

# **PACKAGING OF RADIOACTIVE WASTES FOR SEA DISPOSAL**

REPORT OF A TECHNICAL COMMITTEE MEETING  
ON CONTAINERS AND PACKAGING FOR OCEAN DUMPING  
ORGANIZED BY THE  
INTERNATIONAL ATOMIC ENERGY AGENCY  
AND HELD IN VIENNA  
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**PACKAGING OF RADIOACTIVE WASTES FOR SEA DISPOSAL**  
**IAEA, VIENNA, 1981**

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## FOREWORD

The Convention on the Prevention of Marine Pollution by the Dumping of Wastes and Other Matter, known as the London Dumping Convention was adopted by an inter-governmental conference in London in 1972 and came into force in 1975. The Convention is intended to promote the prevention of pollution in the marine environment through providing effective controls on the dumping of waste and other matter " in all marine waters other than the internal waters of states". Radioactive material is included among the many pollutants covered by the Convention. Under the terms of the Convention, the International Atomic Energy Agency was given the responsibility to define the radioactivity level of waste material unsuitable for dumping at sea and make recommendations regarding the dumping of radioactive waste falling outside of the definition. This the Agency has done in providing the contracting parties in 1976 with provisional Definitions and Recommendations which later were revised. The revised Definitions and Recommendations became operative for purposes of the Convention in 1978.

In 1977, the IAEA Board of Governors agreed that there is a continuing responsibility for the IAEA to contribute to the effectiveness of the London Dumping Conventions by providing guidance relevant to the various aspects of dumping radioactive waste at sea.

In the light of the above responsibilities, the IAEA organized a Technical Committee Meeting from 3 to 7 December, 1979 to assess the current situation concerning the requirements and the practices of packaging radioactive waste for dumping at sea with a view to providing further guidance on this subject.

The present report summarizes the results of this meeting. The report has been compiled with the help of a consultant, W.L. Lenneman, USA. It was further reviewed and finalized by the Chairman of the Committee J.D. Cunningham, Ireland together with the Scientific Secretary J.U. Heinonen.

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## 1. INTRODUCTION

Over the past three decades several countries have taken the advantage of the ocean as a disposal medium for certain types of radioactive wastes. In 1950's and 1960's the controlled dumping of radioactive wastes into deep oceans was practiced by different countries on an individual basis without international controls since at that time no such mechanism existed.

From 1967 until 1976, the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development organised, provided guidelines and supervised disposal operations in which, at one time or another, eight OECD Member Countries disposed of solidified packaged low-level wastes into the deep oceans. Several other countries participated in the control of these operations to ensure the safe disposal of the wastes. Experiences during the early NEA-organised operations established basic criteria for the packaging of wastes which were issued in 1974 in a NEA publication entitled "Guidelines for Sea Disposal Packages of Radioactive Wastes".

In 1972, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention) was adopted by an international conference in London and came into force in 1975 having been ratified by the appropriate number of countries. It is designed to prevent pollution of the marine environment through the provision of effective controls on the dumping of waste and other matter "in all marine waters other than the internal waters of States". Radioactive material is included among the pollutants. The Convention gives the International Atomic Energy Agency (IAEA) the responsibility to define those radioactive wastes or other high-level radioactive matter which are unsuitable for dumping at sea and to make recommendations regarding the dumping of radioactive wastes which are not considered unsuitable in the definition.

In 1974, the IAEA submitted a Provisional Definition and Recommendations which the Contracting Parties accepted for purposes of the Convention. During 1975-1978, the Provisional Definition and Recommendations were reviewed and revised by the IAEA, resulting in a Revised Definition and Recommendations of 1978, which was accepted as a replacement to the Provisional Definition and Recommendations. Both the provisional and revised versions contain recommendations and background information regarding general requirements for packages for the disposal of radioactive waste into marine waters.

In 1977, the IAEA Board of Governors agreed that there is a continuing responsibility for the IAEA to contribute to the effectiveness of the London Dumping Convention by providing guidance relevant to the various aspects of dumping radioactive waste at sea. Waste packaging was one of the suggested areas of particular importance.

In 1977, the OECD Council adopted a decision establishing a Multilateral Consultation and Surveillance Mechanism for Sea-dumping of Radioactive Waste (the NEA Mechanism). This Mechanism is designated to further the objectives of the London Dumping Convention and it provides for the establishment and review of standards, guidelines and procedures for the safe disposal of radioactive wastes taking into account the provisions of the London Dumping Convention and the IAEA Definition and Recommendations.

In October 1978, NEA convened an expert group to revise its 1974 guidelines in light of current information and experience and on the requirements of the London Dumping Convention and the IAEA Recommendations. This revision was published as "Guidelines for Sea-Dumping of Radioactive Waste, Revised Version, April 1979 " (NEA Guidelines). NEA's experience and its 1974 guidelines had provided a basis for the IAEA's provisional and revised recommendations regarding the packages for dumping radioactive waste at sea.

In 1979, the IAEA convened a Technical Committee Meeting to assess the current situations concerning the waste packaging techniques and practices with a view to providing further guidance.



## 2. SCOPE AND PURPOSE

The purpose of the Technical Committee Meeting was to review both the current IAEA Recommendations regarding packages for the sea disposal of those radioactive wastes not considered in the Definition as being unsuitable for disposal at sea and the 1979 NEA Guidelines for Sea Dumping Packages of Radioactive Waste with a view to

- (1) considering the experience and experimental data relating to the packaging of radioactive wastes for ocean dumping,
- (2) evaluating the extent to which the 1979 NEA Guidelines complied with the requirements of the IAEA Recommendations and could be used as a basis for recommending more definitive guidance to the Contracting Parties of the London Convention, and
- (3) identifying those areas to which further attention should be paid or in which more detailed guidance is required.

### 3. GLOSSARY OF TERMS

The following glossary of terms has been prepared to explain and/or clarify the intended meaning of certain words and concepts as they are used in the text of this report. Furthermore, use of the glossary avoids redundant explanations and repetition of long titles. Terms and titles that appear to be identified or explained sufficiently in the text are not included in this glossary.

