SAFETY IMPROVEMENT OF THE DISPOSAL FACILITIES USING MODIFIED BACKFILL MATERIALS

Thesis presented

By

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يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ
وَالَّذِينَ أُوتُوا الْعِلْمَ
دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ
خَبِيرٌ.

(سورة المجادلة، آية 11)

Allah will exalt in degree those of you who believe, and those who have been granted knowledge. And Allah is Well-Acquainted with what you do.

For my father, who tried his best not to be his worst.

And for my mother, who made sure we never saw him at his

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Abstract

As a result of nuclear power introduction and its important role at each part of our daily life, there were a problem of managing the resulted radioactive or nuclear waste. Radioactive waste elements have different half-life, so in waste management system the elements managed according to this properties, for the last process of the system; as to be stored or disposed in deep geological repositories if it is a high radioactive waste or at near surface if it is low or intermediate level radioactive waste.

Most of countries all over the world studied clay well as a backfill material as it is the main crucial part in their geological repositories. A lot of studies were conducted to study its mechanical, physical, swelling, thermal properties and chemical properties. Also, studies handled the effect of salt concentrations to its adsorption capacity.

This work handles the modification of MMT by introducing Charcoal and AcrylicAcid to modify its swelling properties and enhance its permeability function as a backfill material. The introduction of these materials were done by two methods to evaluate the economic factor if it will be applied. Also, the study handled the introduction of acrylic only. They all prepared using Gamma rays with 40 KGy irradiation dose. They were characterized using FTIR, TGA, SEM, EDX and ICP.

The composites give a promising results regarding to their thermal stability only 1% is the total loss of their initial weight for PAACM and ACM but for AM2 it only lose 0.5% of its initial weight. The composites have a highly porous surface it can be seen by naked eye plus SEM micrograph. EDX analysis also attain the changes occurred in the composites and the substitution occurred within the composite interlayers. For batch characterization of these composites, a lot of factors were studied such as (pH, Temperature, contact time, concentration, solid content, competing ions). Various data were obtained for pH PAACM works at 5.5 for both Cs and Sr, but for ACM it has two cases for Sr it work at acidic medium and alkaline medium with high removal value for both. For Cs it works around 5.5, and for AM2 at pH 6 for both Cs and Sr.

They have a high adsorption capacity after studying the optimum conditions as the follow: PAACM 11.5 mg/g, AMC/Cs 22.5 mg/g, AMC/Sr 27.3mg/g, and for AM2/Cs 46 mg/g, AM2/Sr 26.3 mg/g.

The maximum temperature for each composite as the following: PAACM/Cs at 55 oC, PAACM/Sr at 25 oC, AMC/Cs at 35 oC, AMC/Sr at 55 oC with a steady adsorption rate and AM2/Cs at 45 oC, AM2/Sr at 35oC. The composites gave a great expectation regarding to theirdesorption behavior since only a small fraction has been desorbed with a total loss equals 1.6 %.

Key words:

AcrylicAcid, MMT, Charcoal, Adsorption, Desorption, Backfill materials, Sr, Cs, Radioactive waste, Disposal facilities, engineered barriers.

Introduction

1.1. Historical background.

Nuclear wastes are one of the most importantenvironmental problems that facing the world **(Yildiz et al., 2011)**, so countries must address the disposal of very large quantities of waste containing long-lived radionuclides. Geological formations that contain clay minerals are used as repository for the radioactive wastes. They act as natural barriers against their leakage.

1.2. Origin of Radioactive and Nuclear Waste.

The main sources of radioactive waste are uranium and thorium mining and milling, nuclear fuel cycle operations (uranium conversion and enrichment, fuel fabrication and spent fuel reprocessing), operation of nuclear power plants, decontamination and decommissioning of nuclear facilities and institutional usesof radioisotopes (medicine, industry,agriculture, research reactors and test facilities) (**Zakrzewska-Trznadel, 2006**). So there was a need to radioactive waste management. Fig. (1) Illustrating the sources or radioactive waste.

