بسم الله الرحمن الرحيم

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Conditioning Characterization of Low Level Radioactive Waste

By

Afra Fathelrahman Osman

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Supervisor: Dr. Isam Salih Mohamed

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Examination committee

Title	Name	Signature
External Examiner	Prof. . Mohammed Osman Sid Ahmed	
Supervisor	Dr. Isam Salih	
Internal Examiner	Dr. Ibrahim Idris Suliman	

Date of examination: 2\02\2011

DEDICATION

TO MY MOTHER

MY FATHER

MY HUSBAND

BROTHERS, SISTERS AND TO ALL MY FRIENDS

WITH LOVE

AFRA

Acknowledgement

I WOULD LIKE TO EXPRESS MY SINCERE THANKS AND APPRECIATION TO MY SUPERVISOR DR. ISAM SALIH FOR HIS GUIDANCE, ENCOURAGEMENT AND ADVICE THROUGHOUT THE COURSE OF THIS PROJECT. WITHOUT THAT THIS WORK WOULD BE EXTREMELY DIFFICULT.

I AM ALSO EXTREMELY GRATEFUL TO HAJO IDRIS FOR HIS VALUABLE ASSISTANCE, SUGGESTION AND COOPERATIVE WORK DURING THE WHOLE PERIOD OF THE PROJECT.

ABSTRACT

This study has been carried out in the radioactive waste management laboratory Sudan Atomic Energy Commission. The main purpose of this work is method development for treatment and conditioning of low level liquid waste in order to improve radiation protection level in the country. For that purpose a liquid radioactive material containing Cs-137 was treated using the developed method. In the method different type of materials (cement, sands, concrete. .etc) were tested for absorption of radiation emitted from the source as well as suitability of the material for storage for long time. It was found that the best material to be used is Smsmia Concrete. where the surface dose reduced from 150 to 3 μsv/h. Also design of storage container was proposed (with specification: diameter 6.5cm, height 6cm, placed in internal cylinder of diameter 10.3cm, height 12.3cm) and all are installed on the concrete and cement in the cylinder . Method was used in the process of double-packaging configuration. For more protection it is proposed that a mixed of cement to fill the void in addition to the sand be added to ensure low amount of radiation exposure while transport or storage.

الخلاصة

أجريت هذه الدراسة في معمل وحدة النفايات المشعة بهيئة الطاقة الذرية السودانية. وكان الغرض الرئيسي من هذا العمل تطوير طريقة لمعالجة وتكييف النفايات السائلة ذات المستوي المنخفض من اجل تحسين مستوي الحماية من الإشعاع في البلد.

لهذا الغرض من المواد المشعة السائلة التي تحتوي علي Cs-137 الذي تمت معالجته بأسلوب متقدم.في هذه الطريقة نوع مختلف من المواد(الاسمنت-الرملة-الخرسانة...الخ) تم اختبارها لامتصاص الإشعاع المنبعث من المصدر وكذلك مدي ملاءمة المادة للتخزين لفترة أطول. وقد وجد إن أكثر المواد الأفضل استخداما هي الخرسانة الصغيرة،حيث خفضت جرعة السطح من150الي µsv/h20. واقترح أيضا تصميم حاوية تخزين(مع المواصفات:القطرcm 6.5 -الارتفاع 6cm وضعت في اسطوانة قطرها الداخليcm 10.3 -الارتفاع 12.3cm) ويتم تثبيتهم علي الخرسانة والاسمنت في الاسطوانة.

وقد استخدمت الطريقة في عملية تهيئة التغليف المزدوج.لزيادة الحماية يقترح أن يكون خليط من الاسمنت وتملا الفراغ بالرمال وذلك لضمان التعرض لكمية قليلة من الإشعاع أثناء النقل أو التخزين.

Table of Contents

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introductions

The use of radioactive materials in industrial applications, agricultural, medical and scientific research produces a tremendous waste. The amount of waste resulting from the various activities mentioned above varies according to application leading to increase in hazard to the environment. The importance of the safe management of radioactive waste for the protection of human health and the environment has long been recognized, and considerable experience has been gained in this field.