- |                                  |  |
|----------------------------------|--|
| conditioning                     | - those operations that transform wastes into forms suitable for transport and/or storage and/or disposal. Operations can include volume reduction, converting the waste to more stable forms, containerisation, and additional packaging. |
| container                        | - the outer shell of package into which waste is placed.   |
| deep sea                         | - in the context of the sea-dumping of radioactive waste is that part of the ocean whose water depth is generally in excess of 4,000 metres.   |
| definition                       | - the IAEA Definition of high-level radioactive waste unsuitable for dumping at sea under the provisions of the London Dumping Convention [3]  |
| disposal                         | - the act of controlled discarding of waste without the intention of retrieval.  |
| dumping<br>(also sea<br>dumping) | - any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea. [2,3]  |
| filler or<br>filler<br>material  | - a free-flowing material that will harden within a reasonable time to solid, used to take up void space within a package.   |
| high-level<br>waste              | - radioactive waste defined by the IAEA as unsuitable for dumping at sea for purposes of the London Dumping Convention [3]   |
| immobilisation                   | - conversion of radioactive waste to a solid form that has a low potential for movement by natural processes.  |

immobilisation- material or agent	- a material such as fluid concrete, hot bitumen or powders with which radioactive waste will combine to form a solid product incorporating the radionuclides.
low-level	- the description of radioactive waste whose concentration of radionuclides fall below the levels defined by the IAEA as high-level radioactive waste unsuitable for dumping at sea for purposes of the London Dumping Convention [3].
matrix	- the solid mixture of incorporated waste and the immobilisation material.
package	- consists of the assembly of the container, the conditioned radioactive waste, plus other filling agents or matrices, and the closure cap.
packaging	- the act of manufacturing a package.
Recommendations	- the IAEA Recommendations which the Contracting Parties of the London Dumping Convention should take into account when issuing special permits for the dumping of radioactive materials [3].
sea disposal	- disposal of material into the sea, such as by dumping.
solidification	- processing a liquid or fluid waste so as to immobilise it, converting it to a dry stable solid. See also immobilisation.
solidification agent of medium	- see immobilisation material.
waste	- material contaminated with radionuclides which are disposed of. The term as in the text of this report always means radioactive waste whether or not it is so identified.
waste management	- all activities, administrative and operational, that are involved in the handling, treatment, conditioning, transportation, storage and disposal of waste.
void	- is an inclusion free space within a package.

significant void - is an inclusion of such size, as is likely to render the package liable to catastrophic implosion during descent through the sea if the package is not fitted with a pressure equalisation device.

#### 4. SCIENTIFIC AND TECHNICAL BACKGROUND

##### 4.1 Experience

The overall safety of the disposal of radioactive wastes in the deep oceans depends on a number of factors such as operation procedures, the characteristics of the disposal site, the amount and composition of the waste, and the way the waste is conditioned, packaged, transported and handled.

Sea-disposal of waste materials contaminated with radionuclides was practised by several countries on an unilateral basis beginning as early as 1946. These disposal operations were conducted under the direction of the competent national authorities of those countries. The packaging techniques utilised were based on the technologies available at that time. A list of countries which carried out sea disposal operations unilaterally is summarised in Table I together with the disposal location and the weights, numbers and radioactive contents of the packages disposed of.

Present day experience of the disposal of packages of radioactive waste at sea stems mainly from those operations that were conducted since 1967 under the auspices of the Nuclear Energy Agency of OECD (NEA/OECD) and since 1977, under the terms of the OECD Multilateral and Surveillance Mechanism for Sea-dumping of Radioactive Waste.

Since the first NEA-supervised operation in 1967, up to eight European countries (Belgium, France, Federal Republic of Germany, Italy, the Netherlands, Sweden, Switzerland and the UK) have disposed of solidified radioactive wastes at three sites located in the Northeastern Atlantic with a depth of approximately 4 km.

Records of the amount of waste which has been disposed of over the period of 1967 - 1979 have been maintained by the NEA and contain information on both the total weight and the composition of the waste based on a grouping of the radionuclides. Up to 1975, the amounts of dumped radioactivity were recorded under two waste categories: alpha activity and beta/gamma activity including tritium. Since 1975, the tritium activity has been recorded separately. A summary of the amounts disposed of under the auspices of the NEA is given in Table II.

The conditioning of radioactive wastes, i.e. their treatment and packaging, is an important factor in ensuring the safety of sea disposal operations including the protection of the environment. The methods used

produced packages which provided for safe handling and complied with national and international regulations governing safe transport of radioactive materials.

Several different types of packages have been used. Monolithic-type packages have the radioactive wastes solidified into concrete or bitumen such that there are no significant voids. Another type of packages that contain void spaces is provided with pressure equalisation devices. In some cases, pre-fabricated concrete cylinders have been used. Examples of typical packages currently in use are described in an annex of the 1979 NEA Guidelines for Sea-Dumping Packages of Radioactive Waste[1].

Administrative controls are applied at waste packaging facilities to ensure that radioactive wastes are properly treated and packaged. These controls include quality assurance programmes to verify that procedures are followed and final packages meet the approved standards and specifications. However, when one considers the many thousands of packages that have been prepared (see tables I and II), a statistical number can be envisaged which would fall outside the standards established for acceptable packages and would fail to accomplish the desired containment. Packages not meeting standards have occurred in a very small number of cases causing some minor contaminations of a transport vehicle or a ship's hold. Isolated instances have occurred where a few packages have failed to sink and been retrieved. These failures were investigated and attributed to inadvertant human errors or deviations of process parameters. Human errors or failure of lifting attachments also have resulted in the dropping of some waste packages with the potential of injury to the workers although none have been injured by this industrial type accident. In general, the number of waste packages failing to meet approved standards or procedures has been less than 0.1% of the total number of packages handled. When a package is not suitable for disposal, it is returned to its origin for re-packaging.

Over a decade of experience in the disposal of packaged radioactive waste at sea has indicated two areas which merit particular attention. They are radiation protection and conventional industrial safety. Improvements over the years in the design of waste packages and in the operating procedures have resulted in preventing the contamination of transport vehicles and in lowering radiation doses to transport personnel, dock workers and the ship's crew to well within the accepted radiation protection limits. Handling methods and procedures adopted during sea-disposal operations have kept industrial-type accidents to a minimum.

