the new policy may call for interim retrievable storage instead of final disposal of the waste. Alternatively, borehole disposal or even geological disposal of certain types of radioactive waste, for example high-activity and long lived disused SRS, may be the preferred option, compared to near surface disposal [12], [13]. In such cases, significant design changes to existing repositories or complete physical retrieval of the waste from the facility may be required by the regulatory body.

2.2.3 Compliance with QMS requirements

Many of the older disposal facilities were initially designed, constructed and operated without an extensive QMS programme in place. The application of enhanced quality management processes to such facilities has indicated deficiencies, requiring corrective action(s) [2], [6]. In this regard, concerns have arisen regarding waste inventory records that need significant revision and improvement.

2.2.4 Compliance with revised waste acceptance criteria

An important consideration in the near surface disposal option for radioactive waste is that it requires the activity of the waste to decay to adequately safe levels during the repository institutional control period. The concentration and/or inventory of long lived and high-activity radionuclides in the waste packages and the repository need to be limited in accordance with the results of a site-specific safety assessment. Since this has not always been the case in the past, several older repositories have been discovered to contain excessive amounts of high-activity and long lived radionuclides; consequently, the estimated radiological impacts for some evolution scenarios exceed current safety standards [3].

This issue is addressed in most countries by the specification of waste acceptance criteria (WAC), identifying the types and categories of waste that may be accepted for disposal in a near surface facility. The WAC may include specific activities or concentration limits for certain radionuclides, with higher limits applying if the waste is conditioned and disposed of as waste packages, offering longer term containment.

The WAC are generally site specific and based on current disposal regulations in a given Member State. If the latter changes, the WAC may also change accordingly, and may exclude waste previously permitted for disposal, such as high-activity and long-lived waste or disused SRS. This may require retrieval of the waste disposed of in the past that does not comply with the new WAC for the repository [2], [6]. The availability of an adequate waste inventory record, showing the activities and concentrations for key radionuclides, is a pre-requisite for establishing whether the waste being disposed of is in compliance with the WAC for the repository.

2.2.5 Changes in repository operational practices

Some countries have concerns about the poor performance of their closed and/or operating repositories and are now planning to undertake upgrading measures to improve operational procedures and practices in accordance with new regulatory requirements. Upgrading measures can involve retrieval of the waste, *in situ* immobilization of the waste, *in situ* decontamination, *in situ* containment, improved capping, installation of cut-off walls or other engineered barriers, or other corrective actions [2], [6]. In a number of countries, including the USA, United Kingdom, Norway, France, Bulgaria, Hungary, Poland, Romania and some Member States of the former USSR (Baltic countries, Moldova and Belarus), safety re-assessments and remedial measures have been carried out or are planned, as a part of a comprehensive assessment of the performance and long term safety of many of the earlier disposal facilities.

Based on safety requirements, upgrading operational procedures at other 'Radon' type repositories are also being considered [27]. Typical safety-related operational issues with the 'Radon' facilities, as well as many of the other older near surface repositories, stem from three major problems:

- the repositories contain high-activity waste and/or long lived radionuclides in quantities that exceed the current repository WAC
- deficiencies in design and/or lack of engineered barriers, particularly borehole facilities for the disposal of disused SRS;
- Improper siting of the repository (e.g. close proximity to high-density population areas).

2.2.6 Selection of waste treatment and conditioning methods

If a decision is made regarding retrieval of the waste from the facility, it is important to plan further treatment and conditioning of the retrieved waste, in particular if the waste is in an unconditioned form. It is likely that only properly conditioned waste will be accepted for disposal in a new or upgraded repository in accordance with the repository WAC. In order to properly plan for the treatment, conditioning and packaging of the waste, it is important that the following information is available on the properties of the waste, as part of an improved and revised waste inventory record for the repository:

Radiological properties

- Type of radiation, half-life, fissile material, heat generation
- Activity level, activity concentration, specific activity, contact dose rate
- Nature of contamination (fixed, non-fixed)

Physical properties

- Solid waste (compactable, non-compactable, metallic, non-metallic)
- Liquid waste (slurries)

Chemical properties

- Solid waste (combustible, non-combustible, pyrophoric, explosive, chemically reactive, self-ignitable, stable composition, corrosivity, microbial activity, gas generation, toxicity)
- Liquid waste (aqueous, organic - combustible, non-combustible, pyrophoric, explosive, chemically reactive, self-ignitable, stable composition, corrosivity, gas generation, toxicity)
- Gaseous waste (noble gases, airborne effluents, explosive, combustible, chemical reactive, self-ignitable, stable composition, toxicity)

Biological properties

- Infectious/pathogenic
- Degradable
- Putrescible

2.2.7 Improved records management system

In addition to complying with Article 12 of the Joint Convention, negative experience with many of the older disposal facilities has provided convincing arguments for repository upgrading, including the development of an improved waste inventory records management system. In this regard, the waste inventory records for many of the older repositories need to be restored, revised and verified and subsequently transferred to new national waste inventory records management systems that are consistent with international practices and procedures [22–25]. This also applies to existing storage facilities where the available records are inadequate or missing.

