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Inspection and verification of waste packages for near surface disposal

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FOREWORD

Extensive experience has been gained with various disposal options for low and intermediate level waste at near surface disposal facilities. Near surface disposal is based on proven and well demonstrated technologies. To ensure the safety of near surface disposal facilities when available technologies are applied, it is necessary to control and assure the quality of the repository system's performance, which includes waste packages, engineered features and natural barriers, as well as siting, design, construction, operation, closure and institutional controls. Recognizing the importance of repository performance, the IAEA is producing a set of technical publications on quality assurance and quality control (QA/QC) for waste disposal to provide Member States with technical guidance and current information. These publications cover issues on the application of QA/QC programmes to waste disposal, long term record management, and specific QA/QC aspects of waste packaging, repository design and R&D.

Waste package QA/QC is especially important because the package is the primary barrier to radionuclide release from a disposal facility. Waste packaging also involves interface issues between the waste generator and the disposal facility operator. Waste should be packaged by generators to meet waste acceptance requirements set for a repository or disposal system. However, it is essential that the disposal facility operator ensure that waste packages conform with disposal facility acceptance requirements.

Demonstration of conformance with disposal facility acceptance requirements can be achieved through the systematic inspection and verification of waste packages at both the waste generator's site and at the disposal facility, based on a waste package QA/QC programme established by the waste generator and approved by the disposal operator. However, strategies, approaches and the scope of inspection and verification will be somewhat different from country to country depending upon the individual Member State's QA/QC system for waste management. In this context, this publication is a collection of current information about various Member States' QA/QC programmes. It reviews them in terms of common approaches and technical procedures as well as applicable technologies. This TECDOC will benefit Member States, especially developing countries, that are planning, establishing or upgrading existing near surface repository systems.

This publication is intended to provide technical guidance and current technical information about assuring compliance of waste packages with near surface disposal facility acceptance requirements by means of inspection and verification. It, therefore, discusses concepts of waste package inspection and verification, waste acceptance requirements, establishment of a waste package QA/QC programme, technical activities, inspection and verification procedures, and waste generator/disposal facility operator interface issues.

The report was developed with the help of consultants and through an Advisory Group meeting held in 1996. K.W. Han of the Division of Nuclear Fuel Cycle and Waste Technology was the responsible IAEA officer.

EDITORIAL NOTE

This publication has been prepared from the original material as submitted by the authors. The views expressed do not necessarily reflect those of the IAEA, the governments of the nominating Member States or the nominating organizations.

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1. INTRODUCTION

1.1. BACKGROUND

The IAEA is producing a set of technical reports covering important issues related to disposal activities in order to assist Member States, especially developing countries, in their planning and implementation of near surface disposal of radioactive waste. Near surface disposal is defined as the disposal of waste, with or without engineered barriers, on or below the ground surface where the final protective covering is of the order of a few meters thick, or in caverns a few tens of meters below the Earth's surface. Typically short lived, low and intermediate level wastes (LILW) are disposed of in this manner.

As part of the IAEA's series of reports, siting and design issues have been dealt with to cover the principal elements of a multi-barrier concept for disposal, that is, the geological and engineered barriers. The waste package itself, a component of a multi-barrier concept, is dealt with in detail in this publication. A waste package is defined [1] as the product of conditioning that includes the waste form and any container(s) and internal barriers (e.g. absorbing materials and liner), as prepared in accordance with requirements for handling, transportation, storage and/or disposal. Waste should be packaged by generators to meet waste acceptance requirements set for a repository or disposal system [2, 3]. However, it is essential that the disposal facility operator ensure that waste packages conform with disposal facility acceptance requirements.

Assurance can be achieved through a systematic inspection and verification of waste packages (checking documents, assaying waste packages, other means) based on a set of detailed specifications derived from waste acceptance requirements. However, the strategies, approaches and scope of such inspections will be somewhat different from country to country depending upon the individual Member State's regulatory and quality assurance systems applied to waste packages in their production, storage, transport and disposal. Thus, this publication summarizes common technical issues for inspection and verification as well as practices in Member States, and provides practical guidance to Member States.

1.2. OBJECTIVE

The objective of this report is to provide technical guidance to demonstrate compliance of waste packages with acceptance criteria for a near surface repository by means of inspection and verification procedures.

1.3. SCOPE

This report identifies general procedures, practices and technical issues involved in the inspection and verification of packages containing short lived, LILW by near surface disposal facility operators. It also refers to the responsibilities of parties involved to support inspection and verification, as well as technical and administrative interface issues.

1.4. STRUCTURE

This report outlines safety and regulatory requirements for waste packages. It discusses the importance of quality assurance as a tool to ensure that waste packages are compliant with

disposal facility acceptance requirements, it lays out the key elements of a waste package quality assurance system and it provides some insight into how compliance is achieved through waste package inspection and verification (Section 2).

In more detail, the report describes waste acceptance requirements considered during inspection and verification activities for waste packages (Section 3).

The report outlines the essential features of a waste package quality assurance programme including authorization, review and approval (Section 4). Further issues associated with historical wastes are also addressed.

The report then provides further guidance to inspect and verify the generator's waste package quality assurance programme. It provides several examples of how inspection and verification can be undertaken of waste received by the repository operator (Section 5).

Finally, the report discusses interface issues such as waste tracking and documentation and the critical issues of non-conformances and corrective actions, i.e. how the repository operator and waste generator should interact to resolve non-conformances and to prevent further production of unacceptable waste packages (Section 6).

Examples of policies and practices of Member States are provided in the Annex.

2. NEEDS, PURPOSE AND RESPONSIBILITIES FOR INSPECTION AND VERIFICATION

The objective of waste package inspection and verification is to ensure confidence in the acceptability of packages for subsequent disposal at a chosen repository. As such, the programme of inspection must satisfy the needs of a range of audiences including those of regulators, the repository operator and the waste generator.

2.1. SAFETY AND REGULATORY REQUIREMENTS

There are three phases associated with repositories, i.e. pre-operational, operational and post-closure, which all have an impact on quality requirements of waste packages [4]. The pre-operational phase includes site selection, facility design, safety studies and construction. The operational phase includes waste disposal itself and those aspects necessary to prepare the site for closure. The post-closure phase will concentrate on monitoring the integrity of the repository. During the last two phases, the safety of the repository relies to some extent on waste packages (for example, on their integrity and durability), including their associated quality management system. However, it is during the first phase that waste acceptance criteria will be established although these may be reviewed and updated as necessary from time to time.

The safety and regulatory requirements for packages therefore must address: (a) the safety of workers during the management and emplacement of the wastes and during

installation of site closure measures and (b) the safety of members of the general public during both the operational and post-closure phases. Safety must include both radiological and non-radiological aspects. Radiological safety will include radiation and contamination levels associated with the waste packages and, in particular, the performance of the total waste package in terms of potential release of activity into the environment. Non-radiological safety aspects will include both conventional safety issues associated with mechanical handling and the safety of the package and its contents in terms of exclusion of dangerous materials such as explosives and significant levels of toxic wastes (the definition of significant levels would be Member State specific).

Waste acceptance criteria will take into account either generic studies or site-specific safety assessments and will address all the aspects identified above. Safety standards against which to judge these assessments exist at the international level [4] and may require adaptation at a national level. Typically, waste acceptance criteria will include aspects on radionuclide content, the physical, chemical and biological properties of the wastes and on the nature of the waste containers. These are discussed in more detail in Section 3 of this publication.

If the repository site is located away from the generator site, transport of the waste from the waste generator to the repository may impose certain additional requirements on waste packages. This may depend on whether the disposal package is itself adequate to meet the required safety standards for waste transport [5] and appropriate national standards or whether some form of reusable overpack is used for compliance with transport requirements. In particular, transport requirements should be consistent with the IAEA transport regulations [5]. The extent to which the repository operator wishes involvement in these aspects will vary from operator to operator, but compliance with these requirements for transport has to be included in a waste generator's overall waste management quality assurance programme and in many cases is also likely to be required by the repository operator.

2.2. QUALITY ASSURANCE

2.2.1. Importance of quality assurance

The establishment of a quality assurance system is an important requirement of the IAEA's safety standards for radioactive waste management [6, 7].

In principle, the quality assurance requirements for design, construction and operation of repositories will be similar to those for other nuclear facilities [4].

Quality assurance systems have to be developed and implemented by both waste generators and repository operators. The quality assurance system for a repository needs to define, to a large extent, the activities undertaken by the waste generators. Therefore, the repository operator will require the waste generator to provide the documentation necessary to comply with the repository operator's quality assurance requirements. With respect to the nature and the proper performance of any treatment, the determination of radionuclides, toxic and other materials subjected to concentration limitations [3], consignment documentation or any other actions that could affect the safety of disposal [4] will also be required.

2.2.2. Key elements

The repository operator should issue:

- formalized waste package design and manufacturing requirements to be complied with by the waste generator;
- standard format sheets listing all the information to be provided by the waste generator for each waste package.

The repository operator should review the quality of information supplied by the waste generator to provide an adequate level of assurance concerning the acceptance characteristics of the waste [4].

In any case, this information will cover proper definition of the nature and content of radionuclides, toxic materials and other materials subjected to concentration limitations in the waste.

Generally, conditioning of waste and preparation of waste packages is the responsibility of the waste generator. Sometimes, conditioning activities are achieved by the repository operator or by a third party. In any case, a quality assurance programme needs to be prepared detailing the arrangements to ensure the effective management and control of waste from its generation through to acceptance by the repository operator. (Refer to Section 4 for details).

2.3. INSPECTION AND VERIFICATION

2.3.1. General approach

Safe disposal of LILW is in the interest of the regulatory body, the repository operator and the waste generator.

The waste package is a key component for assuring the safety of the repository during operations and containment of waste to meet safety requirements established by the Member State regulatory body and after disposal operations cease and the facility is closed.

Assurance that waste package quality meets the waste acceptance criteria is the responsibility of the waste generator.

Independent and adequate inspection and verification of the waste generator's data for waste to be disposed of should be the responsibility of the repository operator.

Inspection of waste packages must be understood as an integrated activity giving suitable assurance of waste package quality and waste generator compliance with the repository waste acceptance criteria.

There are several approaches for waste package inspection and verification, depending on the policies of individual Member States. The Annex gives descriptions of some national policies and practices. In the following paragraphs, the most widely applied approach for waste package inspection and verification is given.

2.3.2. Process overview

Requirements on waste acceptance criteria for waste packages may be derived from the regulatory body and other national or international standards. These requirements, as well as specific conditions that may be determined from the safety analysis for the repository, would be documented in the site specific waste acceptance criteria.

Figure 1 provides an example of a process to achieve waste package quality reflecting the establishment of site specific waste acceptance criteria and the responsibilities of the waste generator and repository operator. It has to be noted that further waste conditioning may be performed by either the waste generator or the repository operator.

2.3.3. Responsibilities

In carrying out work between different organizations it is always necessary to be clear about their respective responsibilities and the nature and management of the interfaces. The responsibilities within each organization will be documented within the appropriate management systems. It is therefore valuable to jointly review the interfaces identified in each system and ensure that they are compatible and that a common understanding exists on how the interfaces will be managed. It is preferable that the repository operator has a document describing the management of interfaces which can be accepted by and be common to all or at least many of the waste generators.

In terms of responsibilities, as shown in Figure 1, three main areas could be identified as follows:

- regulatory body, to define safety regulations and general waste acceptance criteria;
- repository operator, to define site specific waste acceptance criteria and authorize acceptance of waste packages for disposal;
- waste generator, to ensure that waste packages are produced under a waste package quality assurance programme and within waste acceptance criteria.

(a) Regulatory body

The regulatory body has overall responsibility in a Member State to ensure compliance with safety requirements in any nuclear facility. Similarly for a radioactive waste repository, the regulatory body oversees the overall safety affecting workers, public and the environment. The waste package is an important component of a multi-barrier approach to achieve the desired level of safety during operation and closure of the repository and the subsequent post-closure phase. The regulatory body may provide guidance on:

- general waste acceptance criteria under a national waste management policy;
- site specific waste acceptance criteria;
- licence conditions for various activities at different stages (design, construction, operation, closure);
- compliance methodology by periodic returns, visits, reviews, audits;
- review and approval of systems for non-conformances, modifications, unusual occurrences, etc.