TABLE I : COUNTRIES UTILISING SEA DUMPING OF RADIOACTIVE WASTE UNILATERALLY

COUNTRY	PERIOD	LOCATION	APPROX. WEIGHT (Tonnes)	NO. OF PACKAGES	APPROX. RADIOACTIVITY (Curies)
United States of America	1946 - 1967	Pacific/ Atlantic	25,000	86,500	94,000
United Kingdom	1949 - 1966 1968, 1970	Atlantic	47,664	117,544	143,200
Netherlands	1965 - 1972	Atlantic	935	2,365	62
Japan	1955 - 1969	Pacific	656	1,661	452

TABLE II : RADIOACTIVE WASTE DUMPED INTO THE SEA UNDER THE AUSPICES OF THE NEA/OECD , 1967 - 1979

Year	Gross Weight (Tonnes)	Number of Packages	Approx. Radioactivity in Curies		
			Alpha	Beta-Gamma	Tritium
1967	10,900	35,790	250	7,600*	--
1969	9,180	23,205	500	22,000*	--
1971	3,970	8,331	630	11,200*	--
1972	4,130	8,444	680	21,600*	--
1973	4,350	9,803	740	12,600*	--
1974	2,270	4,001	420	100,400*	--
1975	4,460	10,633	780	30,500	30,000
1976	6,770	13,663	880	32,500	21,000
1977	5,600	7,427	950	36,300	31,900
1978	8,040	12,692	1,100	43,000	36,600
1979	5,415	8,687	1,415	40,925	42,250
* Including Tritium					



#### 4.2. Packaging technology

The technology for the packaging of radioactive wastes was developed over the years in the light of experience and increasing technical expertise. This technology is still being improved by the utilisation of improving knowledge on material properties and on the physical and chemical processes that are involved or could evolve under the different circumstances possible.

The Committee in reviewing the scientific basis of the current packaging practices with a view to identifying areas to which further attention should be paid discussed the following four areas in greater detail; -

- The compatibility between waste and the material used for immobilisation.
  - Effects of radiation on waste packages.
  - Physical impact on waste packages during disposal operations.
  - The effect of the marine environment on the waste packages.
- (1) Compatibility between the waste and the agent used for immobilisation is necessary to ensure that the resulting mixture forms a solid matrix having sufficient mechanical strength and leach resistance to ensure that release of radionuclides is adequately low. Each material used as an immobilisation agent, such as cement, bitumen and organic polymers, has physical and chemical limitations regarding tolerance to pH, temperature, mixing time, waste-agent ratio, and chemicals.

It is important to understand the effects of these various parameters as well as the specific inherent material properties of the immobilisation agent. It is important to understand the chemical reactions that may occur between the waste and the immobilisation agent in case immobilisation may be adversely affected or the product have poor integrity.

A number of undesirable effects have been identified. These effects may include swelling, cracking, incomplete solidification and reduction in mechanical properties of the immobilisation agents; cement, bitumen or organic polymers. Many of these effects are specific to particular waste immobilisation agent systems and although many of these phenomena are

understood, further studies should be directed towards establishing tolerance limits to assure satisfactory waste matrices.

It is expected that the effect of the inter-relation between the waste matrix or the filler and the container will be very small. Experiments with temperature changes and their effects on the integrity of packages are currently being undertaken and seem to bear out the given expectation. However, a more detailed examination of some possible effects would be helpful, especially the effect of the pressure changes during the descent of packages to the deep sea bottom, and the effects of different expansion co-efficients.

(2) In principle, radiation can affect waste matrix properties such as leachability, mechanical strength, friability and physical form. Stability of the waste matrix to radiation interactions is necessary to prevent possible degradation of the matrix's properties or pressurisation of the package which could result from gaseous radiolysis products. Low-level wastes generally have low specific radiation activities and consequently, in most cases, radiation hardly causes any significant undesirable alterations to the conditioned matrix.

However, the results of some investigations indicate that in the case, for example, of certain types of immobilised power plant wastes, stability might be affected by radiation over relatively long time periods [ 13]. The research performed up to now has mainly been directed towards studies involving radiation effects on immobilisation agents alone. Further studies should be directed towards determining radiation effects on specific waste immobilisation agent combinations.

(3) Packages may suffer physical impact during the disposal operation in which they may be transported by a combination of rail, truck and ship movements from the location of waste conditioning to the disposal site. These packages should be designed in such a way to be transported in accordance with the relevant provisions of the IAEA Transport Regulations and of other applicable international and national requirements. Essentially all national regulations incorporate the "Regulations for the Safe Transport of Radioactive Materials" 1973, IAEA Safety Series No. 6<sup>[9]</sup> and "Advisory Material for the Application of the IAEA Transport Regulations" 1973, Safety Series No. 37<sup>[11]</sup>.

In summary, the packages must be designed in such a manner that loss or dispersal of the radioactive contents would not result after a physical impact of the type which might occur during movement of the packages. Tests that have been carried out have shown that the packages

used at present fulfill that requirement. Both tests conducted and operational experience show that the impact resulting from packages falling 10-15 m from a ship to a sea surface has shown no failures to the packages when these have been manufactured to specifications. [ 5, 6, 8 ]

The velocity of the package upon impact with the sea floor sediments has been calculated to be around several metres per second depending on container configuration and specific gravity. This can be converted to an equivalent free-fall in air onto a steel-surfaced concrete block of about 20-30 cm. Therefore, if the waste packages are designed to meet IAEA Transport Regulations, they can be expected to retain their integrity during the normal impacts experienced during sea-dumping operations.

If packages contain voids, other tests are necessary to show the effectiveness of pressure equalisation devices. Such tests have been conducted in Japan [ 6 ] and the UK [ 12, 15 ]. These tests were of two types:

- (a) Pressure autoclaves were used to simulate the rate of increase in pressure experienced as the package descends to the sea bed;
- (b) photographic documentation of packages during actual descents.