The International Atomic Energy Agency (IAEA) define radioactive waste as materials and products contaminated with radioactive isotopes in quantities greater than the allowable limit (subject, specified by the competent international bodies), is not expected to be subject to future use in any area of production and testing. Included in the term radioactive waste closed radioactive sources and consumers that do not have any for later use. Radioactive waste occurs in a variety of forms with very different physical and chemical characteristics, such as the concentrations and half-lives of the radionuclide's this waste may occur:

- In gaseous form, such as in ventilation exhausts from facilities handling radioactive.
- Materials in liquid form, ranging from scintillation liquids from research facilities to high level liquid waste from the reprocessing of spent fuel.
- In solid form, ranging from contaminated trash and glassware from hospitals, medical research facilities and radiopharmaceutical laboratories to vitrified reprocessing waste or spent fuel from nuclear power plants when it is considered a waste.

Radioactive waste may also contain chemically or biologically hazardous substances and it is important that hazards associated with these substances are adequately considered in radioactive waste management.

The internationally agreed objective of radioactive waste management is to deal with radioactive waste in a manner that protects human health and the environment now and in the future, without imposing undue burdens on future generations. Liquid radioactive waste has been generated from the use of radioactive materials in industrial applications, research and medicine. Liquid low-level wastes are precipitated using chemical methods, followed by solidification in drums. Solidification is done using cementation processes. Cementation is most frequently used for processing low-level waste, the cement mix is usually storage in containers, preventing the radioactive cement from coming into direct contact with ground or surface waters. The method used is suitable for sludge containing Sr-89, Sr-90, Pu-289, and Am-242, because these radionuclides are firmly bound by cement.

On the other hand cesium and ruthenium can easily be leached and certain wastes should therefore suitable treated prior to cementation. The addition of clay to the cement mix gives the optimal improvement in the relation of strontium and cesium. Apart of chemical sludge cement fixation has been employed for evaporators concentrates, saturated, sorption material and small volumes of high level wastes.

The types of equipment used for radioactive waste cementation differ significantly. Different types of cement or mortar mixers commonly used in the building industry are mostly employed. The equipment is operated continuously or intermittently and the cement mix is discharge either into transport containers or large bunkers [1].

The objective of conditioning is to produce a waste package acceptable for handling, storage, transportation or disposal. For these reasons, the waste package produced in a conditioning process should comply with the transport regulations, requirements for long term storage and/or waste acceptance criteria for disposal, as applicable.

The purpose of this study was to determine the waste conditioning performance of low-level wastes in cement-clay mixtures.

1.2 Study Objectives

General objective

The objective of this study is to treat liquid radioactive waste in order to separate as much of the radioactive components as possible from the wastes in a concentrated form and then store in safe manner and in small volume.

Specific objectives

1. Estimate the radiation dose during conditioning of low level wastes (LLW)
2. Identify more effective materials to be used in the conditioning process
3. Control of radioactive contamination during the process

CHAPTER TWO

LITREURE REVIEW

2.1 RADIOACTIVE WASTE

It is the waste product contains radioactive material. It is usually the product of a nuclear process such as nuclear fission, though industries, not directly connected to the nuclear power industry may also produce radioactive waste.

Radioactivity diminishes over time, so in principle the waste needs to be isolated for a period of time until it no longer poses a hazard. This can be hours to years for some common medical or industrial radioactive wastes, or thousands of years for high-level wastes from nuclear power plants and nuclear weapons reprocessing.

The majority of radioactive waste is "low-level waste", meaning it has low levels of radioactivity per mass or volume.

The main approaches to managing radioactive waste to date have been segregation and storage for short-lived wastes, near-surface disposal for low and some intermediate level wastes, and deep burial or transmutation for the long-lived, high-level wastes.

A summary of the amounts of radioactive wastes and management approaches for most developed countries are presented and reviewed periodically as part of the IAEA Joint Convention on Safety of Spent Fuel Management and the Safety of Radioactive Waste Management [2].

2.2 source of radioactive waste

Radioactive waste comes from a number of sources. The majority of waste originates from the nuclear fuel cycle and nuclear weapons reprocessing. However, other sources include medical and industrial wastes, as well as naturally occurring radioactive materials (NORM) that can be concentrated as a result of the processing or consumption of coal, oil and gas, and some minerals. Some of the wastes are generated in heavy machines such as tanks, airplanes and many industrial applications [3].

2.3 Classification of Radioactive Wastes

In order to manage nuclear wastes, it is useful to classify or group them into categories based on the properties of the waste, which can be done in a number of ways.