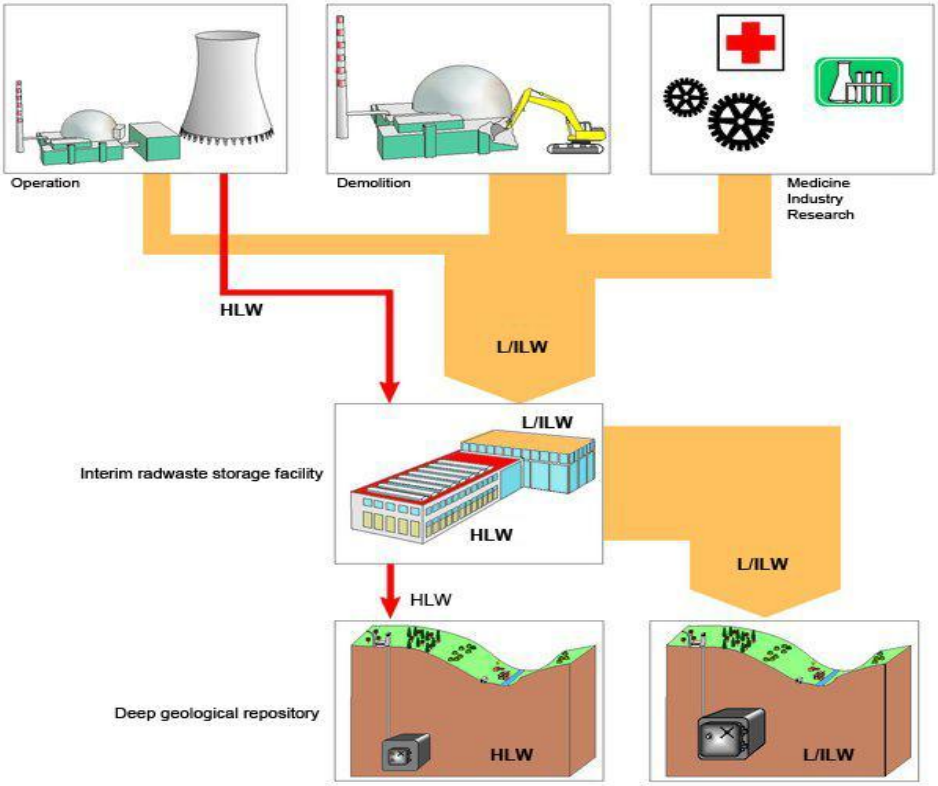

Fig. (1): The sources responsible for radioactive and nuclear waste with illustrating the treatment process and disposing the waste.

1.3. <u>Radioactive Waste Management.</u>

To ensure the safe discharge into the environment, liquid radioactive waste has to fulfill very strict requirements connected with the limits of radioactive substances and other impurities (suspended particulates, Biofoulants and organic or inorganic chemicals). To reach the standards described in national regulations, the waste has to be treated, including volume reduction and reduction of radioactive compounds and other solutes in the effluent. There are many methods used for liquid radioactive waste treatment, including chemical precipitation, sedimentation, ion exchange, thermal evaporation, biological methods **(Ipek *et al.*, 2002; IAEA TECDOC- 1086, 1999; IAEA TECDOC-1336, 2003; IAEA TECDOC-1492, 2006)** and membrane permeation. In addition to waste disposal, there is also a requirement for isolation and purification of radionuclides for specified applications.