In each case, the work included a detailed examination of the package and showed that if the pressure equalisation devices used allow a rapid ingress of sea water into the void spaces, the packages will remain intact during descent.

(4) The effect of the marine environment on the waste packages was considered under two aspects, the effect on the container and the effect on the waste matrix area. The main factors which need to be considered are corrosion caused by seawater, effects of sediment, effects of micro-organisms, hydrostatic pressure, dissolved oxygen content, oxidation reduction potential, but other factors include pressure, dissolved oxygen content and the oxidation reduction potential.

There is some information on the corrosion of steel-encased concrete packages from the US examination of recovered waste packages that were dumped in the 1950s. The results indicate lifetimes of the steel drum containers of at least 15 years [18].

Experiments have been carried out on packages to study their reactions to high pressure. The experiments done in the UK [15] confirmed the adequacy of the present pressure equalisation techniques. Recent experiments done in Japan indicate that with adequate pressure

equalisation systems, the deformation of the container and/or package is slight and corrosion effects then become more important [6,16]. In this respect, special attention should be given to corrosion of the reinforcement bars which are used in many concrete packages. If no pressure equalisation system is used where significant voids exist in a package, experiments have shown that large deformations can occur, depending on the contents and the mechanical strength of the package itself. Some research is being undertaken concerning the pressure equalisation systems and further research should be encouraged. [6]

There is at present little known about the influence of sediments on the breakdown of containers by corrosion. From the US examination of some recovered waste packages, it probably can be concluded that the effect is very small compared to other influences on the packages [18]. However, it can generally be stated that whilst shallow sediments are generally well oxygenated, those at greater depths tend towards a reducing condition in which enhancement of corrosion by bacterial action is more likely.

The effect of the temperature on the container itself is so minimal that research in this field is not necessary. The influence of the temperature on the corrosion rate is also well known and in general, corrosion rates are inversely related to the temperature.

Experiments have shown that, especially for bitumen, there can be swelling problems if certain types of waste salts or resins are present. Similar effects have been observed for cement matrices. As swelling might result in the release of some radioactive contents, particular attention should be paid to possible swelling effects [22].

Corrosion of waste matrix material has been observed. Based on experimental data, it was estimated that it would require more than 100 years in marine environment before a concrete waste matrix would lose its integrity [16]. In this context, however, it is strongly emphasised that the corrosion rate is heavily dependent on the type of cement used in the process as well as on the properties of the actual matrices.

Breaching of the waste matrix may occur: as well due to low compressive strength of the waste matrix or inadequate pressure equalisation. It has been shown that where the concrete waste matrix has a compressive strength of about 150 kg/cm<sup>2</sup>, pressure equalisation devices are not needed [6].

Preliminary results of temperature experiments indicate that in the case of cement and bitumen, no adverse phenomena would be observed if the temperature differences remain within 30 degrees and above the freezing point for a period of 20 to 30 minutes [6].

The leachability of radionuclides or soluble components from the solid matrices or the waste itself has been studied extensively for particular nuclides and in some cases for the actual waste form. Further research in this field should be encouraged, especially with regard to the use of bitumen as a matrix [19, 22].

## 5. EVALUATION

### 5.1 Packaging requirements

The Committee examined the 1979 NEA Guidelines for Sea-dumping which are designed to meet as a minimum the requirements both of the London Convention and the IAEA Revised Definition and Recommendations insofar as these relate to the packaging of radioactive wastes. The Guidelines develop and extend these requirements. The Committee noted that the packages should be designed to ensure containment of the waste during their descent to and impact on the sea floor and to minimise to the extent reasonably achievable subsequent releases of radionuclides to the sea. The Committee considered that the requirements laid down in the NEA Guidelines are fundamental to good radiological protection practice and meet the requirements of the London Dumping Convention and the IAEA Recommendations. The Committee did not consider it necessary to impose additional general requirements. It wished however to offer the following remarks to qualify and supplement the NEA Guidelines:--

- (1) While both the IAEA Recommendations and NEA Guidelines prohibit the dumping of liquid wastes except for small quantities, the Committee considered the dumping of small quantities is undesirable and should, where practicable, be avoided.
- (2) Void spaces in packages should be kept to the practicable minimum and where possible filled with suitable material of a specific gravity of not less than 1.2. The need for pressure equalisation should be avoided where practicable but if used the devices should be of simple construction and enable packages to reach the sea floor without deformation. The Committee felt that further tests should be undertaken to prove the design and effectiveness of pressure equalisation devices.
- (3) Buoyant materials, if present, should be treated so that they have a specific gravity of not less than 1.2 or be included with materials of higher specific gravity to ensure a resulting specific gravity of not less than 1.2 for the contents of the package.

- (4) The contents of packages, i.e. the matrix with its incorporated wastes, should have a specific gravity of not less than 1.2. Matrices and filler materials should have sufficient compressive strength to preclude physical damage to the package or its contents during descent of the package to the sea bed and possess good corrosion resistance in the marine environment. Filler materials must not be detrimental to the integrity of the package.
- (5) Fabrication of packages should be relatively simple as elaborate packages are difficult to construct and normally increase the possibility of failure to meet design specifications.
- (6) Consideration should be given to studying methods of improving the resistance of concrete to seawater by, for example, the addition of fibres or polymers.
- (7) While noting that bitumen has many characteristics favouring its use as a matrix material for radioactive waste packages, the Committee considered that further studies should be undertaken to confirm its behaviour in the marine environment.
- (8) The Committee considered that the NEA Guidelines sufficiently cover the design of waste packages with respect to their safe handling and transport. It stressed that packages should be designed to comply with the relevant requirements of IAEA Regulations for the Safe Transport of Radioactive Materials.

## 5.2 Radiological protection

The Committee endorsed the provisions of the NEA/IAEA Recommendations and the Guidelines relating to radiological protection. The radiological protection principles to be followed in the design and manufacture of waste disposal packages and during disposal operations are those which are fundamental to sound protection practices. National authorities are thus enjoined to ensure that the radiation protection requirements laid down in the IAEA Basic Safety Standards for Radiation Protection are observed. These requirements are based upon the system of dose limitation of the International Commission of Radiological Protection, the main features of which are

- (1) no practice shall be adopted unless its introduction produces a positive set benefit;

- (2) all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account; and
- (3) the dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission.