For example, radioactive waste can be classified by the level of radioactivity present (high, intermediate, low, or below regulatory concern), by the dominant type of radiation emitted (alpha, beta, gamma, or X-ray) or, by its half-life (a length of time required for the material to decay to half of its original value). Also, radioactive wastes can be classified by their physical characteristics (primarily, solid or liquid, but they can also exist in the gaseous state). A quantitative way to classify radioactive waste is by specific activity or activity concentration; i.e., by the activity per quantity of waste (mass or volume). The heat generated in a sample (that depends on half-life, concentration, and type of radiation) can also be used for classification. Finally, waste can be classified for security and non-proliferation purposes (e.g., designated as "special nuclear materials"), for worker safety, and for transportation [4].

These various classifications have advantages and disadvantages depending upon how the information is used. In many places around the world, radioactive wastes have traditionally been classified on the basis of their characteristics and how the waste was produced via a top down, generator-oriented approach. This has resulted in inconsistencies, overlaps, and omissions which lead to conflicts between the source-defined classifications and the waste acceptance criteria developed from the disposal systems. Such generator-oriented waste classifications do not fully capture the associated hazards and, thus, are insufficient to ensure public health and environmental safety. Whatever qualitative framework is used, the length of time radioactive waste must be isolated from the public is determined primarily by its half-life and energy. The heat generation, concentration, and type of radiation determine the shielding and handling requirements for the disposal of the waste.

Although the classification of radioactive wastes varies from country to country, three groupings are generally accepted internationally [5].

2.4 Types of radioactive waste

2.4.1 High-level Waste (HLW)

HLW generally refers to the radioactive nuclides at high levels from nuclear power generation, (i.e. reprocessing waste streams or unprocessed spent fuel) or from the isolation of fissile radio nuclides from irradiated materials associated with nuclear weapons production. When the spent nuclear fuel from reactor operations (civilian or defense) is chemically processed, the radioactive wastes include nuclides from the aqueous phase from the first extraction cycle (and other reprocessing waste streams) as it contains high concentrations of radioactive fission products. As a result, HLW is highly radioactive, generates a significant amount of heat, and contains long-lived radionuclides. Typically these aqueous waste streams are treated by the principle of "concentrate and contain," as the HLW is normally further processed and solidified into either a glass (verification) or a ceramic matrix waste form. Spent nuclear fuel not reprocessed is also considered as HLW. Because of the highly radioactive fission products contained within the spent fuel, it must be stored for "cooling" for many years before final disposal by isolation from the environment. This final disposal of HLW is placement within deep geologic formations. Relative to the total volume of waste produced from commercial power generation, HWL constitutes only a small fraction (a few percent). However, the vast majority of the radioactivity (95%) resides in the HLW. The only disposal option for this class of waste is burial in a deep geologic repository [6].

2.4.2. Intermediate-level Waste (ILW)

ILW contains lower amounts of radioactivity than HLW but still requires use of special shielding to assure worker safety. Reactor components, contaminated materials from reactor decommissioning, sludge from spent fuel cooling and storage areas, and materials used to clean coolant systems such as resins and filters are generally classified as ILW. The most common management option is "delay to decay" for short-lived solid waste, but for the long-lived waste, the "concentrate and contain" principle (solidification for deep geologic disposal) is required. ILW comprises about 7% of the volume and, roughly, 4% of the radioactivity of all radioactive wastes. The disposal options for this class of waste are burial in a deep geologic repository for the long-lived radionuclides and near-surface burial for the short-lived ones.

2.4.3 Low-level Waste (LLW)

These include research laboratories, hospitals using radionuclides for diagnostic and therapeutic procedures, as well as nuclear power plants. LLW includes materials that become contaminated by exposure to radiation or by contact with radioactive materials. Items such as paper, rags, tools, protective clothing, filters and other lightly contaminated materials that contain small amounts of short-lived nuclides are usually classified as LLW. By its nature, LLW does not require shielding during normal handling and transportation and both principles of "delay to decay" and "dilute and disperse" can be employed for disposal depending on the exact nature of the waste. Often, it is advantageous to reduce the volume of LLW by compaction or incineration before disposal. Worldwide it constitutes ~90% of the volume but only ~1% of the radioactivity associated with all radioactive waste. However, wastes containing small amounts of long-lived radionuclides can be included under the LLW classification. The disposal options for this class of waste are near-surface burial or no restrictions depending on level of radioactivity. The International Atomic Energy Agency (IAEA) noted that these classifications, HLW, ILW and LLW, although useful for some purposes, have some important limitations. Specifically the limitations cited are no "clear linkage to the safety aspects in radioactive waste management's, especially disposal," The "current classification system lacks quantitative boundaries between classes," and no "recognition of a class of waste that contains so little radioactive material that it may be exempted from control as a radioactive waste [7].