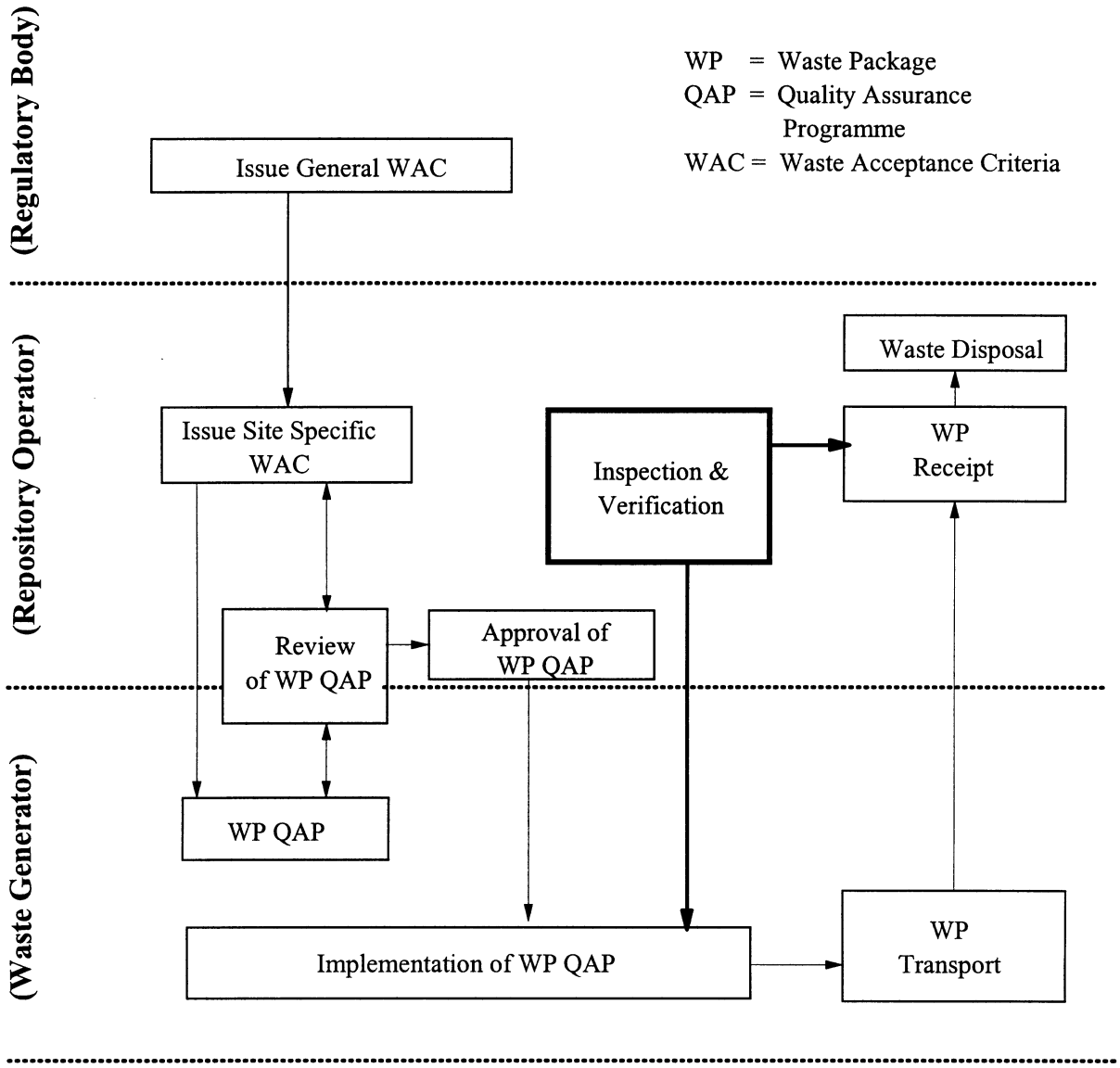

Fig. 1. Involved parties' major responsibilities for waste package process.

(b) Repository operator

The repository operator should establish site-specific waste acceptance criteria that encompass requirements of the regulatory body and the repository. Confirmation of compliance with the site-specific waste acceptance criteria is through inspection and verification, performed by suitably qualified personnel at the waste generator site, the repository or a combination of both.

The criteria affecting waste packages should include requirements addressing:

- package contents (radiological and non-radiological);
- acceptable waste form and container parameters;
- quality assurance;
- reporting and documentation; and
- record keeping.

Inspection and verification conducted at the waste generator site could include:

- review of waste container procurement records including manufacturing certification statements and testing results;
- evaluation of operating procedures affecting waste packaging;
- evaluating test results from conditioning activities; and
- evaluating results of quality assurance programme oversight activities (surveillance, audits).

Inspection and verification conducted upon receipt of generator-certified waste packages at the repository, prior to final acceptance by the repository operator, could include:

- administrative review of shipping papers to verify compliance with weight restrictions, package handling and size limitations, radiation dose and contamination limits;
- conducting standard waste package verifications (radiation fields, external contamination, and weight);
- use of non destructive examination (e.g. radiography) and assay techniques to perform a limited verification of selected waste packages;
- destructive examination and sampling of selected waste packages.

Detailed discussion on inspection and verification methods and procedures is provided in Section 5.

(c) Waste generator

The generator of the waste has the primary responsibility to meet waste acceptance criteria established by the repository operator and transportation requirements. Additionally, the waste generator may be financially responsible for actions that must be taken to correct deficiencies identified during inspection processes.

Each waste generator has to establish a quality assurance programme describing his overall plan, approach, methodologies, and quality assurance methods that will be implemented to meet the repository operator's waste acceptance criteria. This programme, discussed further in Section 4.1, should require approval by the repository operator prior to acceptance of waste.

Each waste generator has to establish internal inspection procedures [2] to provide confidence that conditions that may affect the quality of the final waste package are monitored and controlled. In general, these internal inspection procedures should address:

- evaluation of raw waste, adequate inventory assessment and control of materials subjected to concentration limitations;
- control of materials used to condition wastes;
- quality of waste containers;
- control of conditioning procedures;
- measurements made during waste loading or conditioning activities;
- verification of the waste package documentation prior to transportation to the repository;
- non-conformance control and corrective action (e.g. with respect to an operating process envelop [8]).

Such inspection should only be performed by persons that have been properly trained and qualified for the task. Appropriate documentation (procedures, checklists, surveillance reports, audits, results of independent samples) must be maintained for inspection by the repository operator.

3. WASTE ACCEPTANCE CRITERIA FOR DISPOSAL

The overall safety of a near surface repository depends on the combined characteristics of the site, the repository and the waste package and is of concern to the regulatory body, waste generator, repository operator and also to the public. Waste acceptance criteria may include general criteria issued by the regulatory body and site specific criteria identified by the repository operator [4]. Important features of the general and site specific criteria are given below.

3.1. GENERAL CRITERIA

The regulatory body should provide guidance to ensure safety of the entire repository system. Over the life of the repository, short- and long-term isolation of the repository inventory from the environment has to be provided by the repository system. The general criteria provide guidance in technical areas related to waste acceptance, for which more specific criteria could be developed by the appropriate repository operator based on the safety assessment of the repository.

Important aspects of the general criteria may include but are not limited to [4, 9]:

(a) Stabilization of waste

– solid, non-dispersible form.

(b) Radionuclide content and associated factors

– limitation of radionuclide inventories and/or concentrations;
– identification of the type, characteristics and contents of radionuclides;
– limitation of external radiation field;
– control of surface contamination.

(c) Physical, chemical and biological properties

– sufficient mechanical strength for handling and to bear design loads in the repository;
– control of the physical and chemical characteristics of materials that can cause chemical, biological or radiolytic processes giving rise to gas and/or heat generation, corrosion and accumulation of degradation products, and swelling of materials;
– limitation of free liquids;
– control of materials that may represent chemical or biological hazards.

(d) Fire hazard properties

– control of the combustible, pyrophoric and other fire hazard properties of waste

packages.

(e) Configuration and identification

- compatibility with handling, transport and emplacement systems;
- package identification.

3.2. SITE SPECIFIC CRITERIA

Site specific criteria may be needed to augment and/or quantify general criteria defined by the regulatory body or international standards [4]. Site specific criteria may be determined based on results of repository safety assessments, considerations due to the design of the repository, environmental considerations and requirements for protection of the general public. Some examples of the need for site specific criteria that may need to be established by the repository operator could include:

(a) Enhancement of repository safety

Since waste packages will be placed in a near surface repository, the repository operator could require that the waste packages are capable of supporting several meters of overburden upon closure of the repository. This could require the waste generator to place this waste into a container designed to support the additional weight of the cover. The lack of this additional criterion could lead to a compromise of the repository system through the collapse of the protective cover.

(b) Standardised operation

To provide a cost-effective service, the repository operator may require all waste generators to adhere to specific waste package designs to minimize handling requirements and equipment, improve operational safety, utilize repository space and minimize exposure.

(c) Radionuclide concentration limits

The repository layout may require on the concentration of specific radionuclides within waste packages. For instance, heat release from radioactive decay may affect the engineered barrier after closure of the repository. To avoid such degradation, the repository operator could set upper limits of radionuclides in specific waste packages.

4. WASTE PACKAGE QUALITY ASSURANCE PROGRAMME

4.1. PREPARATION OF THE PROGRAMME

Guidance on the establishment of a quality assurance programme has already been published by the IAEA [2, 6, 7].

Each waste generator has to implement a quality assurance programme (a separate program could be implemented for each waste package category). The objective of this programme is to enable the waste generator to certify waste packages and to provide the

repository operator with a complete plan of the approach, methods and quality assurance measures used by the waste generator to meet waste acceptance criteria. The programme forms the auditable baseline against which the repository operator can evaluate compliance with waste acceptance criteria.

Key elements addressed in the waste package quality assurance programme need to include:

- strategy and quality assurance methods used to verify compliance with repository waste acceptance criteria;
- organizational and management structure including roles and responsibilities of key personnel involved with waste generation, packaging, and compliance activities,
- overview of processes generating the waste requiring disposal, including conditioning that will be performed to meet the repository waste acceptance criteria;
- description of the waste generator quality assurance system and controls to be implemented (internal surveillance, audits, calibration programmes, reporting of deficiencies) to meet the waste acceptance criteria and other operational requirements of the repository;
- description of methods used to characterize the final waste form for disposal (characterization tests on non-radioactive mockups, sample collection methodologies, laboratory methods, data interpretation, record keeping);
- description of methods used to assess the activity for each waste package;
- description of methods used for packaging waste for transport and disposal. Procedures may be written according to the general guidelines defined by the repository operator in the waste acceptance criteria;
- description of methods for transmitting data to the repository for review and approval prior to shipment;
- description of methods for records management, including retention times.

Appropriate reviews and approvals should be performed as described in Section 4.2.

4.2. AUTHORIZATION, REVIEW AND APPROVAL

4.2.1. Authorization

In general, authorization for acceptance of each waste package category to the repository is the responsibility of the repository operator. Approval of the quality assurance programme has to be part of the authorization process and should cover key elements identified in Section 4.1 and any supporting documentation.

A preliminary audit must also be part of the authorization process and has to be conducted by the repository operator at the waste generator's site and, if different, at the conditioning site. This audit has to cover all the aspects that may have an effect on waste package quality. The main reference document for audit implementation will be the quality assurance programme as defined in Section 4.1. The quality assurance programme and the preliminary audit report will be used to determine whether the waste generator is authorized to consign waste packages to the repository.

4.2.2. Review and approval

To confirm continued compliance with the quality assurance programme, the waste generator has to periodically review the activities performed. Any resultant changes that may have an effect on package quality should be submitted to the repository operator for information or approval as required.

A programme of periodic audits has to be carried out by the repository operator during waste package production and shipment from the waste generator to the repository operator, to confirm the effectiveness of the quality assurance programme and to identify areas for continuous improvement. The frequency would be defined by the repository operator.

Periodic meetings need also to be held to review technical and package quality problems, and to evaluate the eventual impact of any modification that could affect the quality assurance programme.

4.3. APPROVAL OF HISTORICAL WASTE

There may arise occasions when waste packages are prepared for disposal, at least in part, prior to the establishment of a fully approved waste package quality assurance programme. This is most likely to arise for historical reasons where waste has been prepared for interim storage prior to availability of the waste acceptance criteria and/or repository. It may also arise where a waste generator has processed waste without adequately considering the needs and requirements for its disposal. Clearly, in a well managed system, the latter will not occur. All efforts have to be made to identify waste generators prior to actual waste generation, and to ensure that the necessary requirements of the repository operator for acceptance of waste are adequately implemented.

However, in cases where waste does exist prior to authorization of the quality assurance programme, consideration may need to be given to assess its acceptance for disposal. Waste that does not meet the requirements of the waste acceptance criteria may need to be considered further and acceptability can only be judged on a case-by-case basis. Such reviews need to cover all the aspects of the current quality assurance programme. In addition, all available information should be reviewed and the importance of any deficiencies assessed in terms of the potential adverse consequences. The review needs to take into consideration the volume, activity and other characteristics of the waste, including regard for any potential adverse consequences on other waste in the repository and on the overall performance of the repository itself [10]. The review has also to consider the need for any further work or measurements including their practicality and the costs of such work. This will depend on the nature of the waste and the extent of any conditioning already carried out. However, such considerations must not lead to the acceptance of any waste if there are any significant uncertainties remaining.

As examples, the nature of such waste, including its activity content, may be sufficiently known or limits placed on the important properties and parameters by knowledge of the process in which the waste was generated. In other cases, the volumes may be sufficiently small that on an infrequent basis, greater levels of uncertainty on the activity assessment may be acceptable provided other aspects can be satisfied. However, in other cases, the levels of activity or non-radiologically hazardous substances may not be adequately known or

estimated. In such cases, this waste can only be accepted based on an approved programme of work possibly including either non-destructive examination/assay or intrusive sampling to obtain additional information. The appropriate level of such sampling will depend on the uncertainties and associated adverse consequences and could be on a proportionate basis. The basis of such work must, however, always be discussed between the waste generator and the repository operator and agreement reached before the work commences.

It may also be necessary, depending on the circumstances and on national approaches, for the regulatory bodies to be involved.