The Committee noted that dose equivalents which may be received in future should be taken into account and due regard paid to minimising collective doses including those arising from occupation exposures.

In order to facilitate good radiological protection practices, it is necessary for individual packages to be so marked that they are readily identifiable. This identification must be sufficiently permanent to survive the transport phase of the disposal operation. It may also be desirable to identify some dumped packages for longer periods for the purposes of investigating their behaviour in the marine environment [25]. The minimum identification requirements are that the package should

- (1) be recognisable as containing radioactive materials,
- (2) bear a serial number that permits recourse to records for identification,
- (3) bear a colour code to permit ready recognition of the surface dose category to which it belongs,
- (4) when radioactive packages are transported under special arrangements, conformity with the colour code of the IAEA Regulations for the Safe Transport of Radioactive Materials is not required. If required, both it and the colour code for the surface dose category should be used in such a manner that both are readily identifiable.

### 5.3 Quality assurance

There must be prior agreement between the operator and the relevant national authority on any method to be used for fabricating radioactive waste packages. This agreement should include the type of waste, its immobilisation agent, method of immobilisation and the type of container to be used. The national authority must undertake such inspections as may be necessary to ensure that the agreed procedures are being observed and the packages have attained the required specifications.



The subjects to be considered in this agreement should include the following:-

- (1) raw materials,
- (2) conditioning or immobilisation methods,
- (3) quality of the matrix,
- (4) quality of the container,
- (5) quality of the package.

Appropriate specifications should be clearly identified with those of the package being consistent with national and international requirements including those of the IAEA Recommendations, the NEA Guidelines and the IAEA Regulations for the Safe Transport of Radioactive Materials.

Quality control procedures are required to ensure that fabrication procedures and design specification are observed. These procedures should commence with ensuring that all raw materials including containers conform to their design specifications and should include inspection at all stages of the fabrication of packages. Detailed working instructions should be issued to each operator and a record card kept for each package. This record should include the following

- (1) the type, number, activity, origin, and other relevant facts of each individual item of waste in the package,
- (2) the identification number and overall activity, i.e. the estimated quantities of radionuclides in the package,
- (3) the method of conditioning or immobilisation of the wastes,
- (4) the type of package,
- (5) the radiation level of the package, and
- (6) the volume, weight and specific gravity of the package.

The packages must be carefully weighed to ensure that the specific gravity exceeds 1.2 and clearly marked with its identification number, radiation level and an indication of the country of origin. During fabrication, a senior operator should supervise the operators and check the record cards.

Arrangements should be made during storage periods so that the national authority representative can inspect the waste packages. He should select as a minimum, record cards at random, inspect the relevant packages and reject any which are unsuitable for sea-disposal. He should also order random control tests and, if necessary, carry out any physical tests that

he believes are necessary, e.g. those laid down in the IAEA Transport Regulations. Any other tests thought necessary to ensure the quality of the packages should also be carried out to determine that the packages are safe for handling and disposal.

As a further precaution, it is suggested that prior to transport from the storage site to the sea port, each package be checked by smear tests for external contamination, weighed and its radiation level and markings verified.

An example of a quality control procedure for packaging is that used in the Netherlands and presented in the references [23] and [24]. From those references, Appendix I is compiled presenting lists of items and processing stages that were (are) subject to quality control.

## 6. CONCLUSIONS AND RECOMMENDATIONS

- 1 The Committee, noting the decision taken by the IAEA Board of Governors that it would be appropriate for the IAEA to contribute to the effectiveness of the London Dumping Convention, recommended that the IAEA considers the appropriateness of preparing guidance on licensing, operational and administrative procedures covering technical aspects of waste solidification and packaging for the disposal of radioactive wastes in the deep oceans, within its general responsibility in this regard.
- 2 Having regard to the recommendations of the IAEA and the requirements of the 1979 NEA Guidelines and in particular to the requirement that packages should be designed to ensure containment of the waste during their descent to and impact on the sea floor, the Committee concluded that the scientific and technical basis of the techniques used for conditioning wastes is reasonably acceptable.
- 3 There is a clear need for further investigations to determine or, in some cases, confirm release rates from packages, particularly those having a bitumen matrix, to provide for a more detailed assessment of the impact of the packaged radioactive wastes into the marine environment. The Committee felt therefore that further research should be encouraged on the short- and long-term behaviour of waste packages in the marine environment of the deep oceans.
- 4 The Committee recommended that full account be taken of the need to optimise radiological protection procedures in current and future techniques for the design, fabrication, handling and disposal of waste packages.
- 5 Cognizant of the experiences already gained from sea-disposal operations, the Committee recommended that research and development activities should be continued with the objective of improving the techniques used in the preparation and handling of waste packages with due consideration being given to problems to the incorporation of certain types of wastes in matrices and the compatibility of the solidified matrix with sea water. The Committee cautioned that matrices resulting from the incorporation of liquids, slurries, precipitates, etc. into solidification agents should first be tested for conformance with the requirements of the IAEA

Recommendations and NEA Guidelines. In this regard, generic tests would be suitable.

6 With respect to certain aspects of waste conditioning and packaging, the Committee recommended the following:-

- (1) The dumping of small quantities of liquid wastes absorbed in a solid substrate should be avoided to the extent possible.
- (2) Waste packages for sea disposal should, as far as is practicable, be of monolithic structure. The Committee recognised that there are exceptional instances requiring the use of pressure equalisation devices. In that case, there should be a demonstrated assurance of the satisfactory performance of the pressure equalisation device to be used.
- (3) Buoyant materials should be reduced to small pieces and particular attention should be taken to condition them so that the resulting specific gravity of the conditioned form is not less than 1.2.
- (4) Solidification agents for the conditioning of a liquid waste or slurry to a solid matrix should be carefully chosen and the critical waste/solidification agent ratio that compromises the integrity of the matrix should be determined and not exceeded.
- (5) Filler materials should be sufficiently free-flowing to fill accessible void spaces easily, have a specific gravity of not less than 1.2, possess good mechanical strength and corrosion resistance in the marine environment.