2.5 Waste management program

Once created, radioactive waste will undergo some of the following stages depending on the type of waste and the strategy for its management:

2.5.1 Pre-treatment

It is the first step that just after waste generation. It may involve collection, segregation, chemical adjustment and decontamination and may also include a period of interim storage. The aim of this step is to segregate waste into streams that will be managed in similar ways, and to isolate non-radioactive wastes or those materials that can be recycled.

2.5.2. Treatment

It involves changing the characteristics of the waste by volume reduction, radionuclide removal or change of composition. Typical treatment operations include:

1. compaction of dry solid waste or incineration of solid or organic liquid wastes (volume reduction);
2. filtration or ion exchange of liquid waste (radionuclide removal); and
3. Precipitation or flocculation of chemical species (change of composition).

2.5.3. Conditioning

It involves operations transforming radioactive waste into a form that is suitable for handling, transportation, storage and disposal. This might involve immobilization of radioactive waste, placing waste into containers or providing additional packaging. Common immobilization methods include solidification of LLW and ILW liquid radioactive waste in cement, and verification of HLW in a glass matrix. Immobilized waste may be placed in steel drums or other engineered containers to create a waste package. Figure (1.1) shows a container used as interim storage for conditioning the generated waste [8].

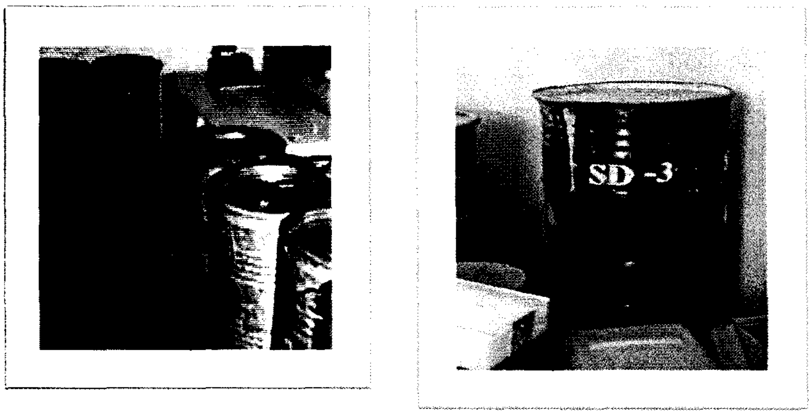


Figure (1.1): container contains Cs-137and Sr-90 disused sources after conditioning processes.

2.5.4 Storage

Storage of radioactive waste may take place at any stage in the radioactive waste management process and aims to isolate the radioactive waste help protect the environment and make it easier to control its disposal. Storage may be used to make the next step in the management process more straightforward or to act as a buffer between or within steps. Waste might be stored for many years before it undergoes further processing and disposal. Some storage facilities are located within a nuclear power plant or a licensed disposal facility; others are separate facilities [9].

2.5.5 Retrieval

This involves recovering waste packages from storage either for inspection, for disposal or for further storage in new facilities. Some storage facilities are designed so the equipment that deposits waste can be operated in reverse to retrieve waste packages. Others may need retrieval equipment to be installed [10].

2.5.6. Disposal

Disposal occurs when packages of radioactive waste are deposited in a disposal facility with no intention of retrieval. Disposal may also include discharging radioactive wastes such as liquid and gaseous effluent into the environment and transfer of wastes from one site to another [11].

2.5.7 Compaction

Compaction is a mature, well-developed and reliable volume reduction technology that is used for processing mainly solid man-made low-level waste (LLW). Some countries (Germany, UK and USA) also use the technology for the volume reduction of man-made intermediate-level/transuranic waste. Compactors can range from low-force compaction systems (~5 tonnes or more) through to presses with a compaction force over 1000 tones, referred to as super compactors. Volume reduction factors are typically between 3 and 10, depending on the waste material being treated.

Low-force compaction is typically applied to the compression of bags of rubbish, in order to facilitate packaging for transport either to a waste treatment facility, where further compaction might be carried out, or to a storage/disposal facility. In the case of super compactors, in some applications, waste is sorted into combustible and non-combustible materials. [1]

Combustible waste is then incinerated whilst non-combustible waste is supercompacted. In certain cases, incinerator ashes are also supercompacted in order to achieve the maximum volume reduction.