5. INSPECTION AND VERIFICATION BY THE REPOSITORY OPERATOR

This section is written with the assumption that conditioning is implemented at the waste generator's site. The requirements identified in this section are, however, applicable if conditioning is implemented at another site or at the repository.

5.1. AT THE WASTE GENERATOR'S SITE

5.1.1. Qualifications and procedures

Inspection and verification have to be carried out by suitably qualified personnel using approved procedures. Personnel need to:

- possess appropriate academic background and work experience;
- be able to get an overview of the process generating the waste package, including conditioning;
- be familiar with and understand the relevant procedures and methods to be implemented by the waste generator;
- understand demands and implement specific inquiries, as defined prior to inspection.

According to the general quality assurance programme for disposal, a specific procedure must be written to define inspection and verification at the waste generator site. The procedure will deal with:

- methodology,
- preparation (planning, programme, etc.),
- implementation,
- reporting and supporting records,
- non-conformances and corrective actions.

5.1.2. Verification by document review

Document review needs to verify that waste packages meet the requirements defined in technical documents of the waste generator in line with the waste package quality assurance programme.

These reviews need also to be carried out to a defined scope and follow an agreed plan covering the major aspects of waste conditioning.

(a) Scope

Document review may involve all documentation identified in the quality assurance programme, in particular:

- files relevant to waste packages with all the records from waste collection to packaging prior to shipment;
- operating procedures and test methods used for conditioning and checking the final waste form for disposal;
- documentation related to the control of the process parameters (calibration programmes, reporting of deficiencies, etc.).

(b) Plan

To perform a document review, specific plans may be used, which may provide references to associated documents and reporting format. Such plans may include:

- successive operations from raw waste collection to packaging;
- requirements for each step;
- identification of waste generator applicable reference;
- reference of record relevant to operation;
- results of review (conformance, deficiencies, non-conformance, corrective actions required).

(c) Major aspects

Raw waste

- General characteristics,
- Absence of prohibited materials, such as liquid, toxic chemical, explosive, pyrophoric material, or methods used to make safe any such materials.

There should be information available on waste collection and segregation that could be supported by direct inspection.

- Activity evaluation

  Activity evaluation of raw waste is generally based on indirect methods (radiation field measurement and activity calculation), and/or direct method (measurement of the whole waste package or of samples). The evaluation may consist of calculation checking and/or review of all parent documentation, such as reference spectra for the waste, calibration of equipment, etc.

- Collection and pretreatment of waste

  Checking of record sheets will confirm that applicable procedures have been followed (intermediate container; prohibited mixtures; dimensional limits; activity limits; eventual treatment such as compaction, cutting, etc.).

Container

– General acceptance

A check needs to be made to ensure that procedures have been implemented for containers, including minimum compliance with the container specification, for:

- dimensional control (assessment sheet);
- leak tightness test if required (assessment sheet);
- verification of specific operator's requirements (to be recorded);
- proper identification and tracking.

– Supplementary documentation

If containers have a specific function, as defined in waste acceptance criteria (i.e. containment of radionuclides, durability), supplementary documentation has to be recorded and could be checked during inspection of the container construction material. Records could be provided on:

- materials of construction (metals and coatings for metallic containers; cement and aggregates for concrete containers);
- manufacturing data (formulation, parameters, non-destructive test records).

Conditioning process

– General acceptance

Checking of documents may summarize all the general information relevant to conditioning (date, place, specific devices if any).

– Operating procedure

The quality assurance programme implemented by the waste generator may produce records for the conditioning procedure which could be reviewed during verification, e.g.:

- receipt of constituent materials for immobilizing matrix and for any encapsulation layer (including recording sheets, assay records if any);
- control sheet relevant to formulation;
- conditioning parameters (such as mixing time, sequence of addition, etc.).

– Control after conditioning

Review could include filling level, visual examination report (absence of liquid, specific non-conformance if any).

Waste package

– General acceptance

Waste generator files need to include control sheets giving:

- waste package weight;
- specific activity of significant radionuclides present;
- radiological control (dose rate and surface contamination);
- visual inspection report (absence of defects which could affect handling, transport and storage of waste packages);
- calibration records;
- non-conformance record sheets.

Reviews need to be carried out for all relevant documentation, including reviews of records relevant to calibration of equipment to be used for control.

– Supplementary documentation

Waste acceptance may require, in some cases, supplementary inspection. Such inspection may be non-destructive, or require destructive sampling of a percentage of packages [3]. Implementation of such tests should be recorded and reviewed during documentation checking.

5.1.3. Direct inspection

Direct inspection provides an opportunity to ensure that relevant parameters meet the waste acceptance criteria at all stages of waste packaging. It has to be carried out within a well defined scope following a plan covering major aspects of waste package production.

(a) Scope

– Direct inspection may cover waste package manufacturing steps from raw waste collection to segregation, conditioning and on-site storage;
– Inspection needs to be implemented in any part of waste generator facilities performing the operations listed in an inspection plan;
– The frequency of inspections will depend on various factors, such as results of previous inspections, the length of a conditioning campaign, the number of waste packages, the radionuclide content of waste packages, the past performance of packaging, etc.

(b) Plan

At the beginning of inspection, the inspector has to review the implementation of prior corrective actions. The inspection plan needs to include key elements such as:

– processes to be reviewed,
– measurements to be taken,
– analysis and reporting of results.

Prescribed forms may be used that identify values for measurements that have to be implemented at the waste generator sites.

(c) Major aspects

Raw waste

– General characteristics (presence of prohibited materials)

The presence of prohibited materials needs to be checked by direct examination of primary containers used for waste collection.

Inspection will also deal with:

- effective information by posters, notices, etc.;
- specific collection of prohibited materials only in designated container and methods adopted to deal with them;
- pretreatment of waste containing moisture and solvents, including chelating agents.

– Activity evaluation

Direct measurements may be observed if performed during the visit, or indirect measurements may be performed for example radiation fields.

– Collection and pretreatment of waste

The devices and processes implemented for collection and specifically for treatment like cutting, compaction, etc. may be observed.

Container

Inspection may be implemented on selected containers to check:

– dimensional control,
– absence of defects which could affect handling, transport and storage of the waste package.

Conditioning process

Inspection has to include, as a minimum, a visit to the waste conditioning facilities and general checking of operations to verify compliance with an approved process description. Special attention needs to be given to the storage conditions of constituent materials for the immobilizing matrix and for the encapsulation layer, as necessary.

Waste package

– General assessment

Inspection has to be implemented on selected waste packages to confirm:

- labelling/tags/identification marks;
- weighing (implementation of repeat measurement);

- radiological measurement;
- visual inspection (i.e. absence of defects which could affect handling, transport and storage of waste packages).

– Supplementary inspection

In the case of specific non-destructive or destructive testing performed by the waste generator as defined above, inspection may also cover overseeing the tests and evaluation of results. Prior to destructive testing, consideration needs to be given to subsequent re-conditioning.

5.1.4. Follow-up action

Inspection and verification at waste generator facilities may be implemented per an established procedure and need to define follow-up of non-conformances and corrective actions.

Full and up-to-date information from inspection and verification activities need to be maintained in a database to assist with the planning and scheduling of any additional inspection and verification.

Formats have to be defined for non-conformance and corrective action and need to include waste generator replies with time limits for implementation.

5.2. AT THE REPOSITORY

The majority of controls to ensure the acceptability of waste packages for disposal are generally carried out prior to receipt of the packages at the repository itself. These include those identified in the quality assurance programme (Section 4) and the inspections carried out at the waste generators' site (Section 5.1). However, it is important to carry out some inspections on receipt of waste packages at the repository, as this is the last opportunity to verify that the waste package meets the criteria for acceptance.

Inspections must be aimed at demonstrating to the repository operator and also to the regulator that the packages meet the required specifications. Some tests are to ensure that no damage or other deficiencies have occurred since dispatch of the package from the waste generator's site. Other tests add further confirmation on the suitability of the container and its contents for disposal.

The range of inspection and verification activities carried out on receipt of waste packages are:

– administrative checks,
– visual checks,
– direct measurements.

Examples of these are given in Table I and are discussed below. In practice, it is a combination of all three of these methods that is generally adopted at the repository. When the repository is not fully equipped to carry out specialized tests such as tomography, torque test,

destructive test, etc., expertise from other bodies may be utilized. It is likely that such tests may have to be carried out in facilities outside the repository.

TABLE I. EXAMPLES OF WASTE PACKAGE INSPECTION AND VERIFICATION AT THE REPOSITORY

Administrative checks	**Visual checks**	**Direct measurements**
Completeness of consignment record	External package condition	Weighing
Package identification	Tamper seals	Radiation dose survey
Weight	Package closure	Radiological contamination survey
Activity limits		
Dose rate	Package labelling/ identification	Tightness (torque) testing
Surface contamination		Radiography/tomography
Shipment number		Activity measurement
Special conditions		Container integrity survey
Container type		Destructive testing
Fissile mass		

5.2.1. Administrative checks

On or prior to the receipt of waste packages, a consignment/shipment record listing the appropriate details of each package should be received. At this stage, important verification checks have to be carried out. A formal procedure for receipt and inspection of waste packages needs to be established by the repository operator. This procedure should address all verifications necessary to ensure that minimum transportation and repository requirements have been met. The procedure has to include a checklist or another appropriate record to document administrative review of shipping consignment forms. Examples of administrative verification checks include:

(1) *Completeness of consignment record:* This is to check that all necessary parts of the form have been fully completed. If any omissions are found, no further processing of the waste package should be carried out until the situation is remedied. This might entail embargoing the waste pending receipt of new documentation. If any new data are entered onto any forms, these must be carried out only under an approved procedure.

(2) *Package identification:* Prior to shipment, the waste generator has to notify the repository operator of the identification of packages that are certified as conforming, using a unique identification number for each package. The repository operator must verify that the packages received have the identifiers specified on the pre-shipment notification. This may be performed through a tracking system as described in Section 6.

(3) *Weight:* The recorded weight of the package needs to be checked against the allowable limits for that type of container.

(4) *Activity limits:* The recorded activity levels need to be checked against both package limits and limits for the repository site as a whole. The latter might include, for example, maximum quantities of either volume or certain activity classes, which can be disposed of in a specified period. Checks for numerical correctness of the data can be carried out, for example to ensure that summations and specific activities are correct.

(5) *Radiation field:* The recorded radiation field information has to be reviewed to ensure that the package is within acceptable levels for safe handling and disposal.

(6) *Surface contamination:* Waste packages will generally be expected to be free of contamination. Any significant contamination, above defined criteria, must be brought to the attention of the appropriate authority at the repository.

(7) *Shipment number:* The unique shipment number of the waste package has to be checked against the systems used for issue of such numbers. For example, numbers may be issued centrally by the repository operator or regulator or might be issued by each waste generating site. Any deviations from the range of identification numbers expected need to be investigated. Generally, prior notification of the delivery should have been received and confirmation carried out that the documentation received relates to the delivery notified and expected.

Special conditions: Any deviations from standard conditions must be identified and approved by the repository operator prior to shipment of the waste package. These might, for example, relate to large or heavy packages requiring additional handling facilities at the site, sometimes with several days' notice being required for the necessary arrangements to be made. Another typical example is when waste packages also contain hazardous wastes of a non-radiological nature, in which case additional procedures and/or disposal practices may have to be used. On identification of any special conditions, appropriate checks and actions should then be carried out.

(9) *Container type:* The type of container has to be checked against standard acceptable containers. Any differences from the listing have to be followed up appropriately.

(10) *Fissile mass:* The fissile content of the package has to be checked against acceptable levels both for individual packages and for its intended disposal location. Secondary checks can also be made to ensure consistency with activity levels recorded elsewhere on the forms.

Completed inspection forms have to be filed and available for examination by the regulatory body. Many of the checks can be carried out with the aid of a computer to ensure consistency of checking and data recording. Computers can also be used to prompt the inspector to carry out other checks. As part of a data management system for a repository, checks need to be carried out under an approved quality assurance programme and any modifications to a checking routine must be fully documented and approved.

5.2.2. Visual checks

Visual inspection of waste packages can provide a relatively easy and inexpensive way of increasing confidence in the suitability of the waste package for acceptance by the repository operator and enhancing the safety of operations. Such visual checks can also be carried out at the waste generator's site.

Personnel conducting visual examination have to be suitably trained and qualified. Inspections need to be conducted by use of a formal procedure and the results recorded on inspection forms. Deficient waste package conditions must be reported promptly to appropriate authorities to allow determination of corrective actions, including rejection of the waste package or shipment. Completed inspection forms have to be filed and available for examination.

Visual examination may include:

(1) *External package condition:* Examination of the external condition of the waste package can identify potential problems prior to initiating off-loading operations. Early identification of potential problems allows for remedial actions that could prevent a release or spread of contamination.

Examinations need to be conducted for evidence of waste package damage (dents, punctures, cracks, swelling, etc.), extensive corrosion, evidence of leakage from the package (discoloration, streaking), and damaged or missing waste package closure mechanisms (bolts, screws, welds).

(2) *Tamper seals:* Use of tamper seals, or security seals, on a waste package could indicate attempts to compromise the waste package integrity. Radiological surveys should be immediately performed and corrective actions taken on discovering seals are missing or broken.