7 The Committee considered quality assurance programmes to be an essential part of the procedures involved in the disposal of radioactive wastes and therefore recommended that comprehensive programmes be drawn up and fully documented.

8 The Committee recommended that consideration should be given by the IAEA in the near future to those types of wastes which may arise in the future, such as those arising from the decommissioning of nuclear facilities.

9 The Committee concluded that

- (1) the packaging requirements given in the IAEA Definitions and Recommendations are adequate for the purposes of the London Dumping Convention,

- (2) the NEA Guidelines for Sea Dumping Packages of Radioactive Wastes are consistent with the IAEA Recommendations and contain in some areas, e.g. design specifications, more developed guidance,
- (3) the issue of more specific guidance by the IAEA on packaging of radioactive wastes for sea disposal is not considered an urgent matter provided that the more developed guidance of the NEA Guidelines and the provisions of this report are observed. The matter should, however, be kept under review.

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- Material 5: The effects of marine environment on the package areas studied or being studied. Material 6: The Table of the tests at JAERI and CRIEPI. Material 7: High pressure vessel test equipment for the dynamic behavioural experiments of packages under high water pressures, Material distributed to the Committee Meeting. Central Research Institute of the Electric Power Industry, Tokyo (1979).
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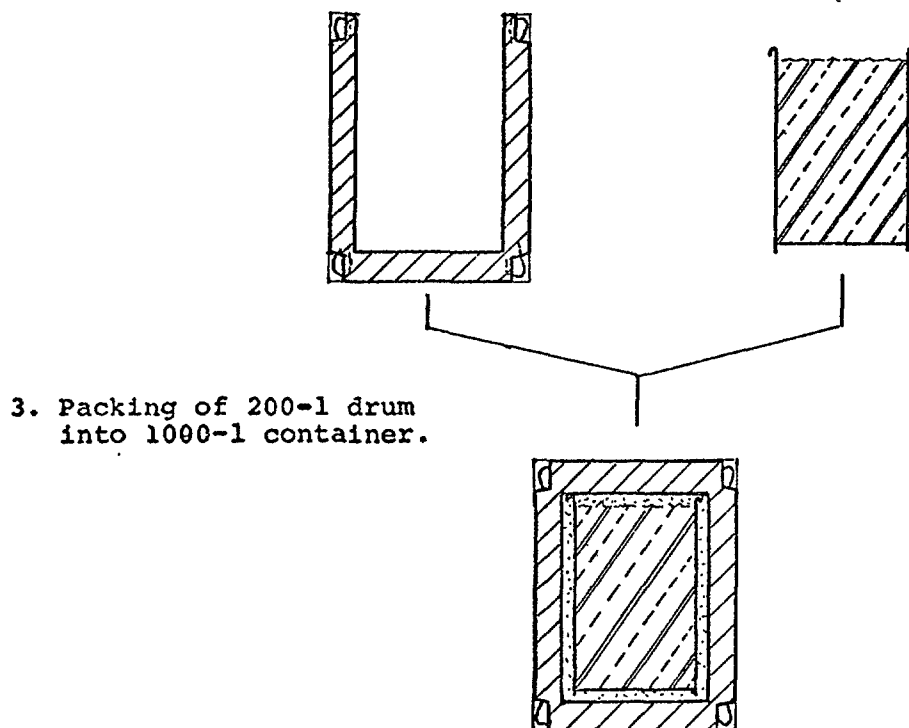
## ANNEX I

### Example of Quality Control of Procedure for Packaging

The following description refers to the management of radioactive wastes from the Dodeuoord Nuclear Power Station in the Netherlands. Part of the wet radioactive waste is dumped at sea after conditioning. During conditioning, the wet waste is mixed with cement and then poured into a 200-l steel drum. After hardening of the waste/cement mixture the 200-l steel drum is packed in a 1000-l concrete container. The following compilation was taken from ref. [23] and it consists of a set of charts presenting the objects of quality control, e.g. container parts, manufacturing as well as the main processing stages, which are schematically shown in the diagram underneath. Finally, data are also listed which are recorded during waste processing and packaging.

#### Diagram processing photographs

1. Manufacture of 1000-l container.
2. Homogenising of wet radio-active waste, mixing with cement and pouring into 200-l drums.