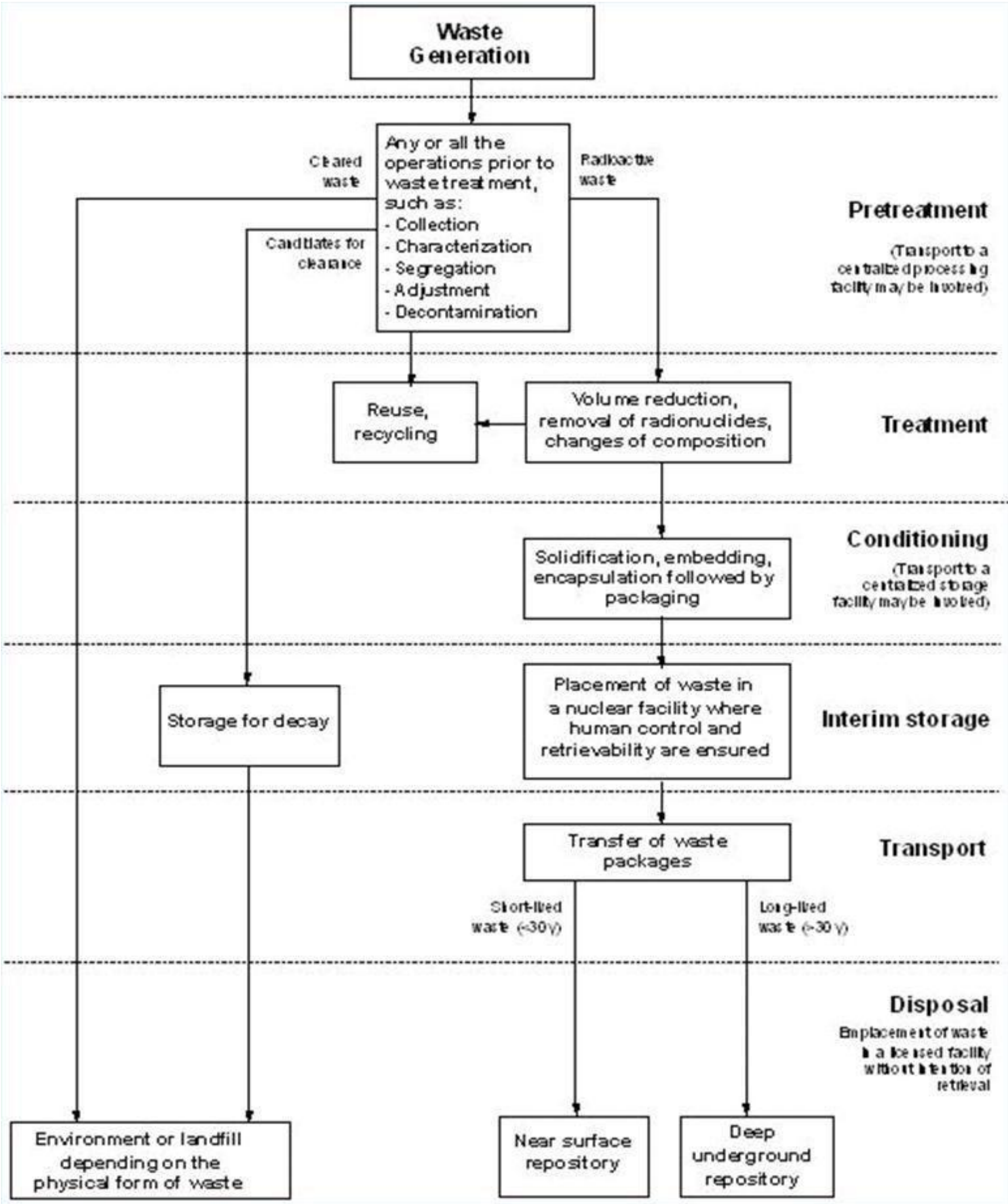

Fig. (3): Radioactive waste management chart.

After all the mentioned steps in radioactive waste management system, the waste may be stored in storage facilities if the countries have no disposal facilities; or stored for a while if its half-life is not so long. The second choice is disposing radioactive waste in deep geological repositories called disposal facilities.

1.4. Disposal Facilities Objective.

The main objective of disposal facilities is to contain the waste; to protect the environment for the next generations also to keep the health of the public and the worker. So there are a lot of tests should be done to ensure the safety of the selected site to be chosen as a disposal facility. The choice is driven by climate, waste form, geological and hydrogeological conditions, plus the assurance that the concept will meet the radiological Performance requirements **(IAEA-TECDOC-1255, 2001)** as Fig. (4) Shows.

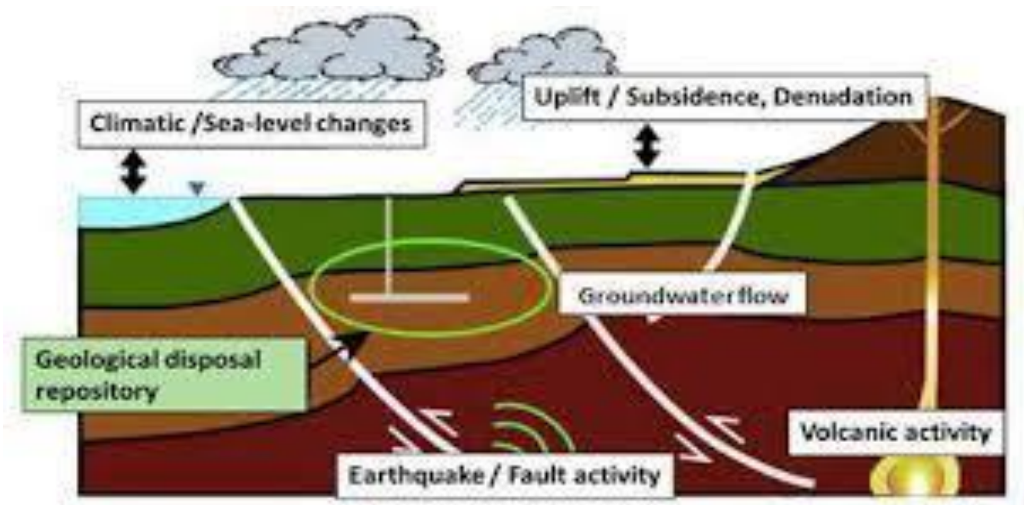

Fig. (4): Some of the challenges that the disposal site may face

1.5. Disposal Facilities Concept.

There are two types of waste disposal facilities LILW and HLW; depending on the waste type the disposal facility change in case of LILW the following type can be used.