(3) *Package labelling/identification:* All required labels and markings must be affixed to the container and in good condition (legible, not torn). Bar codes applied to the external package may also contain required information. Specific external waste package information may be determined by the regulatory body. Examples may include: weight, radiation field, package manufacturer, certification marking or plate, and name of the facility or company that generated the waste package. Comparison of external waste package labels needs to be done with shipment documentation supplied by the waste generator.

5.2.3. Direct measurement [11, 12, 13]

Techniques for direct measurement and verification of compliance with waste acceptance criteria provide an increased level of confidence in waste package documentation supplied by the waste generator. These techniques can range from relatively simple and inexpensive methods (e.g. contamination surveys) to more complex methods (e.g. destructive sampling) that are more expensive due to the need for sophisticated equipment, facilities and highly trained and qualified personnel.

Selection of direct measurement methods has to be based on:

- regulatory body requirements,
- repository operator safety considerations,
- results of other inspections at the waste generator site and repository,
- maintaining the radiation exposure of workers as low as reasonably achievable (ALARA),
- the practicality and cost associated with the implementation of the measurements.

Assay procedures have to be implemented according to specific quality assurance plans, that may include:

- use of proper calibration standards,
- training and qualification of operators including periodical re-qualification,
- record keeping requirements, including appropriate corrective actions determined.

Inspections can either be carried out on all waste packages received or on a proportionate basis. When carrying out inspection on a proportionate basis, i.e. less than 100%, the consideration for selection of waste packages is to be specified. Typical bases for sample selection include:

- new waste generator,
- new waste stream,
- high activity consignments,
- high volume consignors,
- feedback from other inspections and audits.

In any event, a routine cycle should also be established to ensure periodic, e.g. annual, sampling of waste from each waste generator.

Use of direct measurement methods will generally require specific calibration and operating procedures, trained and qualified personnel and equipment maintenance procedures. A structured approach is necessary to ensure that data obtained from direct measurement techniques meet minimum quality objectives and can be used, with confidence, for validating information supplied by the waste generator.

Examples of direct measurement techniques include:

(1) *Weighing:* Digital or analog scales can be used to verify selected waste package weights for comparison with waste generator reported values. Accurate weight determinations support safe handling operations and compliance with radionuclide activity limits specified by the regulatory body.

(2) *Radiation field survey:* Hand-held or portable radiation monitors can be used for verifying waste generator conformance to radiation field limits and accurate reporting of individual waste package field levels to ensure safe repository operations and maintaining ALARA goals for personnel radiation exposure. Survey of all waste packages should be considered, unless doing so would result in unwarranted radiation exposure of personnel.

(3) *Radiological contamination survey:* Survey of external waste packages verifies compliance with acceptance criteria and transportation limits of surface contamination and can serve as an indication of loss of waste package integrity.

(4) *Tightness (torque) testing:* Compliance with waste package closure requirements for metal containers could be verified by checking bolts with a calibrated torque wrench.

(5) *Radiographic/tomographic examination:* Radiographic examinations could be used for verifying physical waste form, compliance with a free liquids criterion, verifying the absence of pressurized containers, and evaluating void space. A typical radiographic system consists of an X ray generation unit, camera-based imaging system, container handling system, data processing equipment, radiation enclosure and operator control system.

Tomography allows non-destructive testing like physical homogeneity, visualization of voids and cracks, and inclusion of pieces of metal by evaluation of density. For example, a source of Co-60 can send beams of gamma rays across the waste package and their attenuation is measured by a set of gamma detectors. Another application of tomography is to identify whether any biological protection is present in old packages when such information is not available.

Inspection of waste packages can be performed in "real-time" and results recorded electronically.

(6) *Activity measurement:* Non-destructive assay of waste packages could be performed to determine the types of radionuclides present in the waste and their associated activity levels to verify the values reported by the waste generator. A variety of non-destructive measurement systems exist that may meet repository assay needs. Measurement methods include: gamma ray (high resolution spectroscopy, transmission corrected methods including segmented and computed tomographic scanners) and/or neutron measurements (passive, passive/active, thermal neutron capture) of fissionable/fertile materials. Typical systems include the radiation detection package, diagnostic equipment and software, waste package handling/interface equipment, and a control system.

Considering the cost of such devices against benefit gained, the repository operator has to consider alternatives between effective implementation at the repository site or by an external agency. Selection of assay instrumentation should take into consideration the type of radionuclides contained in the waste, package geometry, etc. In any case, the repository operator needs to implement activity measurements if conditioning is performed at the repository site on certain waste for which details of activity are not available.

(7) *Container integrity survey:* For metallic waste packages, verification of the thickness of the external (outer) wall can be accomplished using hand-held ultrasonic instruments. Application of this technology would be useful if the containment properties of the waste package are important to long term performance of the repository. Radiation exposures of personnel have to be considered when conducting this type of direct measurement.

(8) *Destructive testing:* Developing and implementing this method can be complex and expensive. Radiation exposure to operating personnel is also a concern. Specialized facilities for radiological containment, such as a glovebox or hot cell, may be required.

Destructive testing can be used to verify the physical contents of a waste package, the presence/absence of prohibited or restricted materials, the homogeneity of conditioned waste, properties of the conditioning matrix, the types and quantities of radionuclides present (notably those that do not emit gamma rays) and to determine the presence of hazardous chemical constituents in the waste.

Examples of situations where destructive testing may be needed include historical waste packages for which limited data exist, examination of waste packages that are suspect and cannot be returned to the generator, or as part of a routine quality assurance programme.

A sampling and analysis plan needs to be developed to document the type of sampling to be performed, the frequency of sampling and the selection method for waste packages, the analytical measurements to be performed, the data quality objectives, the process for reviewing and validating analytical results, the reporting of results and record keeping requirements.

6. INTERFACE ISSUES

Interfaces issues will be associated primarily with waste acceptance criteria and the needs of the repository operator to assure the quality of waste packages. As discussed in earlier sections, the latter may involve document review and inspection and verification carried out at the waste generator's site and at the repository. The important interface issues are related to waste tracking and documentation, non-conformances and deviations and communication of results.

In practice, more than two organizations may be involved, for example the waste may be generated at one site, further conditioned at another and disposed of at a repository. Or it may be that some of the conditioning is done elsewhere but final conditioning such as grouting, is carried out at the repository. In these cases, it is important that the respective responsibilities of the various organizations are clearly defined and the interfaces appropriately managed.

6.1. WASTE TRACKING AND DOCUMENTATION

6.1.1. Waste tracking [11]

Waste tracking systems can be used to manage information associated with wastes from the point of waste generation to the final repository. Generators and repository operators may have independent or integrated tracking systems.

The waste generator has to provide documentation on approved forms with all auditable information relevant to package production (records, testing, sampling, analytical batch data reports, checklists, certificates, etc.). Package labelling has to be implemented for checking,

control and tracking of all information for the waste package. Transmission of data may be by hard copy or through electronic means supported by a database. The repository operator should manage, according to a quality assurance programme, an auditable system dealing with certification of packages and the tracking of waste received.

6.1.2. Documentation

A records management system (RMS) has to be defined and implemented by the repository operator. This system must meet the requirements defined by a quality assurance programme implemented for reception, interim storage, if existing, and the disposal of waste packages. It should record package identifiers and locations and it should be designed to effectively manage the transfer of wastes to and from storage facilities and to final disposal.

The RMS has to provide adequate control and retention for all the information. Records inventory, retention, changes and disposition, should be specified by an authority responsible for records administration.

Data and related information need to be maintained in a central file. Records have to be clearly identified, and secured within a controlled access facility. Data relevant to the electronic tracking system have to be formatted in accordance with the repository operator’s computer system, including internal network requirements.

All data defined in the RMS need to be traceable to the original raw data records, of which some are the responsibility of the waste generator.

The RMS has to include all information relevant to inspection and verification, non-conformance and corrective action performed both at the waste generator's site and at the repository.

The flow of data and records has to be defined in written form with supporting diagrams. Persons in charge of data/record validation and verification have to be identified.

Finally, waste generators must be notified of the acceptability of their waste after standard waste shipments have been verified against acceptance criteria, for non-standard shipments such as historical wastes and for cases were treatments were carried out to correct non-conformances. Validation could be transmitted using hard copy or by using electronic transmittal of data against reference quality assurance parameters to ensure validation of:

- reference data for calculation,
- control parameters,
- compatible format with data generation.

6.2. NON-CONFORMANCES AND DEVIATIONS

A system has to be established for reporting changes and deficiencies in processes affecting the quality of final waste packages, identified during either waste generation or during repository operator inspection and verification. A non-conformance report needs to be

prepared for each uncontrolled and unapproved deviation from an approved plan, procedure, or expected result identified during inspections. The non-conformance report needs to provide the following minimum data:

- identification of person highlighting the non-conformance,
- description of the non-conformance and identification of waste package,
- method(s) or suggestion(s) for correcting the non-conformance (i.e. corrective action),
- schedule for completing the corrective action,
- assessment of the impact of the non-conformance on the quality of the waste package,
- inspector's signature.

The non-conformance report has to refer to completion of the corrective action and subsequent acceptance.

The corrective action needs to address (a) returning a particular non-conforming package to an acceptable condition for disposal, and (b) adjusting the process that generated the defective package so that more non-conforming packages are not generated due to the same cause if it is left uncorrected.

The management of non-conforming waste packages received at the repository is itself an important issue. Much will depend on the nature and significance of the non-conformance. It may be that remedial work can easily be carried out on the waste package to ensure its conformity, e.g. by removal of minor contamination on the external surface of the package. It may be that a non-conforming item can be removed and either treated so as to make it safe for disposal or return it to the waste generator. In other more significant cases where remedial work cannot be carried out, the waste package may have to be returned to the generator. If this is so, particular attention must be paid to its acceptability for transport. In all cases of non-conformance, the measures taken need to be clearly agreed with the waste generator, and with the regulator as appropriate under licence conditions, and suitably documented.

Deviations from standard operating procedure must be approved and such changes incorporated into approved plans and procedures. The need for a deviation may be caused by identification of a process improvement opportunity or due to unusual or non-routine occurrences that affect the operation, but must not be related to an inability to comply with repository waste acceptance criteria or other established requirements.

When a deviation is required, it has to be recorded and approved by appropriate management, including the repository operator if applicable, before initiating the activity or operation that deviates from normal, approved procedures. The record needs to provide the following minimum data:

- identification of affected process, operation or procedure,
- reason for deviation from existing procedures,
- description of the planned deviation,
- description of special equipment or personnel required,
- appropriate signatures.

6.3. COMMUNICATION OF RESULTS

Inspections, verifications, and audits must be documented. Adequate documentation and proper record keeping and retention of results provide a mechanism to demonstrate to the regulatory body that the waste management system is monitored and controlled. A well managed system increases the confidence of the regulatory body, the repository operator and the public.

Results of inspections, verifications, and audits should be reported quickly to appropriate management and operations personnel, to ensure that corrective actions are identified and implemented according to an agreed schedule and to minimize the production of non-conforming waste packages.

A process for documenting results, completing reports, and implementing corrective actions has to be established and scheduled. A typical process may include:

- immediate notification of results to the affected operators, management and staff (also referred to as a close-out meeting),
- formal preparation and issue of the report within a reasonable period of time,
- formal response by affected operators with planned corrective actions and completion schedule,
- acceptance of proposed corrective actions by the originator of the report,
- follow-up and verification to confirm that corrective action has been implemented.

Non-conformances must be categorized and corrective action implemented in accordance with their nature and with the importance of possible consequences.

7. CONCLUSIONS

This report provides an overview of commonly used procedures and practices for inspection and verification of waste packages to be disposed of at near surface repositories. In general, there is a common approach in many countries on this issue and many of the practices can also be found in many national programmes. This is encouraging and adds confidence to the methods being adopted.

It must be recognized that the extent of inspection and verification will vary depending on the number of waste packages, the nature of the waste and their radioactivity and the potential for deviations from the acceptance criteria. While the approaches and practices may be common in many countries, and for many near surface repositories, the extent of waste package inspection and verification can only be established on a country-by-country basis.

A quality assurance programme of inspection and verification activities must be sufficient to ensure a high degree of confidence in the acceptability of waste for disposal. While the quality programme has to be acceptable to the waste generator, it is essential that it

addresses the needs of the repository operator and the expectations of the regulatory bodies and the general public. The programme must be relevant and, therefore, it has to recognize what is practicable and consider the limitations as to what can be reasonably carried out by way of inspections and verifications. Meeting the reasonable expectations of the various stakeholders is important in ensuring and maintaining overall confidence in a waste management system.

Lastly, it is important that the waste package inspection and verification programme is clearly defined. This will commence with defined waste acceptance criteria and includes a range of activities to be carried out up to, and including, the reporting and management of results. This will avoid surprises, differences of understanding and the need for ad hoc decisions. Only in this way can a systematic approach to inspection and verification be carried out and the necessary confidence be achieved in the acceptability of the waste packages for disposal.