2.2.8 Control of fissile materials

Strengthening of the non-proliferation regime, in general, and current political realities, in particular, require accurate and comprehensive accounting for and control of fissile materials in Member States, including radioactive waste. From a review of the waste inventory records of many of the older repositories, it is becoming evident that many facilities have been used for the disposal of fissile materials, such as long lived uranium, thorium and plutonium. In some cases, the amount of such materials was large (for instance, Th-containing waste), and adequate information on the waste inventory, mass, volume and activity was not available. According to current IAEA safety guidance, the near surface option is not considered suitable for the disposal of waste containing long lived radionuclides. In several cases, the waste inventory records indicated only that the waste is either Pu-contaminated or U-contaminated. A review and restoration of the records of the waste inventory, containing fissile materials, is of particular importance to the national waste management organizations and regulatory bodies for accounting and control of nuclear materials, which is an integral part of the international safeguards regime.

2.2.9 Security of disused SRS

In order to ensure security of disused SRS, it is imperative that appropriate measures be applied to prevent unauthorized access to radioactive sources at all stages of their life cycle, including storage, transfer and disposal. To ensure occupational safety, steps need to be taken to control potential radiation exposure from disused SRS, both directly and as a consequence of incidents, so that the likelihood of harm attributable to such exposure is minimal. Security is therefore a prerequisite for safety. Thus, the safety and security aspects of disused SRS are intimately linked and many of the measures designed to address one, will also address the other.

Comprehensive measures that will ensure security of disused SRS are currently under development [38], however, it is already agreed upon that any transfer of sources to another person (e.g. the repository operator) should be documented and that person is authorized in accordance with the applicable regulatory and QMS requirements to receive the transferred source.

In order to implement the procedures described above for the security of disused SRS, all sources should be thoroughly inventoried in accordance with applicable regulatory requirements. The inventory records for disused SRS should include the following particulars:

- location of the source
- radionuclide
- radioactivity on a specified date
- serial number or unique identifier
- physical and chemical form
- history of source use (e.g. logging all source handling operations).

2.3 Considerations for a modern records management system

In accordance with international recommendations [22–25], the revised and verified waste inventory records need to be transferred into a new national records management system.

Procedures for maintenance of waste inventory records management systems are established by regulatory authorities. Hence, a national radioactive waste records management system is country specific. Examples and the experience in establishing such systems in France, Hungary, United Kingdom and the United States of America and other Member States are described in an IAEA publication [23].

It is important to recognize, however, that while retrieving and organizing information, the type and quality of both data and records management systems should be examined in the context of international requirements, such as those mentioned in the Joint Convention [14] and other waste classification and radioactive source categorization systems, the IAEA Waste Management Database, the potential for development of regional repositories and the possibility of future international archiving of repository information [23].

The records management system should be compatible with systems established by other organizations, related to waste management activities, in a given Member State. The system should be planned, developed, implemented and enforced in accordance with written procedures and using validated computer codes.

Within an overall records management system, waste package data is an essential part of required information. The records management system can be used for a variety of purposes with the major one being establishing conformance of the waste and waste packages with the WAC for the repository. It can also be used as a basis for the evaluation of discharges, etc. Such records also form the basis for the fulfilment of the reporting requirements under the Joint Safety Convention and can be a part of post-closure disposal facility records, which may be essential for future generations [14], [22].

The facility records management system should ensure that, as a minimum, the revised waste inventory records are [24]:

- categorized according to the requirements specified in the approved new registration system
- readily accessible and provide the desired information from the system in a proper output format
- stored in a suitable form in a controlled environment and protected from loss or damage
- revised to reflect the actual status of the registry

- Retrievable, regardless of changes in technology.

In addition, records are required to be clear, legible, complete, classified (permanent or non-permanent) and readily available for inspection. The system should be able to identify and track any individual object, service or process involved. The system must be designed to resist tampering or alteration and should provide appropriate backup or redundancy to assure that data will not be lost owing to accidents or unexpected events. Multiple copies of the records and storage at different locations may be required. Only authorized individuals should be allowed access to the records management system. Modification of the documents must be subject to the same level of review and approval as the originals. At any storage facility, records should be maintained for the required period and made, therefore, of appropriate material to resist deterioration for required retention time.

It is considered good practice that the records-keeping systems for radioactive waste management be computerized. It is important, however, to ensure long term maintenance of computer records in a manner consistent with regulatory and other relevant requirements, taking account of the rapid development of computer-based information technology.