1.2

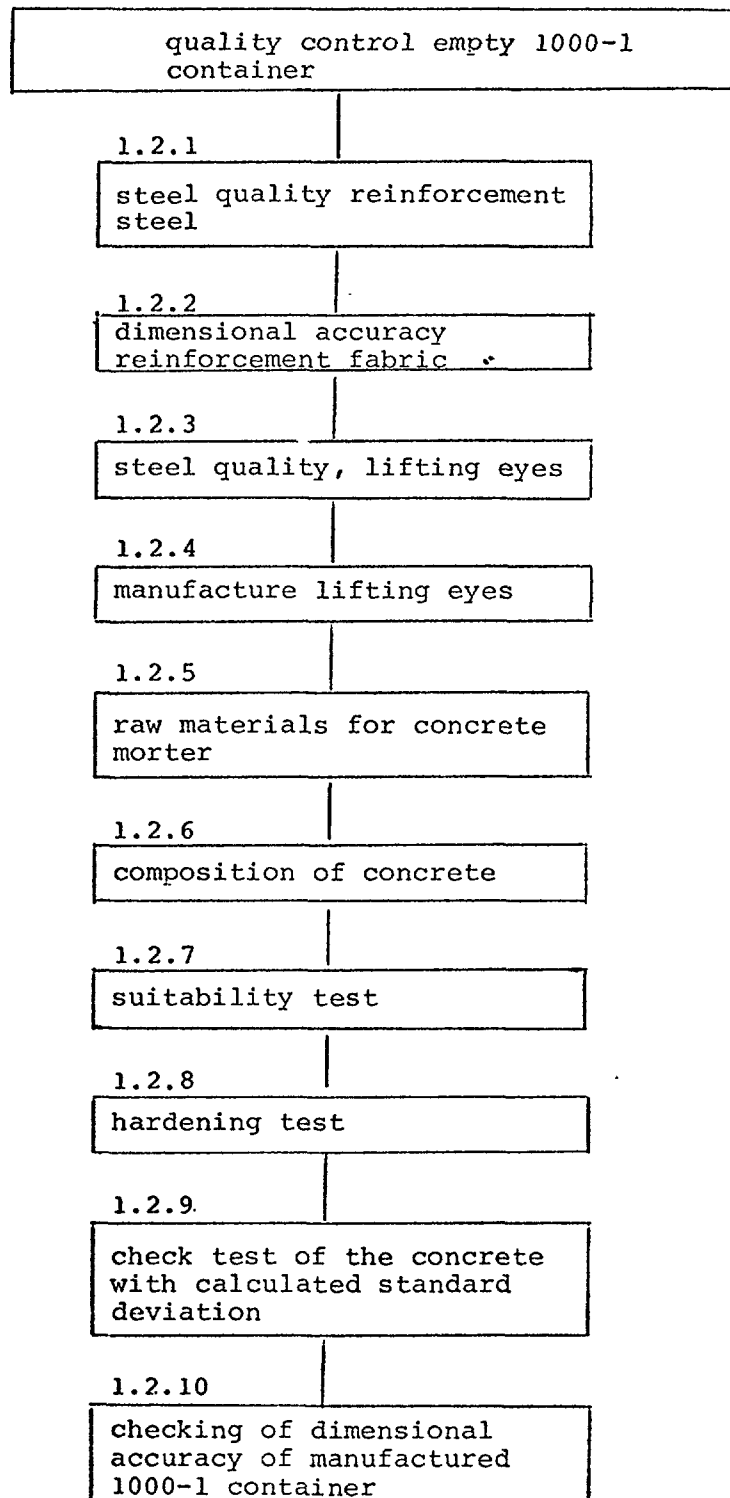


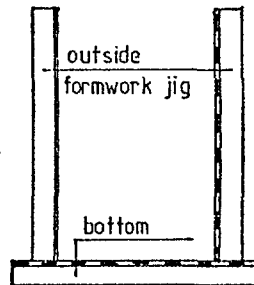
Chart 1 - Container parts subject to quality control.

## manufacturing stages

## quality control

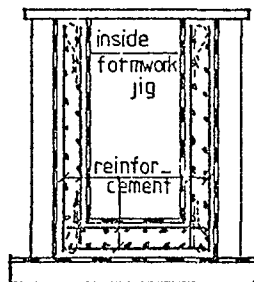
### 1. Erection of outside formwork

Dimensional accuracy



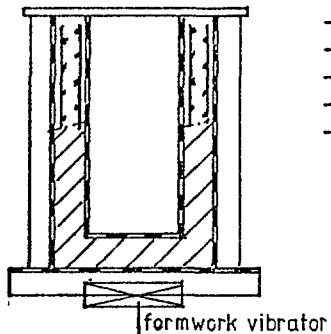
### 2. Fitting of reinforcement incl. lifting eyes and inside formwork

- Steel quality
- Dimensional accuracy
- Welding



### 3. Placing and compacting of concrete mortar

- Raw materials
- Dry concrete mix
- Suitability test
- Hardening test
- Check test



### 4. Finished 1000-1 containers

- Dimensional accuracy
- Damage

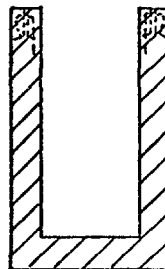


Chart 2 - Manufacturing stages with associated quality control.

2.2.1	Homogenisation of contents of waste storage tanks
2.2.2	
	Taking samples from storage tank
2.2.3	
	Filling of processing tank
2.2.4	
	Homogenisation of contents of processing
2.2.5	
	Determinisation of specific Co-60 activity
2.2.6	
	Determination of isotope composition
2.2.7	
	Mixing of waste and cement
2.2.8	
	Checking of homogeneous mixing of waste-cement
2.2.9	
	Filling of a 200-l drum
2.2.10	
	Check measurement of surface radiation
2.2.11	
	Check for presence of residual water
2.2.12	
	Addition of solid waste components