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Annex

POLICIES AND PRACTICES OF MEMBER STATES

CANADA

1. ACCEPTANCE OF WASTE

Atomic Energy of Canada Ltd (AECL) has been storing radioactive wastes arising from operations at its Chalk River Laboratories (CRL) site along with wastes generated from universities, laboratories and industries across Canada since the mid 1940s. When this IAEA publication was written, efforts were underway to license a prototype, near surface disposal facility. A critical component of the success in implementing the Intrusion Resistant Underground Structure (IRUS) disposal facility is the development of protocols and procedures for waste characterization, classification and processing and conditioning. Acceptance of waste is governed by disposal facility limits established from performance assessments, which determines how much waste might be disposed in a specific engineered disposal facility such as IRUS. The wastes that contain the contaminants that have the most significant impact upon performance assessments must be characterized and monitored adequately.

2. WASTE INVENTORY MANAGEMENT SYSTEM

Wastes are classified for storage and future disposal at CRL based on their radiological properties and according to their processibility. In support of the IRUS disposal facility and for continuing overall operations in the waste management areas at CRL, the Waste Management and Decommissioning Division at CRL has developed a waste inventory management system, WIP-III[1]. The latest version of WIP-III integrates waste inventory management with a variety of day-to-day waste management operations. The acceptance of waste is governed by the Waste Identification Program[2], which requires generators to apply process knowledge to infer the radiological and hazardous properties of their waste. Generators must develop waste management plans, provide facility maps and process waste flow sheets and assess the characteristics of their processes and the routine waste blocks that are generated.

The management functions integrated within WIP-III include: waste inspection and compliance monitoring; the ability to categorize, accept, track and route wastes; maintenance of facility inventories and inventory reporting; generation of invoices for services; the recording of non-conformances and corrective actions, and non-conformance and corrective action reporting. Information about waste characteristics, which includes package and waste form details along with contaminant concentrations and accumulation rates and volumes, is linked to supporting documentation. The implementation of the WIP-III has streamlined waste acceptance, improved package tracking, provided a mechanism for qualifying waste characterization, facilitated package inspection and compliance monitoring and provided the tools needed to manage the transfer of waste packages from storage to disposal.

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3. CONTROL OF WASTE PACKAGES

A dedicated waste reception centre has been implemented to receive, record and inspect radioactive wastes generated at Chalk River and from off-site generators; to select wastes for compliance monitoring to determine if they meet the waste acceptance criteria; and, to segregate and route wastes for processing, storage or disposal. Verification of package contents is performed with both destructive and non-destructive analytical methods. Non-destructive compliance monitoring of the large dynamic range of waste package activities is achieved using gamma ray spectroscopy which employs a combination of collimation, detector volume and distance from source. Destructive compliance monitoring involves following sampling protocols to obtain representative samples which are then analyzed with qualified, documented radiochemical and chemical analytical techniques.

Waste acceptance for disposal is linked to the quality of characterization data available[3]. The verification of data is achieved by periodic inspections at generator facilities and by inspections of selected packages that are received by Waste Management and Decommissioning. A number of general operating procedures have been introduced to assist generators compliance with requirements for the safe handling, storage and disposal of wastes.

4. HISTORIC WASTES

Historic wastes require special consideration for their transfer to a disposal facility because they were not managed and documented according to today's methods. AECL-CRL has developed a novel method to assess its historic radioactive wastes, based on a logical extension its Waste Identification Program (see above) for current wastes[4].

Historic records are entered into WIP-III "as-is". Next, using additional data entry screens, expert interpretation is used to identify historic wastes as similar to a current waste or similar to a mixture of current wastes. Next, the historic waste is assigned the characteristics of a current waste or of a mixture of current wastes, using a "warehouse of information" derived from the Waste Identification Program. Finally, a "validation" of the interpretation is performed.

The interpretation process improves the quality of historic waste inventory records, which will allow AECL-CRL to provide defensible estimates of the characteristics of its historic wastes. The estimates are needed to plan and implement the disposal of historic waste.

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FINLAND

1. GENERAL

In Finland, four nuclear power units have been in operation for 15-20 years and generated more than 5,000 m3 of low and intermediate level waste (LILW). The accumulation of LILW from other sources is only about one percent of that from the NPPs.

The Finnish waste management policy is based on disposal of LILW into rock cavity repositories located at the NPP sites. The repository at the Olkiluoto NPP site has been in operation since 1992. The repository at the Loviisa NPP site is under construction and is scheduled to be commissioned in 1998.

This on-site repository approach involves some exceptional features in comparison with central repositories. The design of the repositories has, to certain extent, been "tailored" to the main waste types coming from the host NPP, enabling relatively broad waste acceptance requirements. There is no clear separation between the waste generator and the repository operator but the NPP organisation is in charge of both duties. Consequently the verification of waste package suitability cannot be performed by the disposal facility operator but it is the duty of the regulatory body.

2. WASTE PACKAGE REQUIREMENTS

General requirements for waste package acceptance are included in the regulatory guide issued by the Finnish Centre for Radiation and Nuclear Safety. The repository specific waste package requirements, so called waste type descriptions, are included in the Final Safety Analysis Report of the particular repository and approved by the regulator. They address the type of waste and its conditioning and packaging method, its radiological properties (dose rates, nuclide specific activities) and its potential adverse characteristics (e.g. flammability, swelling capacity, gas generation potential, concentrations of chemically aggressive substances). Some of the requirements are waste package specific (e.g. each waste package should comply with the dose rate constraint) while the others are specific to a waste emplacement room (e.g. the average of gas generation potential should comply with the constraint for a particular emplacement silo).

3. CONTROL OF WASTE PACKAGES

The design of the repositories was started a few years later than the commissioning of the NPPs, enabling an iterative process between the development of the conditioning and packaging methods and the disposal concept. Some adverse properties of wastes, such as swelling of bituminized resins and gas generation of trash waste, were taken into account in the design of the waste container and the repository. The database concerning the physical and chemical properties of waste types was obtained through analysis of test samples taken during commissioning and the early stages of operation of conditioning processes. The control of most of the relevant properties of waste packages is based on this database and on the control of the parameters of conditioning processes.

Some waste package properties, mainly the radiological ones, must be determined on individual package basis. This is done through dose rate and gammaspectrometric measurements with complementary methods, such as the use of scaling factors.

There is a computer-based record keeping system that contains the relevant information for each waste package, including its management history. These records together with the waste type descriptions contain the information needed to deem the suitability of waste packages for disposal. As the waste generator and the repository operator belong to the same organisational unit, all the records and other documentation created in the various waste management stages are available to both of them.

All waste management activities are subject to the quality assurance programme of the NPP and to a similar regulatory control as other activities at the NPP. This regulatory control includes review of relevant documents and inspection tours to the waste management facilities.

FRANCE

1. INTRODUCTION

ANDRA, Agence Nationale pour la Gestion des Déchets Radioactifs (National Radioactive Waste Management Agency) was created in 1979 within the French Atomic Energy Commission. It became independent with the French Act dated 30 December 1991. ANDRA has operated the "Centre de l'Aube" (C.S.A.) near surface disposal facility since January 1992. Its capacity is 1.000.000 m^3, and will handle waste produced in France for a period of about 50 years. The first disposal facility of "Centre de la Manche" was operational from 1969 to 1994.

Missions of ANDRA relevant to low and medium level waste, accepted in near surface disposal facility, are mainly the following ones: determination of waste acceptance criteria (WAC); verification of compliance to specifications of waste packages; operation of disposal sites. Involved parties' activities and responsibilities are described in figure 1. Waste generators retain, as for other countries, the primary responsibility for meeting WAC and meeting transportation system requirements. ANDRA may, sometimes, perform final conditioning such as compaction and/or grouting at the disposal, for some waste packages preconditioned at generator' sites.

By Executive Order dated August 10, 1984, a special quality assurance (QA) regulation applicable to licensed nuclear facilities, the government defined quality requirements applicable to disposal sites and to any component important to site safety, particularly the first safety-related component, i.e. waste package. To be in compliance with this publication, ANDRA defined a quality assurance program for waste management, which is based on:

- **Definition of quality:** WAC relevant to waste packages received at CSA disposal are defined in general terms in Fundamental Safety Rule No. III 2e, and in detailed ANDRA specifications, which refer to various kinds of wastes, containers and activity levels. General criteria are stabilization of waste form; containment of radionuclides; limitation of specific activities in waste packages; control of chemical species (toxics, chelating agents, liquids, etc.).

- **Achievement of quality:** Acceptance process of waste packages is firstly based on review of files, including process report (detailed description of conditioning), activity evaluation report, characterization program and results. Secondly, a quality evaluation audit is performed as to check procedures and QA system of the generator. Formal approval is then delivered.

- **Verification of quality**, which occurs itself by three ways, during production: inspections at waste generator sites; periodical survey audits of their QA organization; non destructive and destructive examinations of randomly selected waste packages, generally subcontracted to external laboratories. ANDRA has also defined waste tracking system targets, as illustrated in figure 2. The system manage information provided by the waste generator to the repository operator for each individual package, and is based on electronic transmittal of data against reference catalogues.

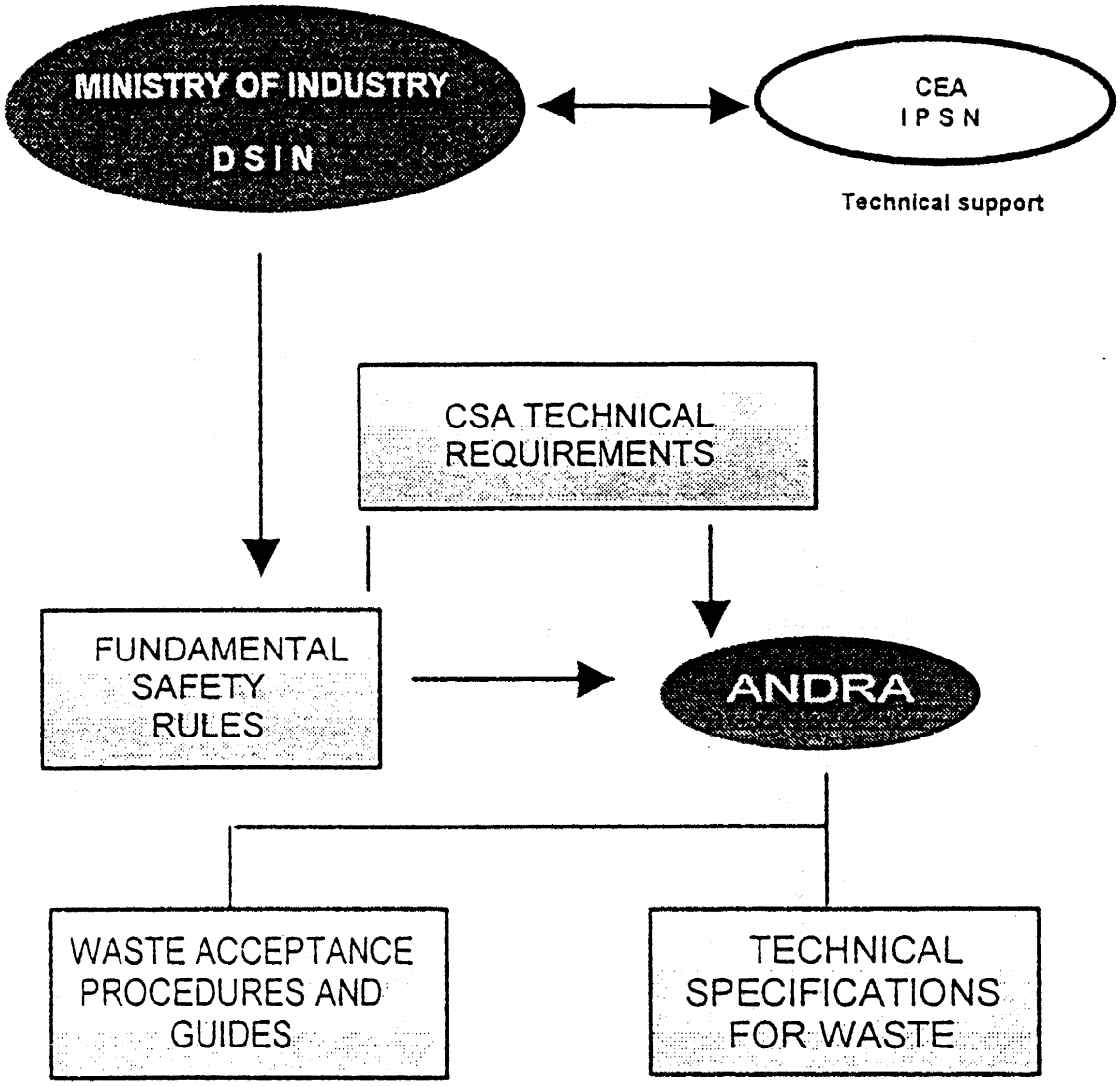


FIG. 1. Near surface disposal regulations and waste acceptance rules in France.

2. INSPECTIONS AT THE WASTE GENERATOR'S SITE

ANDRA inspects the waste generator's site one to three times per year on a randomly selected waste packages in compliance with its own inspection procedure. The information are performed by qualified personnel familiar with the relevant waste package and with ANDRA requirements.

Purpose of inspections is to verify that: produced waste packages meet the requirements defined in ANDRA specifications and all reference documents; procedures defined in files of acceptance process agreed by ANDRA are correctly implemented; produced waste packages meet the requirements defined in waste generator technical documents, i.e. fabrication process parameters, sampling and analysis methods, radioactivity measurements and any other activity pertaining to the waste management process; and data of waste packages given to ANDRA (characteristics, activities, etc.) are correct.