In a given Member State, the lead waste management organization should specify retention times for all records and ensure that records requirements are observed in all organizations involved in waste management activities. Periodic audit or surveillance is necessary to verify whether records management is implemented satisfactorily.

3. METHODOLOGY FOR RETRIEVAL OF WASTE INVENTORY RECORDS

The various activities for the retrieval and restoration of historical waste inventory records should be carefully planned with the aim of retrieving complete, accurate and reliable data, and to optimize the paper work and the level of effort needed. In cases, where the actual retrieval of the waste is required for data verification or characterization purposes, a specific action plan and written technical procedures need to be developed. Furthermore, the methodology needs to take into account consideration of various steps in the series of activities, eventually leading to the development of a revised and adequate waste inventory record. The methodology, as required in a normal feasibility study, prioritization of activities and work plan development are discussed in this section.

Efforts to upgrade old repositories are in line with the measures for strengthening control over radioactive waste, in general, and radioactive sources, in particular. For this reason, and because of the similarity in approaches, the methodology developed by IAEA to retrieve information on disused SRS (i.e. to locate and identify the sources), based on record searches [5] could be adapted, with some modification, for the restoration and revision of historical waste inventory records. This section provides additional guidance to that contained in the IAEA publication [5] and deals mostly with an administrative approach to retrieving waste inventory records. For the sake of completeness, some physical methods for characterization of the retrieved waste, using conventional measurement techniques, are also briefly discussed in this section.

3.1. Stepwise approach to retrieval of waste inventory records

Specific steps or actions that could be involved in the retrieval of data for revising the waste inventory records are described below. The sequence of their implementation and prioritization of the various steps are discussed in Section 3.2.

3.1.1. Initiation of a data search

An administrative search involves various steps and activities to access existing relevant information. The first step is to determine if a data search is needed. Such a decision and search priorities will be based on a review of repository waste inventory records and perhaps, safety assessment. Specifically, this will include examination of the existing information on the waste inventory and assessing the adequacy, completeness and reliability of the records. Account should also be taken of the radioactive waste classes (or categories), their physical form, availability of information, costs involved, etc.

3.1.2. Types of a data search

Methods used to retrieve old waste inventory data during administrative searches have much in common with investigative work and can be broadly grouped into searches for records, studies and interviews.

Record searches and studies represent both the main step and the principal tool of data gathering during an administrative search. This involves the searching of hard copies (e.g. files, SRS certification, logbooks, index or data cards) and electronic records (e.g. text, spreadsheet and database files on hard disks or accessible via Intranet/Internet, or on magnetic tapes, removable discs, etc.). The types of records to be searched and studied include: waste storage and disposal records, waste transport and receipt records, waste processing and characterization records, authorizations, registrations, licences, inspection reports, manufacturer's catalogues, purchase orders, users records, etc. Initially, data retrieval may start as a targeted search, aimed at a particular piece of information, which may expand into more broad-based records search. In the focused search, much of the data is skimmed until the area of interest is found, and this is then examined in detail. The area of interest might be a particular type of waste, a particular time period, or a particular industry, sector or target group.

Interviews may include talks with individuals in person, telephone calls, e-mails and fax messages as well as the use of standardized questionnaires. An interview methodology is needed for all search types and target groups, especially when users, owners, and other individuals are interviewed. To achieve optimum results, it is helpful to prepare a standard set of questions, from which branching or follow-up questions can be developed until a good understanding of the problem is reached. This will ensure that all areas of the subject are covered systematically and will enable the interviewer to return to the subject at a new level of information-gathering spiral. Group discussions could also be utilised, where previous employees are invited, photos or copies of records compiled during that period are circulated, and discussed.

3.1.3. Identification of possible information sources

The next step involves listing the potentially useful targets of the information search. These targets may include documents and records, institutions and persons. Peer reviews and brainstorming by a group of knowledgeable individuals can be helpful in compiling a list of possible information sources and a list of places to start looking for data. A list of places for search may include the following:

- governmental (state) authorities,
- non-governmental and international organizations,
- waste generators,
- users and owners of radioactive materials,
- manufacturers and suppliers of radioactive materials,
- transportation and shipping organizations,
- individuals and organizations involved in the management of radioactive materials.

Governmental authorities include ministries or departments, competent authorities, regulatory bodies, regional or local authorities that have responsibilities in such areas as radiation safety, nuclear power, radioactive waste management, healthcare, environmental protection, control of natural resources, industry, agriculture, transport, education, etc. Governmental authorities will normally have information regarding authorizations, licence applications, inspection reports, transfers of sources, as well as the inventories of radioactive materials and radioactive waste that they have or that are under their own control. Contracting parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [14] are required not only to upgrade the safety of existing waste management facilities, but also to report on the inventories of radioactive waste that is either in storage or has been disposed of in a facility.