Low-force compaction utilizes a hydraulic or pneumatic press to compress waste into a suitable container, such as a 200-litre drum. In the case of a super compactor, a large hydraulic press crushes the drum itself or other receptacle containing various forms of solid low- or intermediate level waste (LLW or ILW). The drum or container is held in a mold during the compaction stroke of the super compactor, which minimizes the drum or container outer dimensions. The compressed drum is then stripped from the mold and the process is repeated. Two or more crushed drums, also referred to as pellets, are then sealed inside an over pack container for interim storage and/or final.

2.5.8 Incineration

Incineration of combustible wastes can be applied to both radioactive and other wastes. In the case of radioactive waste, it has been used for the treatment of low-level waste from nuclear power plants, fuel production facilities, research centers (such as biomedical research), medical sector and waste treatment facilities. Following the segregation of combustible waste from non-combustible constituents, the waste is incinerated in a specially engineered kiln up to around 1000°C. Any gases produced during incineration are treated and filtered prior to emission into the atmosphere and must conform to international standards and national emissions regulations. Following incineration, the resulting ash, which contains the radionuclide, may require further conditioning prior to disposal such as cementation or bituminization. Compaction technology may also be used to further reduce the volume, if this is cost-effective. Volume reduction factors of up to around 100 are achieved, depending on the density of the waste. Incineration technology is subject to public concern in many countries as local residents worry about what is being emitted into the atmosphere. However, modern incineration systems are well engineered; high technology processes designed to completely and efficiently burn the waste whilst producing minimum emissions. The incineration of hazardous waste (e.g. waste oils, solvents) and non-hazardous waste (municipal waste, biomass, tyres, and sewage sludge) is also practiced in many countries.

2.5.9 Cementation

Cementation through the use of specially formulated grouts provides the means to immobilize radioactive material that is on solids and in various forms of sludge's and precipitates/gels (flocks) or activated materials. In general the solid wastes are placed into containers. The grout is then added into this container and allowed to set. The container with the now monolithic block of concrete/waste is then suitable for storage and disposal. Similarly in the case of sludges and flocks, the waste is placed in a container and the grouting mix, in powder form, is added. The two are mixed inside the container and left to set leaving a similar type of product as in the case of solids, which can be disposed of in a similar way. This process has been used for example in small oil drums and 500-litre containers for intermediate-level wastes and has been extended to ISO shipping containers for low-level waste materials. The technology is being used in the immobilization of many toxic and hazardous wastes that arise outside the nuclear industry and has the potential to be used in many more cases.

2.5.10 Verification

The immobilization of high-level waste (HLW) requires the formation of an insoluble, solid waste form that will remain stable for many thousands of years. In general borosilicate glass has been chosen as the medium for dealing with HLW.

The stability of ancient glass for thousands of years highlights the suitability of borosilicate glass as a matrix material. This type of process, referred to as verification, has also been extended for lower level wastes where the type of waste or the economics have been appropriate. Most high-level wastes other than spent fuel itself arise in a liquid form from the reprocessing of spent fuel. To allow incorporation into the glass matrix this waste is initially calcined (dried) which turns it into a solid form. This product is then incorporated into molten glass in a stainless container and allowed to cool, giving a solid matrix. The containers are then welded closed and are ready for storage and final disposal. This process is currently being used in France, Japan, the Former Soviet Union, UK and USA and is seen as the preferred process for management of separated HLW arising from reprocessing. Several other alternative ceramic processes have also been developed which also achieve the desired quality of product (see for example Synroc information page).In-situ verification has also been investigated as a means of 'fixing' activity in contaminated ground as well as creating a barrier to prevent further spread of contamination [1].

2.6 Principles of radioactive waste management

The basic principles of radioactive waste management can be summarized as follows:

1. A strategy should be produced and implemented for managing radioactive waste on a site. This should be consistent with government policy, including the government's overall policy aims on sustainable development, should take into account the possible consequences for present and future generations and should consider the environment and non-human species.
2. Where reasonably practicable, radioactive waste generation should be prevented or minimized, both in terms of quantity and activity.
3. The accumulation of radioactive waste on site should be minimized.
4. Characterization and segregation of radioactive waste should be used to help ensure subsequent management is safe and effective.
5. Radioactive waste should be stored using good engineering practice and in a passively safe condition.
6. Radioactive waste should be processed into a passively safe state as soon as is reasonably practical.

Information that might be required now and in the future for the safe management of radioactive waste should be recorded and preserved [12].