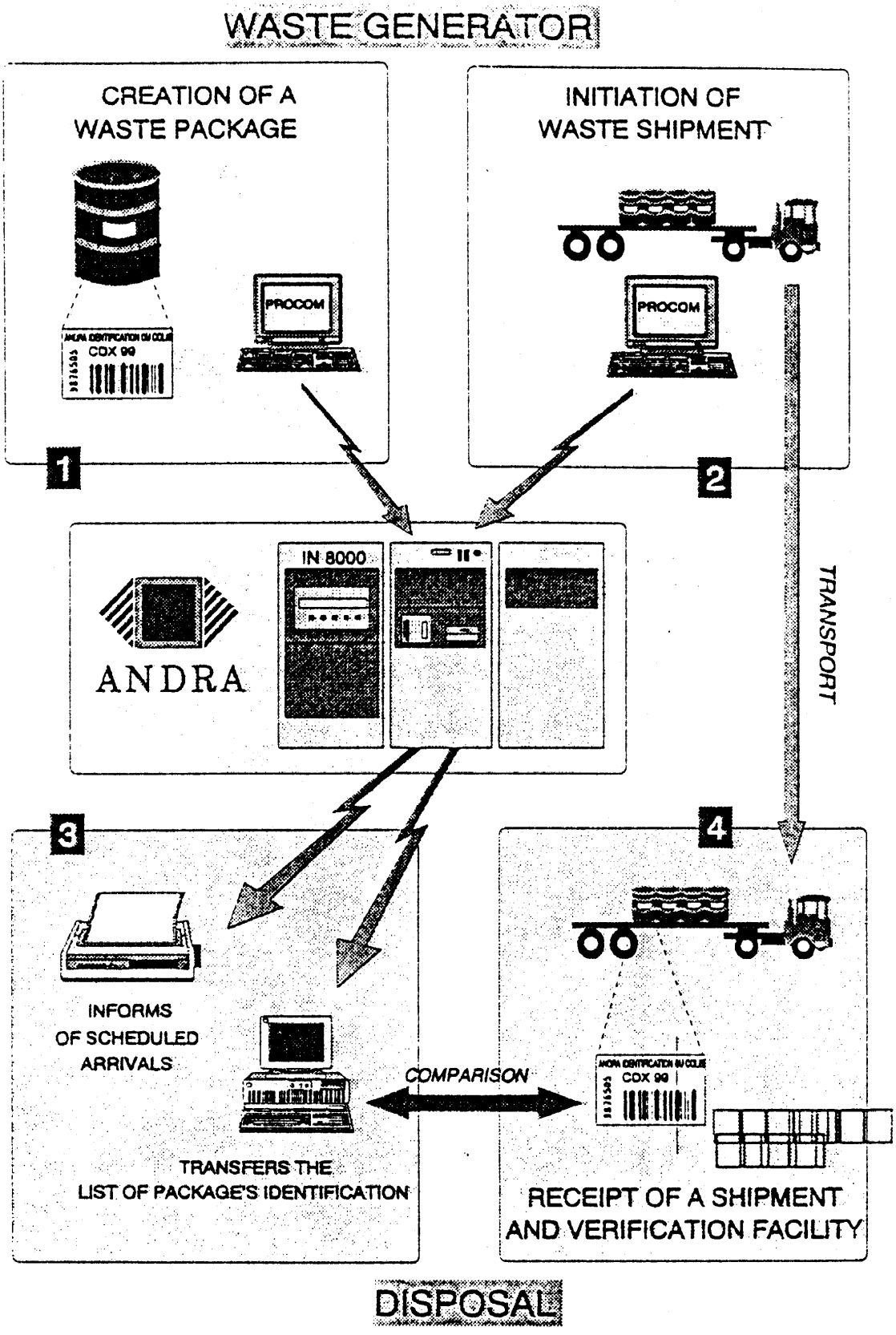


FIG. 2. Waste tracking system in ANDRA.

ANDRA inspections are based on pre-established inspection plans, taking the form of tables describing the sequence of operations, from waste collection to waste package fabrication; the requirements for each operation; and the reference documentation.

The inspections may be broken in two phases, which are document review and direct inspection. Document review concerns all data relevant to:

- raw waste general characteristics (absence of forbidden species), verification of calculated activity reported by the generator, collection procedure, and pre-treatment if any;
- documentation for containers (dimensional, manufacturing data if requires, etc.);
- documentation for process (quality control of constituent materials, formulation for immobilizing matrix and for any encapsulation layer, conditioning parameters, etc.);
- control files relevant to waste packages (reporting of characteristics, particularly specific activity, control sheets giving package weight, radiological control, etc.);
- calibration certificates for all measurement equipments, used in fabrication and control.

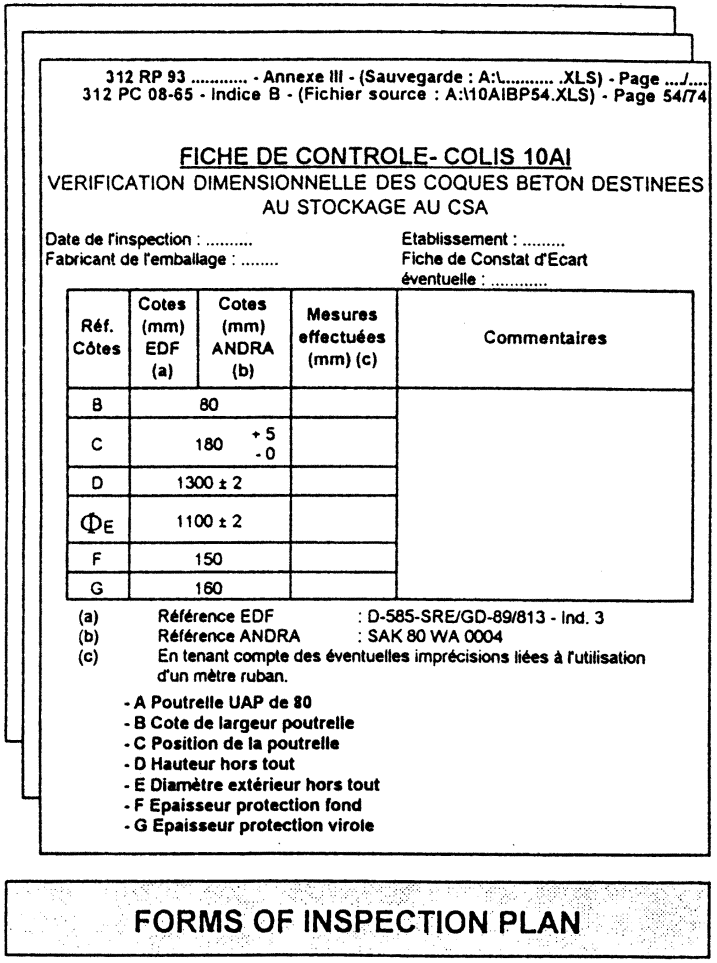
Direct inspection concerns complete package manufacture from raw waste, including:

- checking of waste package content, with control of forbidden materials (oils, free water, etc.);
- dimensional control of waste package (ANDRA inspectors are using specific forms, as illustrated in figure 3 for dimensional control);
- weighing control;
- visual inspection of containers, and specially of their integrity (cracks, rust, leakage, etc.)
- radiation dose survey.

Table 1 provides an example of inspection results in terms of non-conformance discovered.

TABLE 1. NON-CONFORMANCES DISCOVERED DURING INSPECTIONS (FIGURES FOR 1994)

WASTE PACKAGE		**FILE**		**CALIBRATION**		**TOTAL**	
NB items inspect.	NB items N.C.	NB items inspect.	NB items N.C.	NB items inspect.	NB items N.C.	NB items inspect.	NB items N.C.
1662	6% (99)	1397	26% (366)	305	7% (20)	3364	14% (485)



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312 PC 08-65 - Indice B - (Fichier source : A:\10AIBP54.XLS) - Page 54/74

FICHE DE CONTROLE- COLIS 10AI

VERIFICATION DIMENSIONNELLE DES COQUES BETON DESTINEES AU STOCKAGE AU CSA

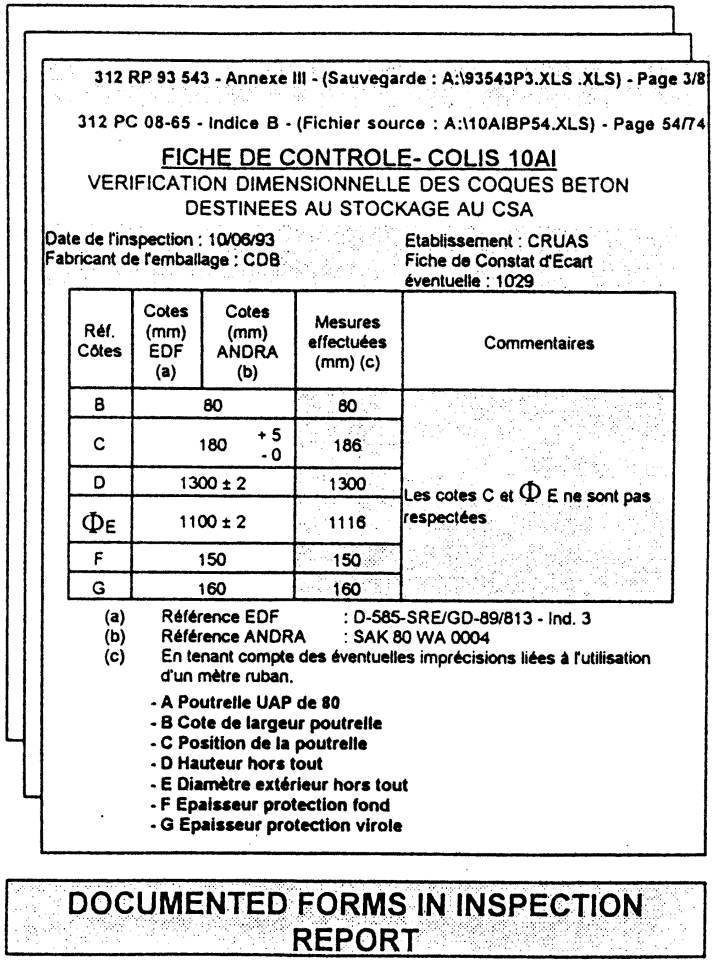
Date de l'inspection : .....
Fabricant de l'emballage : .....
Etablissement : .....
Fiche de Constat d'Ecart éventuelle : .....

Réf. Côtes	Cotes (mm) EDF (a)	Cotes (mm) ANDRA (b)	Mesures effectuées (mm) (c)	Commentaires
B	80			
C	180 +5 -0			
D	1300 ± 2			
Φ_E	1100 ± 2			
F	150			
G	160			

(a) Référence EDF : D-585-SRE/GD-89/813 - Ind. 3
(b) Référence ANDRA : SAK 80 WA 0004
(c) En tenant compte des éventuelles imprécisions liées à l'utilisation d'un mètre ruban.

- A Poutrelle UAP de 80
- B Cote de largeur poutrelle
- C Position de la poutrelle
- D Hauteur hors tout
- E Diamètre extérieur hors tout
- F Epaisseur protection fond
- G Epaisseur protection virole

FORMS OF INSPECTION PLAN



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FICHE DE CONTROLE- COLIS 10AI

VERIFICATION DIMENSIONNELLE DES COQUES BETON DESTINEES AU STOCKAGE AU CSA

Date de l'inspection : 10/06/93
Fabricant de l'emballage : CDB
Etablissement : CRUAS
Fiche de Constat d'Ecart éventuelle : 1029

Réf. Côtes	Cotes (mm) EDF (a)	Cotes (mm) ANDRA (b)	Mesures effectuées (mm) (c)	Commentaires
B	80		80	
C	180 +5 -0		186	
D	1300 ± 2		1300	Les cotes C et Φ E ne sont pas respectées
Φ_E	1100 ± 2		1116	
F	150		150	
G	160		160	

(a) Référence EDF : D-585-SRE/GD-89/813 - Ind. 3
(b) Référence ANDRA : SAK 80 WA 0004
(c) En tenant compte des éventuelles imprécisions liées à l'utilisation d'un mètre ruban.

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- G Epaisseur protection virole

DOCUMENTED FORMS IN INSPECTION REPORT

FIG. 3. Forms for the inspection of LILW packages (ANDRA).

3. INSPECTION REPORT AND FOLLOW-UP

Each inspection report describes verifications performed during the inspection, deviations noted affecting waste package quality, and corrective actions to be taken by the generator. The generator's appropriate implementation of requested corrective actions is reviewed during the following inspection.

In this report, ANDRA reviews all deviations and may make a finding of non-conformance. The waste package may be accepted after it has been reworked or re-conditioned to comply with requirements or after the deviation has been accepted, or the waste package may be rejected.

4. Q.A. SURVEY AUDITS

Q.A. survey audits are scheduled at regular intervals of approximately once every three years. The purpose of Q.A. survey audits performed after waste package acceptance is: verification of effective and satisfactory implementation of Q.A. requirements established prior to waste package acceptance; and review of any changes to the requirements and assessment of changes. Audits are based on ISO 9002 and on the generator's Q.A. documentation, which has been provided as part of the acceptance process file.