Non-governmental (e.g. service and technical organizations, etc.) and international organizations may have knowledge that is useful for the verification of historical waste inventory records. Examples include the International Catalogue of Sealed Radioactive Sources and Devices [39] and also radioactive waste management databases developed by the IAEA. An important area in which, for instance, the catalogue could be useful is providing full information for a particular SRS type or device where only partial information may be available in the records. To date, data have been compiled for hundreds of manufacturers, thousands of source and device models, including drawings of sources and devices, where available. To enhance the usefulness of the catalogue to Member States, the IAEA plans to perform regular updating and maintenance in accordance with appropriate QMS requirements and procedures. This will also include the addition of more complete and balanced information.

Users and owners of radioactive materials and SRS may have documents and records of the materials and sources that they have used or possessed in the past and subsequently transferred to storage or disposal facilities.

Manufacturers and suppliers, or distributors, of radioactive materials and SRS, by the nature of their business, keep a large number of records relating to their products. These records include not only design specifications but also shipment and distribution information.

Individuals who work with radioactive materials, especially early pioneers in this area, should be interviewed. They could assist in specific scientific and technical searches (e.g. measurement methods and procedures), older regulatory documents and waste inventory records- keeping systems. These individuals may be able to provide the necessary information directly or by advising how to continue the search in a particular area.

3.1.4. Examples of data search

The process of searching for inventory records on historical waste can be compared to application of non-linear systems with feedback loops. When searching for information, analysis of the clues and the feedback can often result in a change in the direction of the investigation. This can, in turn, lead to a change in the methodology and even the objectives of the search. This indicates that, in particular cases, to be effective, no limits should be placed on the objectives, scope or direction of the investigations. Some Member States' examples of the methods used to improve and revise the waste inventory records are provided below.

In Romania, a waste characterization programme was undertaken because of inadequacies in the data on the contents of the waste packages. According to available records, disused SRS, in particular high-activity ^{241}Am SRS, were likely to be present in the waste. Thus, all of the existing documents were re-examined to confirm the presence of ^{241}Am SRS. Discussions were held with previous employees on the conditioning of the waste. Based on these discussions, it was concluded that no ^{241}Am sources were present in the storage facility. A survey was conducted of the records of waste collection, treatment, conditioning and disposal, starting with the 1974 records. Based on this survey, it was concluded that higher-activity ^{241}Am SRS (>1 mCi) was first collected in 1999. Taking this into account and the fact that no ^{241}Am SRS still in use could have been disposed off, it was concluded that no ^{241}Am SRS was present in the waste packages at the disposal facility in Romania. Until 1999, only small numbers of low- activity, ^{241}Am SRS from smoke detectors and calibration sources were collected. These findings, which were presented to the regulatory body, were useful in revising the waste inventory records, specifically the ^{241}Am SRS inventory, for the disposal facility.

In Poland, examination of the waste inventory records for the Rozan repository has shown that inadequate data existed on the waste volume and activity, radionuclide inventory and time or date of waste receipt and packaging [40]. To address these gaps in the waste inventory records, some simplifying assumptions were made. For instance, in the case of alpha waste, the activity was assumed to be 5 mCi ^{226}Ra per delivery (which consists of up to 30 drums). This conservative assumption increased the radium inventory by 50%. Using this approach, a revised radionuclide inventory was developed for the Rozan repository, which in turn made it possible to produce a satisfactory safety case for the repository.

Another example from Poland relates to a criticality assessment carried out at the Rozan facility [40]. For this purpose, the masses of the various isotopes of uranium in the waste inventory were calculated. This approach used the total mass of waste in each delivery and the specific activities of the uranium reported. In a number of cases, the calculated masses of ^{238}U were significantly higher than the masses of the corresponding waste packages. The reported uranium activities were corrected accordingly.

As a former military centre in the Baltic region during the Soviet era, Latvia received relatively large quantities of defence-related radioactive waste for disposal at the Baldone disposal facility [41]. A large fraction of the waste inventory was disused SRS. There were several shipments simply labelled as “uranium fission products”, with total activity recorded; however, isotopic content and individual activities were not reported. A preliminary data examination and assessment of the waste inventory records raised some concern about the accuracy of the ^{239}Pu inventory. A detailed analysis of the records and assessment of the data provided a more realistic and improved radionuclide inventory:

- the correct ^{239}Pu inventory in the waste is about 100-fold lower than the initial estimate,
- the “mixture of plutonium isotopes”, as stated in the source certificate, is in fact ^{241}Am.