1.5.1. Covered trench.

This is the oldest and simplest of the disposal concepts that consist of placing waste into excavated trenches and covering the filled trenches with soil. Typical of this concept is the original trench disposal system at the

Drigg disposal facility in the UK **(Ashworth *et al.*, 1997)**. Fig. (5a) illustrates this type of disposal facilities.

1.5.2. <u>Closed vault</u>.

This consists of a concrete vault into which is placed packaged and/or treated waste. The voidage may be backfilled and the structure closed with concrete slabs, which may be sealed by, for example, asphalt. The whole structure is then protected by an earthencap. **(Dutzer and Nicolas, 1996)** This type is shown in Fig. (5b).

1.5.3. Domed vault.

This concept is best typified by the IRUS disposal facility in Canada **(Charles worth and Champ, 1997)** (see Figure 5(c)), in which infiltration is controlled by placing waste in a dry permeable layer and covering the waste with an impermeable concrete roof that is subsequently protected by an earthen cap.

1.5.4. Open vault.

In this concept, a low permeability cap is placed over the filled vault without emplacement of a concrete slab. Waste is however pre-treated to minimize voidage. The cap is designed to accommodate some settlement. This concept is used at the Drigg Site in the UK for the new vault disposal concept as shown in Fig. (5d). In addition to the options involving trenches and vaults, near surface disposal facilities can include caverns tens of meters deep below the Earth's surface. More generally, a range of cavern type, disposal facilities have been used and proposed for disposal of LILW, typically:

- ✓ specially excavated caverns
- ✓ Disused mines
- ✓ Natural cavities

For Cavern type the main rock serve as the main barrier against the following factor:

- ➢ external factors (corrosion and human intrusion).
- ➢ Radionuclide release.
- ➢ Water ingress.

The last 4 concepts are in case of LILW waste, but in case of high level waste the disposal facility must contain a combination of both natural barrier and engineered barrier (waste container and sealing material); **(Komine, 2010** and**Engelhardt and Finsterle, 2003).**

1.6. Function and Nature of Engineered Barrier.

There are a number of pathways by which radionuclides may migrate or be brought into contact with humans, including:

- Infiltration of surface water;
- Groundwater intrusion;
- Subsequent migration of contaminated water (leachate);
- inadvertent intrusion;
- Escape of radioactive gas.

Engineered barriers can be used as physical and/or chemical obstructions to prevent or delay the movement (e.g. migration) of radionuclides via these pathways **(Alonso *et al.*, 2004; Engelhardt and Finsterle, 2003)**. Theyare an integral part of the disposal facility and their incorporation is best achieved early in the design process. However, as additional information is obtained concerning waste characteristics, disposal site characteristics,indigenous material availability and disposal system performance, it should be incorporated into the disposal facility management plan as well as the engineered barriers‟ design to enhance the overall system performance **(IAEA-TECDOC-1255, 2001)**.

1.7. Backfill Functions.

In this study, what is much concerned is backfill material as one of the barriers found in disposal facilities. It has many functions such as, void filling to avoid excessive settlement, limitation of water infiltration, sorption of radionuclides, precipitation of radionuclides, gas control and, if necessary to facilitate waste retrieval. Typical materials used, either singly or as admixtures, include clays, cement grout, rock, soil, etc. The key properties of backfill are: K_d to establish sorption capacity **(IAEATECDOC-1255, 2001)**.