5. CONCLUSION

The inspection and Q.A. audit system implemented in France satisfy stringent French Safety requirements. This system and ANDRA's independence allow a better control of waste package quality.

INDIA

1. INTRODUCTION

The low and intermediate level solid waste in India gets generated during nuclear power production, other nuclear fuel cycle operations such as fuel fabrication, spent fuel reprocessing, operation of research reactors in R&D institutions and use of radioisotopes in industry, hospital, etc. The management of radioactive waste is primarily with two governmental organisations, i.e. Bhabha Atomic Research Centre (BARC) and Nuclear Power Corporation (NPC). Regulatory function is overseen by an independent agency, Atomic Energy Regulatory Board (AERB).

The near surface disposal facilities are co-located with waste generating centres such as nuclear power plants and research institutes due to the long distances involved in India and to avoid movement of radioactive waste through public domain.

The overall safety in disposal of radioactive waste is ensured by multi-barrier approach, i.e. waste form, engineered barriers and geo-hydrology of the site. Waste packaging is very important component in the safety assessment of a near surface disposal facility (NSDF) to act as barrier as well as to facilitate handling. The AERB provides general requirements for the control of exposures to the members of public and occupational workers as a result of operation of NSDF. For a specific site detailed licensing procedure involves clearances during site selection, design, construction, commissioning through operation and post-operation phases.

2. WASTE ACCEPTANCE CRITERIA

A typical authorisation from AERB for transfer of waste from waste generator to waste disposal operator includes guidelines for compliance in respect of quantity of waste handled annually, radioactivity content and types of radionuclides in a package. Waste acceptance criteria for a particular disposal facility requires verification of various parameters before a waste package is accepted for disposal. Some of the important considerations are radionuclide type and content, surface dose rate, contamination, structural stability, leachability from the waste form, corrosive nature of the content and environment, combustibility, gas generation, pyrophoricity, dimensions, weight, handling provisions, etc.

3. IMPLEMENTATION OF WASTE ACCEPTANCE CRITERIA AND WASTE PACKAGE INSPECTION PROGRAMME

Waste acceptance criteria is implemented by interfacing between waste generator and disposal facility operator by having mutually agreed delineation of responsibility. Safety authorities such as radiation hazard control unit, safety and operation review committees, inspectors and expert committees of AERB provide effective mechanism for adherence to the criteria through inspection visits and reviews.

The waste package inspection system is implemented from design through construction and operation by adopting a well defined quality assurance (QA) programme as applicable to other activities in the nuclear programme in India. For various raw material testing procedures as prescribed by Indian Bureau of Standards are followed during construction/manufacturing stage. Strict technical specifications are adhered during the conversion of waste to a particular

waste form. Services of specialised laboratories are availed to control various operational parameters and characterisation of waste product such as leaching, assaying, compression strength, etc.

For different waste streams, conditioning processes are standardised by laboratory/pilot studies before putting up plant scale facilities. Few packages are type tested for verification purpose and, at times, under simulated conditions. The records of waste handled, treated, stored or disposed are meticulously documented and maintained by the waste generator and disposal facility operator. These documents provide information on source of waste, radiochemical characteristics, radioactivity content, radio-isotope, radiation field, presence of toxic, pyrophoric and flammable material if any and quantity (volume or weight). Each waste package has its identification number and its location in disposal facility is recorded.

The waste generator and disposal facility operator are required to send periodic returns to AERB showing compliance with the licence. If there are any variations as compared with licence in specific cases, due approval is required from AERB.

In order to assess the impact of waste disposal at a site a well formulated environmental monitoring and surveillance programme is followed. This programme covers monitoring of condition of engineered structures(barriers), ground water, soil, vegetation and radiation field on the disposal systems and at the fence of disposal facility. Occupational workers are covered by routine and special radiation exposure control programme.

Important factors/requirements influencing the decisions to choose a particular type of packaging in India are summarised below:

- Dimensions, weight, density of waste to be packed.

- Material of construction**:**

  - compatibility with waste,
  - corrosion consideration during storage/disposal, painting or coating,
  - decontamination need for outer surface.

- Provision for handling, transport (lifting lugs, tie down arrangements, etc.), stackability.

- Radioactivity considerations:

  - assaying of waste, radioactivity content, radionuclides,
  - chemical nature, leaching rate,
  - containment during normal and accidental condition,
  - surface contamination status, shielding, radiation field on contact with container.

- Hazardous properties:

  - explosiveness,
  - flammability,
  - pyrophoricity,
  - chemical toxicity.

– Site Evaluation:

  - geohydrology of site,
  - containment provided by civil structures,
  - enviromental monitoring/surveillance features.

– Documentation.

  - radiation field,
  - radionuclide content,
  - chemical nature,
  - volume,
  - shielding,
  - presence of any toxic, pyrophoric and flammable material,
  - marking, labelling and placarding,
  - emergency procedures while handling radioactive consignment/package.

UNITED KINGDOM (I)
(Quality management systems for waste management in BNFL)[5]

1. INTRODUCTION

During the early stages of development of the BNFL specifications for low and intermediate level waste there was agreement between BNFL and their customers that quality assurance would play an important role in the operation of plants producing waste. Although working procedures and instructions have always been available they have not always been formalised or controlled.

In most industries the emphasis, originally, is to ensure product quality through inspection, which simply results in the detection of rejects. No matter how good the inspectors and inspection activities are the production of rejects is still not prevented. Quality control is a development of inspection where the results of inspection activities are used to modify the process. The introduction of quality assurance however was a major improvement and is applied to all aspects of operations from the design stage through to decommissioning. Quality is built into the plant or process ensuring the correct equipment and materials are used, that personnel are suitably trained for their tasks and have the correct information available. Verification of product quality is recognised as an important activity as is the review of the quality assurance or quality management system.

Implementation of quality management systems has resulted in demonstrable control of operations and improved product quality.

2. SELF REGULATING SYSTEMS

Through review and modification the initial quality systems have been improved. The importance of review has been recognised, not only reviews of documentation but reviews of business processes. Effective contract review, self audit and management review ensure that the right activities are carried out, carried out effectively and that overall results are used to improve the process. A typical system is shown in figure 1.

Current systems are being kept up to date by the people who use them, they also feel increased ownership of them. Records are available to demonstrate that operations are being carried out effectively and safely.

3. QUALITY MANAGEMENT SYSTEMS IN WASTE TREATMENT AND PACKAGING PLANTS

3.1. Purpose

The purpose of these systems is to ensure that all activities which may have an effect on product quality are carried out under agreed and verified Quality assurance arrangements.

[5] This paper was contributed by D. Jackman of British Nuclear Fuels plc.

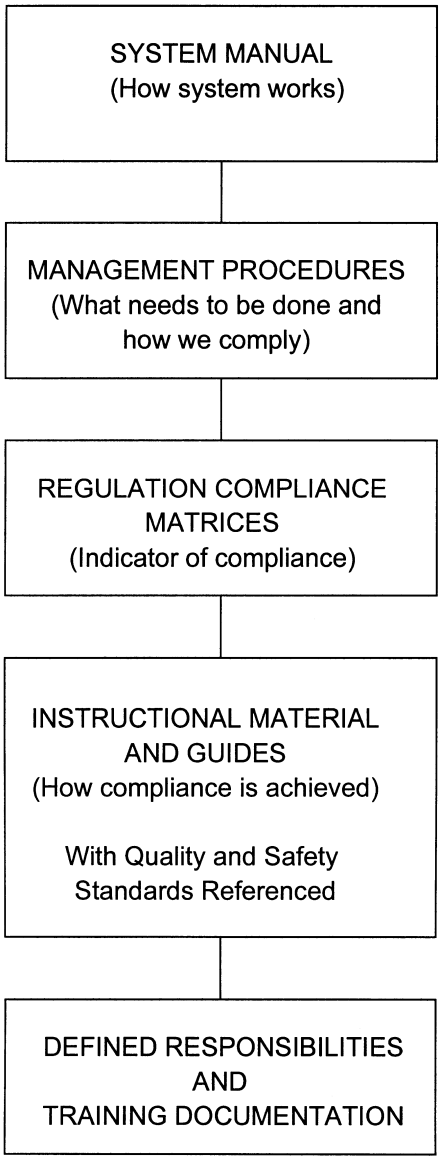

Fig. 1. The document management system.

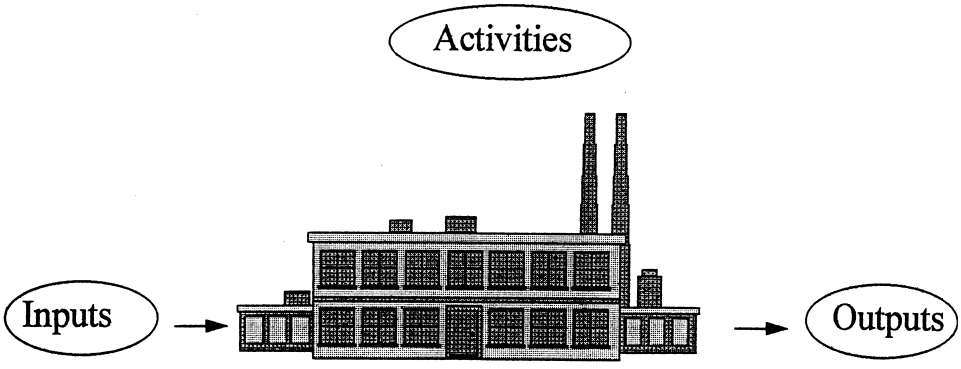

Fig. 2. Product quality strategy.

3.2. Strategy

In the majority of industries confirmation of product quality is normally achieved through testing of the items. Due to the nature of the nuclear industry it is accepted that this is not practical for the product of the waste treatment and conditioning plants.

As an alternative the strategy adopted by BNFL is to control the process which produces the waste package. Any process basically comprises three elements as shown in Fig. 2.

3.3. Inputs

There are two major inputs to the plants which could have an effect on product quality, a) the raw waste and b) the services used within the process, which are bought in from other departments.

a) The raw waste is controlled through "conditions for acceptance" (CFA), these are defined by the waste treatment or packaging plant and are part of their quality management system. The waste producer is responsible for implementing his own arrangements to ensure compliance with CFA. Confirmation of the management and control of CFA and compliance with them is through self audit, which is carried out by the plants themselves, and internal audit, which is carried out by the QA department.

b) The services provided to the waste treatment or packaging plant are also controlled by a quality management system developed and implemented by the service provider. Initial confirmation that services meet the required standard can be provided by an independent third party certification body as part of the initial assessment of the project. Ongoing confirmation is through internal audit.

3.4. Activities

There are several levels of control for plant or process activities:

- 1st party product certification — is carried out by a nominated person against a product specification using authorised procedures. Non conformances raised as a result of this control are assessed by a committee which includes independent specialists, e.g. QA, safety, research and development and in some cases are independently chaired.

- 2nd party verification — is carried out by Company personnel independent of the plant, on a sample inspection of product records. Reports of these sample inspections are also submitted to the above committee for assessment.

- 2nd party review and audit — is carried out by the Company QA department to confirm the implementation and effectiveness of the plants quality management system and where appropriate compliance with site licence conditions.

- 3rd party independent certification — by a body totally independent of the Company, accredited under nationally sponsored Accreditation Services (this role is explained in more detail below).

3.5. Outputs

Effective implementation of the above controls will ensure a product which complies with the specification or customer requirements and provide verified records which are able to demonstrate this.

4. INDEPENDENT CERTIFICATION

To further demonstrate that waste treatment and packaging plants are achieving the relevant standards it is BNFL's policy that the management systems of these plants should be independently certified. Lloyds Register Quality Assurance, a respected company and leaders in the field of certifying nuclear plants, were chosen for this role.

Assessment or audit is carried out against BS 5882 [1] British Standard for the Nuclear Industry and ISO 9002 [2] an International Standard for Quality Systems. There are three stages of the assessment process:

- Document Review — when the documented quality management system, usually quality manual, procedures and working instructions, are assessed against the requirements of the relevant standards.

- Commissioning Assessment — when actual commissioning activities are assessed to confirm they comply with procedures and that the plant itself complies with the design intent.

- Operational Assessment — when active plant operations are assessed to confirm they comply with written procedures.

On completion of a satisfactory assessment, a certificate of approval is issued, which is valid for three years subject to satisfactory maintenance of the system. To ensure the system is maintained to the agreed standard the certifying body carry out six monthly surveillance audits. Every three years the entire system is reviewed to verify that procedures continue to be implemented adequately and are in accordance with the approval standards. A successful review results in the issue of a new certificate for a further three year period and so the process carries on.

REFERENCES

[1] British Standard BS5882:1990 "Specification for a total quality assurance programme for nuclear installations".

[2] British Standard BS EN ISO 9002:1994 — "Quality systems — Model for quality assurance in production, installation and servicing" — Formerly BS5750: Part 2.