At the Puespoekszilagy disposal facility for institutional waste in Hungary, it was recognized by PURAM, the national radioactive waste management organization, that there were gross inconsistencies in the waste inventory records [42–43]. In addition, it was realized that (a) long lived and high-activity disused SRS had been disposed of in the facility; and (b) disposal capacity of the facility could be increased, making room for future arisings of institutional waste in the country. All of these factors contributed to a management decision to upgrade the facility to improve its safety and performance, including retrieval and restoration of historical data records to develop an improved and revised waste inventory for the facility.

A thorough analysis of the available records was carried out to retrieve and restore relevant data in order to develop an improved waste inventory for the disposal facility, and to provide input for safety re-assessments and for planning upgrading measures. The following specific problems related to the waste inventory records were identified for the Hungarian disposal facility.

<table>
<tr><th>Problem</th><th>Cause</th><th>Restoration methods</th></tr>
<tr><td>Incomplete information</td><td>• Poorly-documented characteristics (undocumented waste forms and packages; uncertainties in radionuclide concentrations, etc.)
• Unrecorded information (location of the packages, etc.)
• Information not provided by the waste producer (physical form of disused SRS, etc.)
• Unknown or poorly-documented information on non-radiological hazards (asbestos, organic solvents, pathological agents, toxic chemicals, etc.)</td><td rowspan="3">• Analysis of documentation (records of received waste, records of on-site measurements and verification of received waste, etc.)
• Interviews (with current and former managers and repository staff, including follow-up of anecdotal information, etc.)
• Records at the facilities where the waste was originally generated (radioisotopes used, origin of the sources used, etc.)
• Expert judgement
• Verification of calculations
• Other countries’ experiences
• Retrieval and characterization of the waste</td></tr>
<tr><td>Unreliable information</td><td>• Problems with records (misprints, typographical errors, illegible, etc.)
• Misuse of units
• Inappropriate records keeping</td></tr>
<tr><td>Lost information</td><td>• Loss of shipping documents</td></tr>
</table>

Further details concerning the retrieval and restoration of the waste inventory records for the Puespoekszilagy repository, which is currently underway, are provided in references [42–43].

3.1.5. Process and activity documentation

Since a variety of searches and assessments of available records are performed to obtain and verify additional information on the waste inventory, including SRS, it is essential that not only the revised and updated waste inventory data and information be recorded, but also the processes and procedures that are followed in obtaining the relevant information. Typically, this could involve peer reviews, persons contacted, minutes of meetings, assumptions made, sensitivity analysis performed, sources of other information used. These documents will form the basis for and support the validity of the revised and improved waste inventory records.

3.1.6. Waste retrieval and characterization

For a number of reasons, as described above, the task of retrieval and verification of the waste inventory records for some facilities, using administrative methods, may not be feasible, or the outcome of data retrieval is not satisfactory or unreliable.

In such cases, it will be necessary to physically retrieve the waste from the repository for subsequent characterization to arrive at a reliable and complete record of the waste inventory. The following technologies/methodologies can be used for characterization of the waste as described in [44], [45]:

- Visual observations
- Weighing: digital or analogue scales
- Radiation field survey
- Radiological contamination survey
- Radiographic and tomographic examination

- Activity measurement
- Container integrity survey
- Destructive testing.

Selection of appropriate methodology requires careful planning and preparatory work, including segregation and collection of the retrieved waste. More detailed guidance on the selection and implementation of various characterization methods for the waste retrieved from old storage and disposal facilities is provided in the companion IAEA publications [3], [44].

3.2. Prioritization of data retrieval steps

Prioritization of waste inventory data retrieval activities and data needs could be directed by the regulatory body or developed by the repository operator. For this purpose, safety assessment is normally used for assessing the type of data needs and associated activities required to develop an improved and adequate waste inventory. In particular, safety assessments are important for confirming the acceptability of the waste inventory in the disposal facility and for providing a basis for assessing whether or which data are missing or inadequate in the waste inventory records. As discussed earlier in this report, the guiding factor is the WAC for the repository, which provides pre-determined upper limits on radionuclide inventories and/or concentrations for individual waste packages or the entire repository.

Based on Member States' experiences, large quantities of high-activity, short lived radionuclides (for example, some high-activity SRS) have posed potential problems for operational and post-closure safety at many of the older repositories. The presence of waste, containing long lived radionuclides, is another recurring issue that has required appropriate corrective actions to be implemented at some of the repositories. These are some examples that are important in the prioritization of waste inventory data retrieval activities and identification of the type of data that is needed.

Records that provide documentary evidence of waste package acceptability for disposal, such as waste characterization and packaging records, assay records, and certifications of compliance with the WAC, are considered primary documents for revising and developing improved waste inventory records.