Chart 3 Process stages with checks

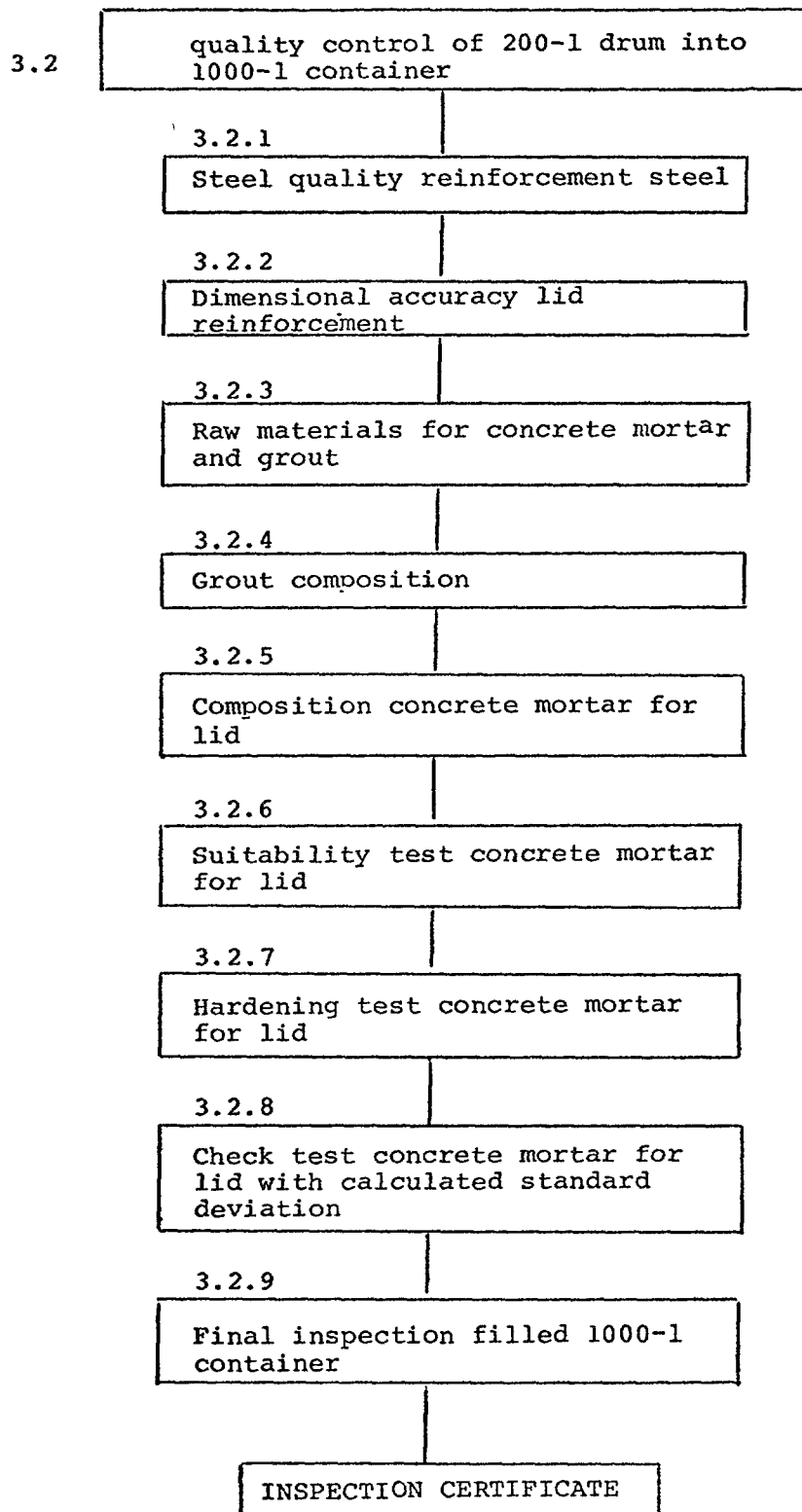
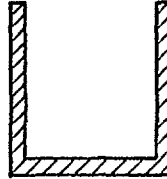


Chart 4 - Preparation stages for placing 200-1 drum into 1000-1 container which are subject to quality control.

Sequence in processing stations

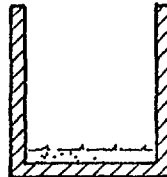
Quality inspections

1. 1000-1 container



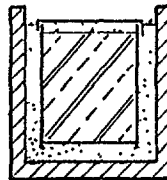
- see para. 1

2. Grout layer, approx. 50 mm thick on bottom of B container



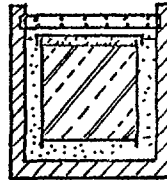
- raw materials for grout  
- grout mixture  
- grout quantity

3. Placing of filled steel 200-1 drum and inserting grout between 200-1 drum and 1000-1 container. Fitting of steel lid to 2000-1 (sic) drum



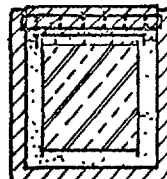
- raw materials for grout  
- grout mixture  
- grout quantity  
- depth

4. Fitting of lid reinforcement



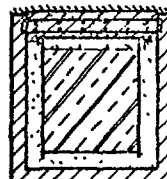
- steel quality  
- dimensional accuracy  
- position

5. Placing of concrete lid  
- preparation of mortar  
- placing and even distribution  
- vibrating of concrete



- raw materials for concrete mortar  
- dry concrete mortar mix  
- suitability test  
- hardening test  
- check test  
- finish

6. Application of curing compound to lid and final inspection



- curing compound on lid  
- final inspection of:  
  . application of curing compound  
  . any possible damage  
  . compressive strength lid

Chart 5 - Manufacturing sequence in processing stations and associated quality inspections

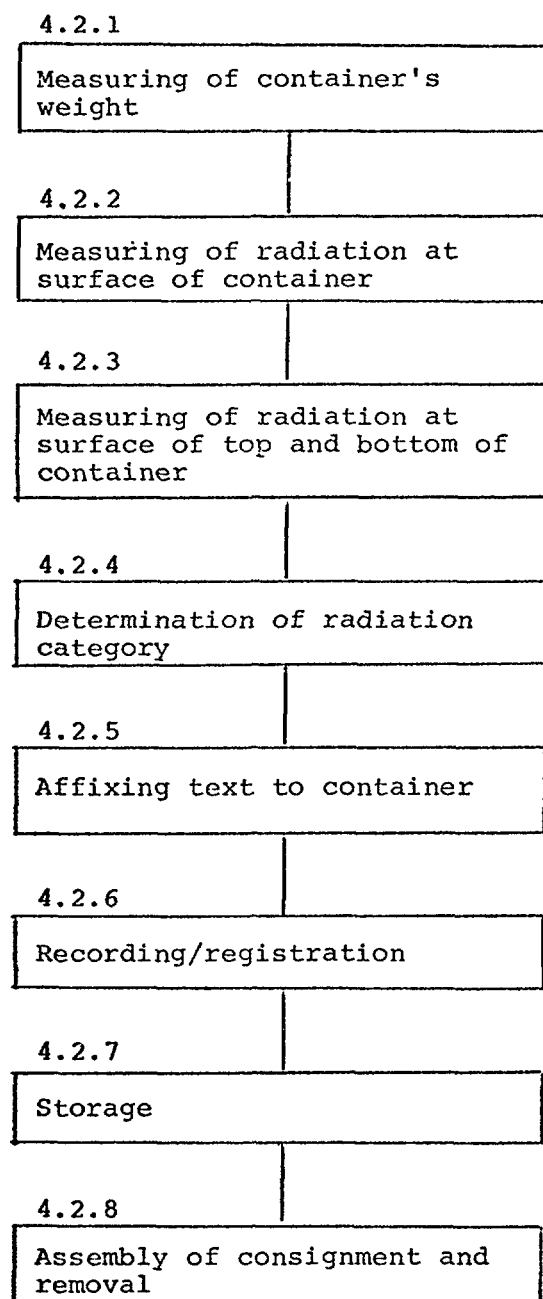


Chart 6 - Recording of data during processing and packing.

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