UNITED KINGDOM (II)
(Waste control arrangements associated with the Drigg low level radioactive waste disposal site)[6]

1. INTRODUCTION

British Nuclear Fuels Ltd (BNFL) operates the UK's principal disposal site for solid radioactive low level waste (LLW) at Drigg. Disposals are from a wide range of sources including nuclear power stations, nuclear fuel cycle facilities including the nearby Sellafield site, isotope manufacturing sites, universities, general industry and clean-up of historically contaminated sites. BNFL also operates a high force compaction and grouting service for LLW prior to disposal at Drigg. In support of these operations, BNFL has in place a comprehensive system of waste controls, part of which is a programme of verification monitoring.

2. DISPOSAL CONSTRAINTS

The main disposal constraints are based on regulatory limits and operational requirements to maintain safety, minimise costs and efficiently utilise the volumetric and radiological capacity of the disposal site.

Consignments of LLW to Drigg are accepted under the terms of an authorisation issued by the Environment Agency under the Radioactive Substances Act. Included in the authorisation are radionuclide activity limits — both in terms of waste specific activity and annual disposal totals (see Table 1). Records must be kept of each consignment disposed of at Drigg. These must include the nature, weight, volume and radioactive content of the waste, with the radionuclide content meaning the activity of the radionuclide or group of radionuclides specified in Table 1.

The annual authorisation limits are based upon a radiological assessment of the Drigg Site which assesses the projected Drigg inventory under closure conditions and places a radioactivity inventory capacity on the site. The present authorisation divides the site capacity by an assumed Drigg lifetime to give the radionuclide annual limits. The authorisation is subject to periodic review to incorporate relevant additional information.

In addition to the authorisation requirements, operational criticality control requires that activity information is provided on the following listed twenty seven fissile radionuclides:

Th-228	U-235	Pu-239	Pa-231	Am-243	Cm-246	Cf-251
U-232	U-236	Pu-240	Pa-232	Cm-243	Cm-247	Cf-252
U-233	Np-237	Pu-241	Am-241	Cm-244	Cf-249	Es-254
U-234	Pu-238	Pu-242	Am-242m	Cm-245	Cf-250	

[6] This paper was contributed by P.D. Grimwood and K.G. Elgie of British Nuclear Fuels plc.

TABLE 1. AUTHORISATION DRIGG DISPOSAL LIMITS

Alpha emitting radionuclides consignment limit	4 GBq per tonne
Other radionuclides consignment limit	12 GBq per tonne
Uranium	0.30 TBq per year
Radium 226 + Thorium 232	0.03 TBq per year
Other Alpha (1)	0.30 TBq per year
Carbon 14	0.05 TBq per year
Iodine 129	0.05 TBq per year
Tritium	10.00 TBq per year
Others (2)	15.00 TBq per year

(1) "Other Alpha" means alpha emitting radionuclides with half-lives greater than three months excluding uranium, radium 226 and thorium 232.

(2) "Others" means the sum of:

(a) beta emitting radionuclides with half-lives greater than three months excluding carbon 14, iodine 129 and tritium. The cobalt 60 content of "others" should not exceed 2 TBq per year.

(b) iron 55.

The operational acceptance specific activity limits for these range from 1 MBq per tonne to 12 GBq per tonne, depending on the radionuclide. Information on the physical and chemical composition of the waste is required to ensure that only relevant waste as defined in the authorisation, i.e. "solid radioactive waste which has been treated or packaged in such a way to render it so far as is reasonably practicable insoluble in water and not readily flammable" is disposed of at Drigg. The waste has also to meet operational requirements in terms of waste form and packaging for the service(s) required (high force compaction/grouting/disposal) and materials to be excluded or prepared and made safe, e.g. hazardous wastes, complexing agents.

3. WASTE CONTROLS SYSTEM

A three tier system of controls consisting of specification, qualification and verification has been developed relating to disposals at the Drigg site:

(a) **Specification** — All LLW accepted for disposal must comply with the wasteform and procedural specification produced by BNFL as the disposal site operator. This specification has been developed so that all waste consignments, as well as meeting the regulatory requirements, are controlled to ensure operational and long term safety objectives are addressed;

(b) **Qualification** — All LLW has to be produced under approved waste generator quality assurance arrangements which detail the effective management and control of the waste from its generation to its acceptance by BNFL for disposal at Drigg;

(c) **Verification** — All waste generators are subject to a programme of audit and waste receipt monitoring which confirm the implementation of the quality assurance arrangements.

4. WASTE SPECIFICATION

The waste specification is a key document as it will include all the technical and operational requirements which the waste generator will have to comply with for their waste

to be accepted for disposal. LLW accepted for disposal at Drigg must conform to the "Conditions for Acceptance by British Nuclear Fuels plc of Radioactive Wastes for Disposal at Drigg" and these requirements are also included in the contractual arrangements for LLW disposals. It contains:

- a definition of LLW,
- radioactivity limits,
- prohibited materials listing (i.e. those materials which cannot be accepted as LLW or that need special treatment prior to acceptance),
- waste conditioning requirements,
- waste packaging and labelling requirements,
- quality assurance requirements,
- procedural and documentation requirements.

5. QUALIFICATION

BNFL as the disposal site operator needs to be assured that there is effective management and control of the LLW from its generation to its acceptance by them. Therefore the consignor is required to have in place a quality assurance (QA) system detailing these arrangements, including waste characterisation aspects. The QA documentation is approved by BNFL before wastes can be consigned. Periodic reviews of the QA documentation are required to ensure that any revisions in the waste specification and consignor operational practices are incorporated.

Most LLW can be readily grouped by the waste generator into wastestreams, where the waste in each particular wastestream has similar characteristics. The characteristics on which to base the wastestreaming system can either be physical (e.g. combustibility, compactibility) or radionuclide composition, i.e. the waste "fingerprint". This system is used for both the disposals at Drigg and also for the UK Radioactive Waste Inventory.

For LLW disposals to Drigg, before the first consignment of any wastestream (or changed wastestream) is accepted, the consignor provides information to BNFL on the physical, chemical and radiochemical composition of the waste in that stream in the form of a "wastestream characterization". This can be either included with or separate from the general description of the QA arrangements. The information which needs to be in the wastestream characterisation, or referenced from it, includes:

- Wastestream number and name;
- Description of the process giving rise to the LLW;
- Physical and chemical composition of the LLW including how prohibited materials are either excluded or made safe;
- Details of the conditioning and packaging of the LLW;
- Method of activity assessment:
  - basis e.g. dose rate conversion,
  - fully referenced derivation,
  - limitations and how non-conforming wastes are assessed,
  - consideration of potential uncertainties.
- Radionuclide fingerprint;
  - how determined e.g. by sampling and analysis,
  - consideration of possible uncertainties,
  - individual radionuclides to be recorded,

- short lived radionuclides excluded unless not in equilibrium,
- justification for radionuclides not included e.g. below de minimis levels.

6. VERIFICATION

Verification is the method by which BNFL as the waste disposal site operator confirms that the waste specification has been complied with and that the waste has been managed by the generator as detailed in their QA arrangements. It is done by a number of means:

- Consignment documentation checking
- Audit
- Waste receipt monitoring.

For LLW disposals at Drigg, the following verifications are carried out.

6.1. Consignment document checking

Each waste consignment from a generator is accompanied by a disposal form which includes the following sections:

- consignment identification
- consignment information
- description of waste
- description of package
- radioactivity
- fissile content
- monitoring information
- certification.

For each waste consignment, this data is manually checked for completeness and entered on a computer system which checks a number of factors including that relevant consignor approvals are in place and that radioactivity and other limits would not be exceeded. If problems are found, the waste consignment is not accepted for disposal until they are resolved.

6.2. Audits

To ensure that the QA arrangements are being complied with, a programme of LLW consignor audits has been established. These audits are carried out by a team of QA, Operations and Technical personnel. Each audit consists of a full documentation review and a "walk-through" of the consignor's LLW management system and will include inspection of wastes. Audits are generally carried out before the first consignment of waste from a new waste generator and at an approximate frequency of three years thereafter. If non-conformances are found during an audit, this is agreed with the waste generator and the action required to be taken is documented and a programme established. If it is considered that further disposals under the existing arrangements would not meet the waste specification, the generator would be suspended from consigning further waste until the action is completed.

6.3. Waste receipt monitoring

Waste receipt monitoring is carried out on all LLW received for disposal at Drigg and is applied to three levels of detail defined as level 1, 2 and 3 monitoring:

(a) **Level 1 monitoring**. This is the measurement of entire consignments (radiation levels, contamination monitoring and weight) and observations during handling and processing of the waste. All waste consignments undergo level 1 monitoring.

(b) **Level 2 monitoring**. This is the non-destructive assay of entire consignments on a container by container (200 litre drum or 1 m^3 box) basis by real time radiography, high resolution gamma spectroscopy, passive and active neutron counting. The assay results are then collated for each waste consignment by a computer system and a consignment report produced. A representative programme of consignments from waste consignors undergoes level 2 monitoring. The emphasis for this is directed to wastes from high volume and/or high activity consignors and using feedback from audits. The Level 2 Monitoring is carried out in a purpose built facility in the Waste Monitoring and Compaction (WAMAC) facility on the following basis:

- In real time radiography, X ray images of the waste drum/box are produced and recorded at a variety of viewing angles to allow identification of waste items contained within them. The waste drum/box can also be gently rocked which allows a view of free liquids (free liquids are a prohibited waste). Very dense materials, such as lead, which could be used as shielding are identified and flagged for special attention.
- The high resolution gamma scanner is used to identify and quantify gamma emitting radionuclides such as fission products, activation products and some fissile material. A germanium detector scans vertically passed a rotating waste drum/box to obtain the best overall measurements of the contents.
- The passive neutron counting system measures time correlated neutrons such as those generated by the spontaneous fission of Pu-240, Pu-242, etc.
- The active neutron counting system measures fissile nuclides, such as U-235 and Pu-239, in a waste drum/box by bombardment by neutrons from a neutron generator and detection of the resultant induced fission neutrons.

(c) **Level 3 monitoring**. This is the destructive assay of a sample from a waste consignment for physical, chemical and radiochemical determination. A representative programme of consignments from waste consignors undergoes level 3 monitoring, including use of the results from the level 2 inspection.

The waste receipt monitoring results are compared with regulatory limits, the BNFL specification and the consignment declarations to confirm customer conformance. In the event of non-conformance, then discussions are held with the waste consignor and corrective actions sought. In the more significant cases no further consignments are accepted until improvements have been established.

7. CONCLUSIONS

BNFL manages a comprehensive system of controls over wastes being disposed of to the UK's LLW disposal site at Drigg. As part of this system of controls, auditing, inspection and waste receipt monitoring play an important part in ensuring the quality of the waste "product" received for disposal and hence in the overall safety of the disposal system.

GLOSSARY

audit. A documented activity undertaken to determine by investigation, examination and evaluation of objective evidence that there is adequate adherence to established procedures, instructions, specification, codes, standards, administrative or operational programme requirements, and other applicable documents.

conditioning. Those operations that produce a waste package suitable for handling, transportation, storage and/or disposal. Conditioning may include the conversion of the waste to a solid waste form, enclosure of the waste in containers, and, if necessary, providing an overpack.

criteria. Conditions on which a decision or judgement can be based. They may be qualitative or quantitative and should result from established principles and standards. In radioactive waste management, criteria and requirements are set by a regulatory body and may result from specific application of a more general principle.

disposal, near surface. Disposal of waste, with or without engineered barriers, on or below the ground surface where the final protective covering is of the order of a few metres thick, or in caverns a few tens of metres below the Earth's surface. Typically short lived, low and intermediate level wastes are disposed of in this manner. This term replaces "shallow land/ground disposal".

non-conformance (quality assurance). A deficiency in characteristics, documentation or procedure which renders the quality of an item, process or service unacceptable or indeterminate.

operator (or operating organization). In waste management, the organization (and its contractors) which performs activities to select and investigate the suitability of a site for a nuclear facility, and/or undertakes to design, construct, commission, operate and decommission such a facility. This term is preferred to "implementing organization" which appeared in earlier literature.

packaging. The preparation of radioactive waste (e.g. spent fuel) for safe handling, transportation, storage and disposal by means of enclosing a conditioned waste form in a suitable container.

quality assurance. All those planned and systematic actions necessary to provide adequate confidence that an item, process or service will satisfy given requirements for quality, for example, those specified in the licence.

regulatory body. An authority or a system of authorities designated by the government of a country or state as having legal authority for conducting the licensing process, for issuing licenses and thereby for regulating the siting, design, construction, commissioning, operation, closure, closeout, decommissioning and, if required, subsequent institutional control of the nuclear facilities (e.g. near surface repository) or specific aspects thereof. This authority could be a body (existing or to be established) in the field of nuclear related health and safety, mining safety or environmental protection vested and empowered with such legal authority.

repository. A nuclear facility (e.g. geological repository) where waste is emplaced for disposal. Future retrieval of waste from the repository is not intended.

verification (of a model). The process of showing that a mathematical model, or the corresponding computer code, behaves as intended, i.e. that it is a proper mathematical representation of the conceptual model and that the equations are correctly encoded and solved.

waste form. The waste in its physical and chemical form after treatment and/or conditioning (resulting in a solid product) prior to packaging. The waste form is a component of the waste package.

waste generator. The operating organization of the facility where the waste is generated.

waste package. The product of conditioning that includes the waste form and any container(s) and internal barriers (e.g. absorbing materials and liner), as prepared in accordance with requirements for handling, transportation, storage and/or disposal.

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Consultants Meetings

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