2.7 Caesium-137

Caesium-137 (^{137}Cs) is a radioactive isotope of caesium which is formed mainly as a fission product by nuclear fission. It has a half-life of about 30.1 years, and decays by beta emission to a metastable nuclear isomer of barium-137: barium-137m (^{137m}Ba, Ba-

137m). (About 95 percent of the nuclear decay leads to this isomer. The other 5.0 percent directly populates the ground state, which is stable.) Ba-137m has a half-life of about 2.55 minutes, and it is responsible for all of the emissions of gamma rays. One gram of cesium-137 has an activity of 3.215 terabecquerel (TBq).

The photon energy of Ba-137m is 662 keV. These photons can be useful in food irradiation and in the radiotherapy of cancer. Cesium-137 is not widely-used for industrial radiography because it is quite chemically reactive, and hence, difficult to handle. Also the salts of cesium are very soluble in water, and this complicates the safe handling of cesium. Cobalt-60, is preferred for radiography, since it is chemically a rather nonreactive metal offering higher energy gamma-ray photons. Cesium-137 can be found in some moisture and density gauges, flow meters, and related sensors.

2.7.1 Cesium Uses

Caesium-137 has a small number of practical uses. In small amounts, it is used to calibrate radiation-detection equipment. It is also sometimes used in cancer treatment, and it is also used industrially in gauges for measuring liquid flows and the thickness of materials. [13].

2.7.2 Radioactive caesium in the environment

Cesium-137 undergoes radioactive decay with the emission of beta particles and relatively strong gamma radiation. Cesium-137 decays to barium-137m, a short-lived decay product, which in turn decays to a nonradioactive form of barium. The major dose from cesium-137 is from the barium-137. The half-life of cesium-137 is 30.17 years. Because of the chemical nature of cesium, it moves easily through the environment. This makes the cleanup of cesium-137 difficult.

Small amounts of caesium-134 and caesium-137 were released into the environment during nearly all nuclear weapon tests and some nuclear accidents, most notably the Chernobyl disaster. As of 2005, caesium-137 is the principal source of radiation in the zone of alienation around the Chernobyl nuclear power plant. Together with caesium-134, iodine-131, and strontium-90, caesium-137 was among the isotopes with greatest health impact distributed by the reactor explosion.

The mean contamination of caesium-137 in Germany following the Chernobyl disaster was 2000 to 4000 Bq/m^2. This corresponds to a contamination of 1 mg/km^2 of caesium-137, totaling about 500 grams deposited over all of Germany.

Due to cesium-137 mostly being a product of artificial nuclear fission, it did not occur in nature to any significant degree before nuclear weapons testing began. By observing the characteristic gamma rays emitted by this isotope, it is possible to determine whether the contents of a given sealed container were made before or after the advent of atomic bomb explosions. [14]

2.7.3 DETECTION:

Cs-137 can be detected using thin window GM equipment.

2.7.4 POSTINGS AND LABELING:

Instruments and article containing Cesium 137 have radiation symbol on the equipment. Users will ensure that the symbol is not marred or defaced. Equipment with a marred or defaced symbol will be turned in for repair/replacement.

2.7.5 PERSONNEL DOSIMETRY:

Millicurie quantities of Cs-137 present an external exposure hazard. TLDs or Film Badges are required.

2.7.6 GENERAL RADIOLOGICAL SAFETY INFORMATION

- Cs-137 often used in a "sealed source" (i.e., encapsulated sources). If the source is greater than or equal to 100 microcuries, the sealed source must be "leak tested" every 6 months. The leak test methodology must be capable of detecting the presence of 0.005 microcuries of removable contamination and must be taken at the nearest accessible location to the source.

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling unsealed Cs-137 or a sealed source that is not shielding within the housing of the instrument (e.g., an irradiator).
- Lead shielding shall be used to minimize exposure from Cs-137
- Indirect viewing aids should be used to minimize exposure from Cs-137.
- Remote handling tools should be used when handling Cs-137.
- Practice procedures without radioactivity prior to performing the procedure with Cs-137. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Cs-137 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.[14]

CHAPTER THREE

MATERIALS AND METHODS

In this study Cement encapsulation is designed for the purpose of conditioning liquid radioactive waste generated by nuclear facilities. Most liquid wastes such as filter cake from effluent treatment plants can be conditioned using this method.
Before the start of treatment devices are equipped with individual control (equipments). Was carried out cementation using rabak cement Portland 20 kilo+ 4litter of water+plate of concreat.was measured to the ph level of water, solidification before treatment to ensure the coherence of a concrete and found that such a concrete suitable for processing. The process of treating the liquid cesium is divided into the followings: measurements of the dose at the surface and at one meter before converted Cs-137 to solid. Also design of storage container was proposed (with specification: diameter 6.5cm, height 6cm, placed in internal cylinder of diameter 10.3cm, height 12.3cm) and all are installed on the concrete and cement in the cylinder . Method was used in the process of double-packaging configuration.