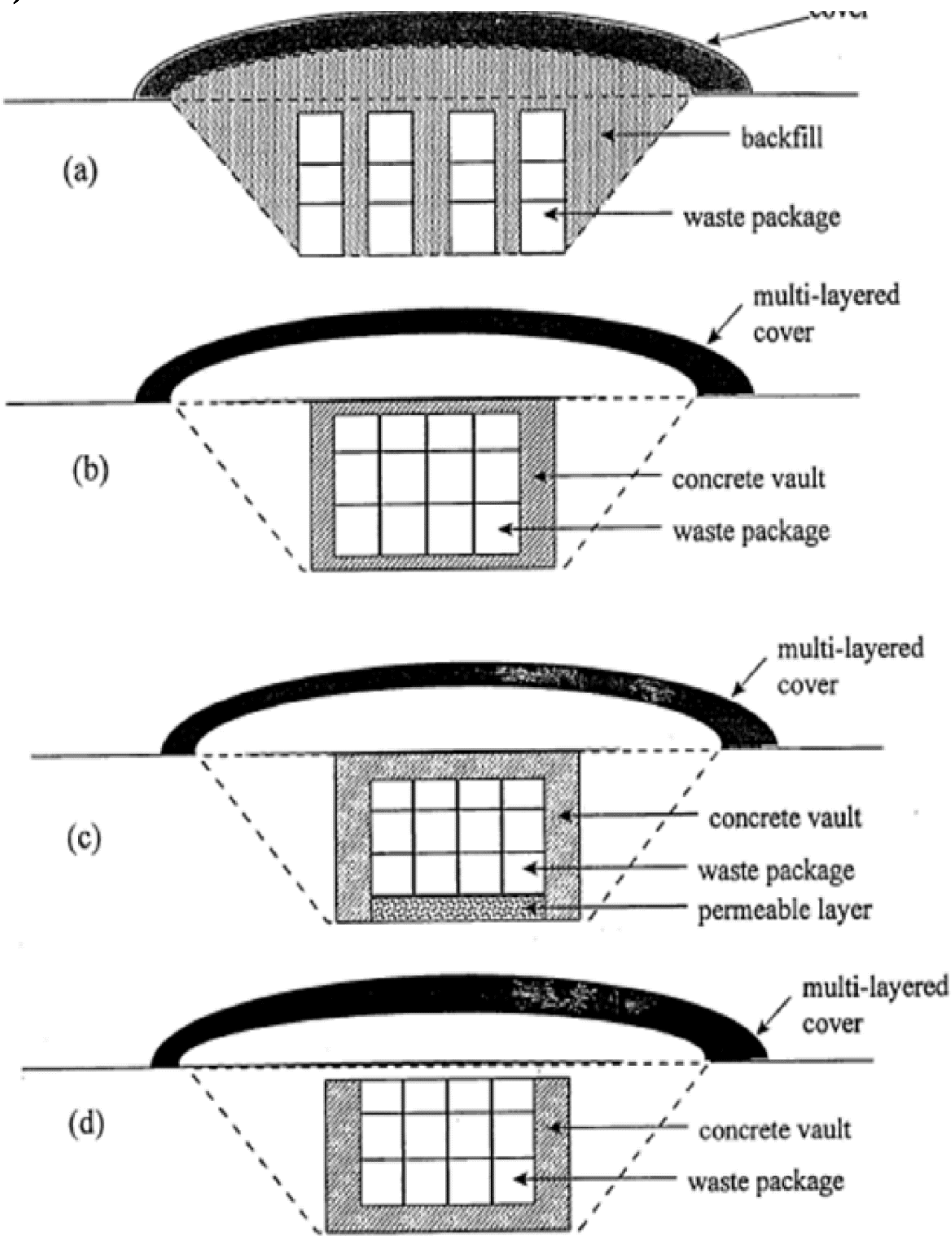

Fig. (5): Example of near surface disposal facility concept
(a: trench disposal, b: closed vault, c: domed vault, d: open vault).

1.8. Clay Importance.

Clays form a crucially important part of many deepgeological repository (DGR) designs for the geological disposal of highly radioactive used nuclear fuel waste. On the one hand, clay deposits are being considered as a potential host rock for a DGR in several countries (e.g., Switzerland, France and Belgium) because of their advantageous physical and hydrogeochemical properties. On the other hand, bentonite-based barriers and seals are essential components of many DGR designs for a variety of host rocks where they would fulfill multiple specific roles in a DGR, such as hydraulic, mechanical, thermal, and chemical protection of the used fuel containers (UFC's) and control of radionuclide migration **(Alonso *et al.*, 2004)**.

1.8. Clay.

Clay minerals are the basic constituents of clay raw materials. Their crystal structure, with a few exceptions, consists of sheets (hence the term used sheet clay minerals or phyllosilicate), firmly arranged in structural layers. The individual layers are composed of two, three or four sheets.These sheets are formed either by tetrahedral $[SiO_4]^{-4}$, abbreviated as tetrahedral “T”, or by octahedral $[AlO_3\ (OH)_3]^{6-}$, termed as octahedral “O”. The interiors oftetrahedrons and octahedrons contain smaller metal cations, their apices being occupied by oxygen from which some are connected with protons (as OH). All these fundamental structural elements are arranged to form a hexagonal network with each sheet. According to the number and the ratio of the sheets in the fundamental structural units, the existing cation substitutions in the octahedrons and tetrahedrons.