The WAC for a waste package or a disposal facility is defined in such a way that the results of the safety assessment conform to the applicable safety requirements for the repository. The top priority in data retrieval activities for many of the older repositories is, therefore, determined by the requirement to identify the specific waste, including disused SRS, which presents a potential hazard to human health and the environment during the lifecycle of the repository. Examples of the types of disused SRS, subdivided into three categories according to their radioactive half-lives, which might be considered for various disposal options, are given in [12], [13].

In some cases, the WAC may be specific to a particular radionuclide, SRS or waste package, in others, to the entire repository. Accordingly, the authorities in a Member State may consider a variety of corrective actions at some of the old repositories and final disposal routes for disused SRS and other waste that exceed the WAC for the waste package or the facility. Thus, the options selected will determine the priority of data needs and associated data retrieval activities.

A large part of the prioritization of activities will occur from the examination of available waste inventory records for the disposal facilities, and while other data retrieval activities are in progress. As specific issues concerning the waste inventory are assessed and addressed, it will become progressively clear where there are gaps or deficiencies in the records that are required for arriving at an adequate waste inventory for the repository, which in turn is needed for the repository upgrading programme, including safety re-assessment. The output of the assessment of the records should be checked for conformance with relevant national regulations harmonized with international standards and guidance [22–25], [46]. Quality, internal consistency and completeness of existing waste inventory records need to be examined and evaluated critically. As an example, the existence and the quality of a national registry of disused SRS is a prime indicator and an information source employed in evaluating the completeness and adequacy of the waste inventory of a disposal facility. If the waste inventory registry is incomplete, then it is important that the registry is revised and improved.

While examining historical waste inventory records and comparing them with other information sources, some of the issues to be considered in their assessment include:

- Are all the known applications of SRS contained in the inventory?
- Are the radionuclides and activities in the inventory consistent with the application of the SRS?
- Are all the likely companies or users of a particular application included?

It should be emphasized that, in assessing the completeness, adequacy and accuracy of waste inventory records for a near surface disposal facility, priority needs to be given, based on safety assessment, to specific types of waste, in particular those containing high-activity and/or long lived radionuclides.

3.3. Assessing the reliability of waste inventory records

In addition to the adequacy and completeness of the records, it is necessary to verify that all data were determined with the accuracy needed to provide reasonable assurance of compliance with relevant quality and safety requirements for the waste packages and the repository. The process of assessing the reliability of waste inventory records includes verifying the content and quality of all relevant information on waste form and waste packages, storage and disposal locations and the quality of the record management system. The focus is on the inventory of radionuclides in the waste packages and the disposal units.

3.3.1. Assessment approach

In view of the absence or lack of QMS requirements applied to some of the earlier repositories in the past, it may be difficult, in some cases, to assess and verify the reliability of the waste inventory records from these facilities with a sufficiently high degree of confidence. In addition to a review and examination of available documentation, it can be helpful to contact specific individuals who have considerable experience and were personally involved in compiling the waste inventory records at that time. Such a process could also shed light on the procedures and approaches used in generating the old waste inventory records. The assessment process should be iterative in nature and is intended to provide additional guidance on the needs, direction and content of the waste inventory data retrieval process.

3.3.2. Peer review

An acknowledged methodological approach to building confidence in the presence of uncertainty is peer review [47]. Although peer review is regarded as part of a QMS, it has its own scientific and technical merit. Peer review is brought to bear on the areas of the work where an independent technical appraisal and review is judged to reduce uncertainty and enhance confidence. One of the well-known areas is scientific activity where confidence in the validity of results depends, to a great extent, on the outcome of the peer review process. Similarly, all activities related to the overall assessment and revision of historical waste inventory records and results relevant to assessing the reliability of the records should be subject to a peer review process as well. Publishing the results of the peer review in open literature would further provide an opportunity for detailed scrutiny by other experts active in the field, as well as by others interested in the topic.

The peer review process for assessing the reliability of waste inventory records may include approaches other than those used in a typical peer review of scientific and technical papers published in open literature. National radioactive waste management programmes normally have specific provisions for the technical review of important activities. In some cases, the operator of a repository may be required by the competent authorities to organize, or the competent authorities themselves may organize critical reviews by independent bodies. Such reviews can add to the peer review process by making use of expertise of various specialists and can be effective in raising the level of confidence in the review process. While it is possible for the local experts involved in the national radioactive waste management and radioactive source control programmes to participate in such an exercise, experience has shown that external assessment, based on input from external experts, provides a more objective and fair peer review.