3.1 Radiation detectors:

Rados-120 detector is used for area monitoring and Geiger Molar (GM) detector used to measure contamination.

3.2 Ionization chambers

Ion chamber is used to determine dose levels. The simplest ionization chamber consists of a small volume of gas at atmospheric pressure contained in chamber.

3.2.1 Accuracy and calibration

All devices that were used in a radiation survey has been calibrated at the secondary standard dosimetry laboratory , Sudan atomic energy commission, Calibration factor of the CANBIRA-RA DIOGM was 0.89 and the calibration factor of RADOS-120 was 0.88.

3.3 Background Measurement

A natural background of dose was made of the natural background level to determine the reference dose results were as follows natural background. Figure (3-1) showing Radose and Canbira.

1. RADOS-120 0 .04 μSv/h

2. GM Tube 5 CPS

3. CANBIRA-RADIOGM 0 .03 μSv/h

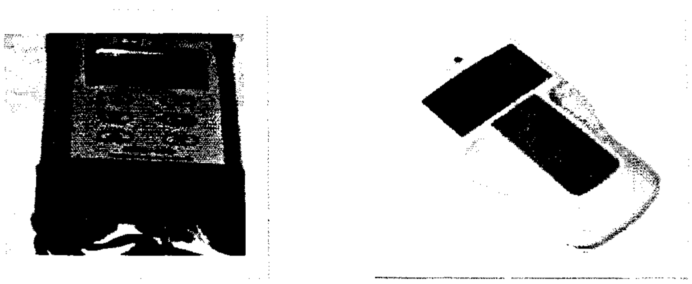


Figure (3.1) showing the devices that were used in radiation dose measurement

CHAPTER FOUR
RESULT AND DISCUTION

In this experiment, radioactive cesium has been converted from liquid to solid, for several reasons, including: reducing the size of storage to ensure a safe manner, and to ensure non-contamination because of the material causes the liquid to the pollution more than solids as it spreads rapidly.

In order to identify suitable materials to be used, different combinations has been selected as shown in Table (4-2). Cement was found to be more solid when tested in comparison with other materials. The hardness of the materials was measured in relation to ph of the material (cement). It is observed that good hardness occurs at low ph values. For that reason and in order to preserve water's edge from erosion of cement, other materials are added. Before and upon completion of the process, measurements of dose rates at the surface and at one meter from the sample, shown in table (4-1).

Table (4-2) represents the materials that were used in conditioning of Cs-137. It is observed that the good sand can be used in Cs-137 cementation was ksnjr sand. This type of sand is considered as most effective in radiation attenuation as other types. The lower dose was 5μSv/h while the maximum was 9 μSv/h (in (sfaia Sand). This indicates that the ksnjr sand is the best one. Also it is shown that the Smsmia Concrete is best concrete in radiation attenuation as dose was 3μSv/h the lowest one in concrete material. Mixture of sand and concrete (Smsmia +ksnjr sand) were good than other in Cs-137 conditioning. The results showed that the obtained values were within the acceptable level for most of the samples. It within is the permissible limits of the radiation level adopted by the IAEA of 10μSv/h.

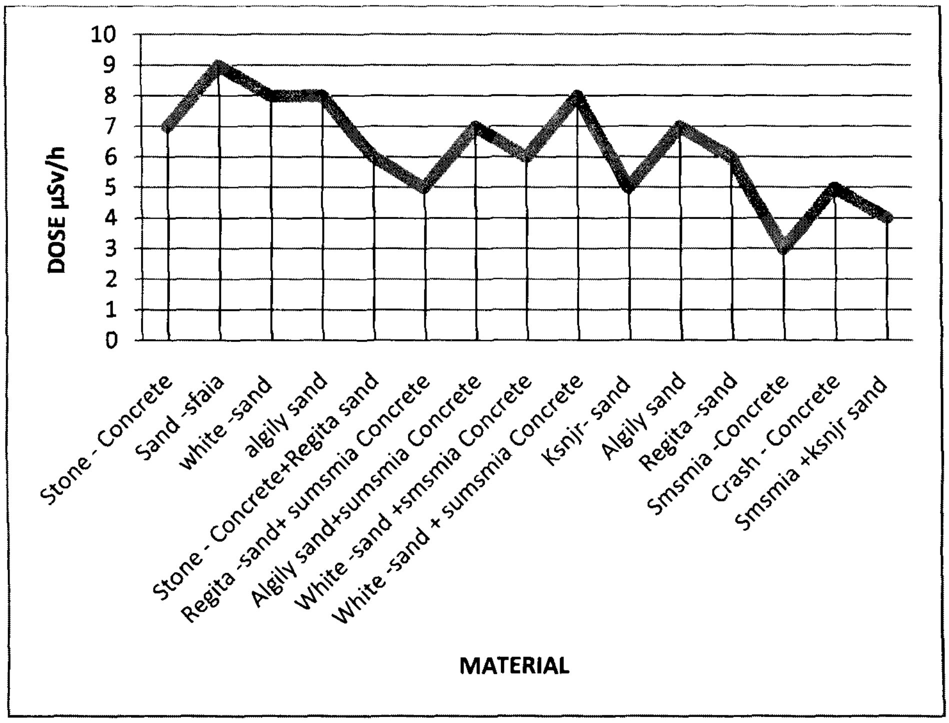
Table (4-1) Details f the cs-137 reading:

Radioactive source	Cs-137
Reading on the surface before converting it to solid	150 μSv/h
Reading at one meter before converting it to solid	20 μSv/h
Reading on the surface after converting it to solid	3.15 μSv/h
Reading at one meter after converting it to solid	0.18 μSv/h
Ph	2.5

Table (4-2) shows the material used for radiation attenuation

NO of sample	Material	Dose μsv/h
1	Stone - Concrete	7
2	Sand -sfaia	9
3	white -sand	8
4	algily sand	8
5	Stone - Concrete+Regita sand	6
6	Regita -sand+ sumsmia Concrete	5
7	Algily sand+sumsmia Concrete	7
8	White -sand +smsmia Concrete	6
9	White -sand + sumsmia Concrete	8
10	Ksnjr- sand	5
11	Algily sand	7
12	Regita -sand	6
13	Smsmia -Concrete	3
14	Crash - Concrete	5
15	Smsmia +ksnjr sand	4

Figure (4-1) presents the data of radiation dose measurement



Conclusion

The radiation dose attenuation of the different materials used in this study are shown in table (4-2) and were expressed in the terms of mean, standard deviation, minimum and maximum. It is observed that the minimum dose was 3µSv/h and the maximum was 9 µSv/h while the mean value of the data was 6.3 µSv/h, Std. Deviation was 1.7

Cement solidification technology compared with other materials has many advantages, such as:

- Requiring simple equipment, easy scaling-up, low working temperature, no trouble of gas cleaning and low cost. It is a suitable technology for treatment of waste radioactive resins, and has been widely used.
- The cemented product is chemically and biochemically stable
- The cemented product is non-combustible.
- The cemented product has good thermal stability.
- Accepted throughout the nuclear industry.
- Simple, low- temperature process.
- Low consumable cost.
- Meets customer requirements and conditions.
- Can be used for other hazardous waste
- Well proven technology.

REFERENCE

1- NUKEM Technologies GmbHZdenek Dlouhy-page 134-disposal of radioactive waste 2007

2- IAEA Joint Convention on Safety of Radioactive Waste 24 Dec.1997

3- INTERNATIONAL ATOMIC ENERGY AGENCY, Standardization of radioactive waste categories, Technical Report Series No, 101, IAEA, Viena (1970)

4- Landsberger S, Plionis A, (2009), web-based course in nuclear and radiochemistry, Journal of Radioanalytical and Nuclear Chemistry, Vol. 280, No.2 ,pp 229–231

5- Classification of radioactive waste general safety guide series no.gsg-1 published Monday, 28 december,2009

6- IAEA Safety series no.99, safety standers for high-level waste disposal, 2006

7- Glenn F. Knoll, Radiation Detection and Measurement pub 1999.ISBN0471073385

8- Alfassi, Z.B. (1994).chemical Analysis by nuclear Method John Wiley and sons: New York, NY

9- IAEA (1999), Safety Standers Series NO.WS-R-1.Date of Issue:Mondy, 21June, 1999.

10- IAEA (2003), radioactive waste management glossary, 2003 Edition,Vienna,Austria

11- IAEA (1997), glossary radioactive waste disposal

12- Environment Agency and the Scottish environment protection agency. December 2007, guidance from the health and safety executive

13- http://www.bt.cdc.gov/radiation/isotopes/cesium.asp

14- Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta,Inc.,1992)