A specific example of an international peer review is the Chisenau disposal facility in Moldova. As a part of the safety assessment of the Chisenau disposal facility, an IAEA expert mission was organized in 1998 with the purpose of reviewing and collecting information relevant to safety assessment [29], [30]. A key issue, addressed by the Expert Team, was the accuracy and reliability of the waste inventory records. The attention of the experts was drawn, in particular, to a conspicuously high inventory value of ~10 Ci for ^{239}Pu. The available records were examined to verify the accuracy of this value. In the receipt records, an entry was noted that the shipment contained “up to 10 Ci” of ^{239}Pu. From this record, it was found out that a single shipment, on a specific date, accounted for virtually all of ^{239}Pu in the inventory. More detailed investigation of the receipt records showed that the delivery comprised a ‘static electricity eliminator’, which was a common type in use at that time in the USSR. Cross-checking of other receipts and shipping records for this type of device received at the facility indicated that the ^{239}Pu value ought to be of the order of 10 mCi, rather than 10 Ci, as reported.

This indicates that the operator mistakenly omitted the “milli” prefix while entering the receipt data record. To further substantiate this assumption, other data records were examined from the same organization. It was found that, for other shipments, the recorded data indicated about 30 mCi of ^{239}Pu per device (5 mCi per source). It was concluded that the large amount of ^{239}Pu in the waste inventory record was the result of a simple entry error. This was further confirmed by the regulatory authority of the Republic of Moldova, which provided specific information on the activity of the above-referenced device to be about $2x10^8$ Bq (5 mCi) per source.

A follow-up of the IAEA international peer review by the Moldovan authorities resulted in a complete revision of the waste inventory records of the Chisenau disposal facility. In the follow-up review, special attention was paid to disused SRS with long lived radionuclides. One particular outcome of this review was a much greater amount of disposed plutonium than was estimated previously in the waste inventory records [29–30]. The increase in the ^{239}Pu inventory appears to be the result of a large number of shipments that were previously omitted.

3.4. Implementation of data retrieval and assessment methodology

This section deals with the implementation of the methodology described above for the retrieval and assessment of radioactive waste inventory data, including disused SRS.

It should be noted that the steps described below may not be applicable to all situations, and the repository operator for a given disposal facility should apply only those steps that are specifically applicable to his/her facility.

3.4.1. Quality management system

At the outset, a QMS regime should be established to include all of the data collection and assessment activities. The key elements of a QMS plan include:

- Document control to ensure that key documents are authorized for use, are traceable and properly maintained
- Adequate record retention times to ensure that records are available at least until the end of the institutional control period for the repository
- Operator training, including for example awareness seminars to understand the importance of maintaining accurate and complete waste management records
- Internal audit to ensure that the waste management policy and procedures have been followed and the accuracy of the waste management records verified
- Peer review to ensure that any ambiguities are critically discussed and clarified
- Periodic review to ensure that documents and data are updated in a timely manner
- Continual improvement to ensure that any system deficiencies are identified and rectified.

3.4.2. Establishing the approach

The approach to implementing the work should be planned in a systematic manner and should include, as a minimum, the following considerations:

- Provision of adequate resources for implementation of the work, including infrastructure, adequate manpower and financial resources, timescales, skill requirements, identification and implementation of training
- Evaluation, choice and validation of relevant software, databases, computer codes.

The output should be an authorized plan, showing the sequence of activities. An adequate budget should be available for its implementation and completion.

3.4.3. Implementation of the approach

Implementation of the approach for waste inventory data retrieval and assessment basically involves implementing the authorized plan, keeping in mind that a specific plan, which is relevant to the existing situation concerning the waste inventory records at a particular repository, needs to be developed.

As a starting point, available records need to be retrieved and collated. In carrying out this exercise, the following data sources need to be considered.

- Analysis of existing documentation, including safety reports, technical reports, health physics records and reports, waste storage and disposal records, waste transport and receipt records, waste processing and characterization records, authorizations, registrations, licences, inspection reports, manufacturer's catalogues, purchase orders, users records, memos, photographs, films, microfiche, scientific publications, files, SRS certification, logbooks, index/data cards, electronic records (e.g. text, spreadsheet and database files) from a range of organizations
- Discussions/interviews with people, including employers, past and current employees, users, owners, manufacturers, suppliers/distributors of SRS, regulators and IAEA. Interviews may include discussions with specific individuals, telephone calls, e-mails and fax messages. Use of standardized questionnaires is advisable, since this facilitates data collection, analysis and follow-up. Data generated by talking to early pioneers of nuclear facilities is a valuable source of information and can often lead to good advice on how to continue the search for more reliable data. Verification of the advice and information obtained in this manner can often be difficult.

As part of data gathering and retrieval activities, it is also often advisable to perform additional investigations, including:

- Sampling and analysis of the waste. In many cases, the waste is not accessible. However, in some cases, it may be feasible to gain limited access to the waste
- Sampling and analysis from the environment surrounding the facility, (including water, grass, the atmosphere, soil, leaves, ambient dose rates), in addition to those collected under the routine environmental monitoring programme.

After collection, detailed verification and validation should be carried out and documented.

3.5. Data verification and validation

A verification and validation methodology should be formulated. This should include the procedures to allow:

- Comparison and evaluation of the information contained in the documentation, and highlighting and analysis of any discrepancies that were identified
- Identification of the primary source of the information. Comparing the information contained in secondary documents should lead to identification of the primary document(s). This can be helpful when trying to determine the accuracy of information
- Attributing varying degrees of confidence to the data and revising or omitting data in the revised inventory, based on the analysis
- Documentation of not only the revised and improved waste inventory data and information, but also the processes and procedures that were followed in obtaining the information. This could typically include peer reviews, the persons contacted, minutes of meetings, assumptions made, sensitivity analysis performed, sources of other information used
- Generation of a revised waste inventory that is adequate and authorized for use.

The data should be verified in accordance with the established methodology.

The data records should be carefully examined, if difficult to interpret. For example, if the mass of a radionuclide (calculated from the reported activity) is not consistent with the total package mass, this may indicate that the activity data are not accurate. Improved data should be sought if the confidence in it is low.

The impact of the assumptions should be determined. For example, if simplifying assumptions prove not to be correct, the assumptions should be challenged and modified. A revised database should be generated.

3.5.1. Establishing a computerized database

The first stage is to develop a plan on how the computerized database will be structured, produced and maintained in line with future developments. This, like all of the activities described here, should be performed following a well-established QMS regime. Consideration could be given to existing IAEA databases. Some planning considerations are presented below.

- The resources (e.g. manpower, facilities, budget), timeframes, management and customer commitment, responsibilities, authorizations required to establish and maintain the database need to be determined.
- The computer hardware and software parameters (e.g. type of software, the fields used in the database, (e.g. decay corrections), computer security) need to be determined. It is worth considering adoption of a barcode system for data recognition and collection. If the customers do not have computers, it is advisable to use forms to collect and compile the information. On-line exchange of information will not be possible if computers are not available.
- The validated data should be entered into a computer, in accordance with the plan.
- Review and update the information in the new system, including making necessary corrections and restructuring the database, if necessary.
- The new computerized data system should be verified and used.

3.5.2. Periodic review

It will be necessary to repeat some of the operations, described above, in accordance with the QMS procedures. This will include:

- Reviewing the total waste inventory.
- Adding new data to the system.
- Updating paper and computer records.
- Records keeping.

The review frequency will depend on a number of variables, including the quantity of data, the facility throughput, number of required changes, the complexity and timescales of repository upgrading programme, if applicable.

4. CONCLUSIONS

A specific area of concern in radioactive waste management is the safety of many of the older near surface disposal facilities for low and intermediate level waste established around the world in the 1950s to early 1960s, long before current regulatory, safety and quality management requirements, as well as more recent disposal technologies, took effect. In many of these facilities, long lived and high-activity waste, including disused radioactive sources, was disposed of along with other institutional waste.

In response to the recommendations of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, many Member States are currently planning or have already implemented comprehensive upgrading programmes, including revision and restoration of waste inventory records, at a number of existing storage and/or disposal facilities.

It is in this context that this report was developed to provide guidance on a methodology to retrieve, assess and verify the historical waste inventory records for such facilities where the records are either not available or inadequate. As part of the overall facility upgrading programme, it is a pre-requisite that an adequate waste inventory is available for carrying out safety re-assessment or planning any corrective action (s) on such facilities.

A variety of circumstances that may require historical waste inventory records to be re-assessed or retrieved, especially for many of the older disposal facilities, is discussed. A systematic process is advisable to help ensure effective planning and implementation of the assessment and retrieval of historical waste inventory records.

The general guidance provided on the waste inventory data retrieval process integrates, in a systematic way, various methods and technical issues, including conversion of old activity and radiation units, and prioritization of data retrieval activities. These technical and methodological issues have been introduced in this publication based on the experience gained and approaches employed in some Member States, as part of the overall upgrading programme at their storage or disposal facilities.

Although not very comprehensive, the general guidance on the historical waste inventory data retrieval process includes the following sequential steps: (a) initiation and types of data search; (b) identification of possible information searches; (c) some examples of data search in Member States; (d) process and activity documentation; (e) assessing the reliability of the retrieved inventory data; (e) implementation of data retrieval and assessment methodology; and (f) data verification and validation.

The specifics of implementation of the waste inventory data retrieval process will vary depending on the specific situation in each country. For example, progress in its implementation within a given country with a well-established radioactive waste management framework is expected to be much faster than in another country that has a less well-developed framework. However, irrespective of the nature and importance of these and other (technical, social, economic, etc,) country-specific factors, it is still important to emphasize that the basic methodology described in this publication will be applicable to each country.

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