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Research article

Radioactive Waste Management of Nuclear Power Plant

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Abstract

Power generation of today struggle with many challenges and as the effects of global warming become obvious many countries seek alternatives to fossil fuel. The increasing interest in nuclear technology is based on its many advantages but the technology also offers challenges in how to cope with prolonged lifetime support and sustainable waste routes. In nuclear fission huge amount of energy is produced as heat, which can be used to generate electricity. The products of fission are radioactive and these can cause endless harm to environment. Radioactive waste is long lived. The radioactive waste should be kept in such an area where the radioactivity cannot create much of an effect on the environment. Radioactive waste management is necessary to isolate radioactive waste from living things. For various types of waste different procedures are followed to reduce the volume of waste and to manage it in a cost effective way. Waste management is improving day by day with new research and thinking. Proper management of radioactive waste can help to increase the number of nuclear power plants around the world.

Keywords- Nuclear, Radioactive Waste, Treatment, Management, Transport.

Introduction

By the term of waste we usually understand a thing, of which its owner (waste producer) wants to dispose. Waste might also be some movable material, the disposal of which is necessary to protect human health and the environment, even when the producer of the waste is unknown. Like all industries, the thermal generation of electricity produces wastes. Radioactive waste is any material that is either radioactive itself or is contaminated by radioactivity, for which no further use is envisaged. These are leftovers from the use of nuclear materials for the production of electricity, diagnosis and treatment of disease, and other purposes. The materials are either naturally occurring or manmade. Since the radioactive wastes are essentially created in a nuclear power reactor, it is accepted that they are the responsibility of the country which uses uranium to generate power. The amount

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of radioactive wastes is very small relative to wastes produced by fossil fuel electricity generation. Used nuclear fuel may be treated as a resource or simply as a waste. All steps in the nuclear fuel cycle generate radioactive waste. Each year, nuclear power generation facilities worldwide produce about 200000 m^3 low-and intermediate level waste and about 10000 m^3 of high-level waste. According to IAEA, a nuclear reactor of 1000 MW (e) produces approximately 30 tons of high level solid packed waste per year if the spent fuel is not reprocessed. In comparison, a 1000 MW (e) coal power plant produces 300000 tons of ash per year. However, radioactive waste emits radiation, which makes it a particular hazard for human health and the environment. It must therefore be managed with special care, from production to disposal.

Types of Radioactive Waste

Radioactive wastes are normally classified into a small number of categories to facilitate regulation of handling, storage and disposal, based on the concentration of radioactive material they contain and the time for which they remain radioactive. The definitions of these categories differ in detail from country to country; however, in general, they can be considered as exempt waste and very low-level waste, low-level waste, intermediate-level waste, and high-level waste.

A. Exempt Waste and Very Low Level Waste

Exempt waste and very low level waste (VLLW) contains radioactive materials at a level which is not considered harmful to people or surrounding environment. It consists mainly of demolished material (such as concrete, plaster, bricks, metal, valves, piping etc.) produced during rehabilitation or dismantling operation on nuclear industrial sites. The waste is therefore disposed of with domestic refuse, although countries such as France are currently developing facilities to store VLLW in specifically designed VLLW disposal facilities.

B. Low-Level Waste

Low level waste (LLW) is generated from hospitals, laboratories and industries, as well as the nuclear fuel cycle. It comprises paper, rags, tools, clothing, filters etc. LLW may include short lived radionuclides at higher levels of activity concentration, and also long lived radionuclides, but only at relatively low levels of activity concentration. It is not dangerous to handle, but must be disposed of more carefully than normal garbage. It doesn’t require shielding during handling and transport. LLW can generally be handled using rubber gloves. Much of the waste generated during decommissioning of a nuclear power plant is LLW. To reduce volume, it is often compacted or incinerated before disposal. Worldwide it comprises 90% of the volume but only 1% of the radioactivity of all radwaste.

C. Intermediate-Level Waste

Radioactive waste that requires shielding but needs little or no provision for heat dissipation is classified as intermediate level waste (ILW). Intermediate level waste contains higher amount of radioactivity and may require special shielding. It typically comprises resins, chemical sludge and reactor components as well as contaminated materials from reactor decommissioning. ILW may contain long lived radionuclides, in particular, alpha emitting radionuclides that will not decay to a level of activity concentration acceptable for near surface disposal during the time for which institutional controls can be relied upon. Smaller items and any non-solids may be solidified in concrete or bitumen for disposal. Worldwide it makes up 7% of the volume and has 4% of the radioactivity of all radwaste. It may be solidified in concrete or bitumen for disposal. Generally short-lived waste (mainly from reactors) is buried, but long-lived waste (from reprocessing nuclear fuel) is disposed of deep underground.

D. High-Level Waste

High-level waste (HLW) is defined to be waste that contains such large concentrations of both short and long lived radionuclides that, compared to ILW, a greater degree of containment and isolation from the accessible environment is needed to ensure long term safety. It generates a considerable amount of heat and requires cooling, as well as special shielding during handling and transport. If the used fuel is reprocessed, the separated waste is vitrified by incorporating it into borosilicate (Pyrex) glass which is sealed inside stainless steel canisters for eventual disposal deep underground. If used fuel is not reprocessed, all the highly-radioactive isotopes remain in it, and so the whole fuel assemblies are treated as high-level waste. Both high-level waste and used fuel are very radioactive and people handling them must be shielded from their radiation. Such materials are shipped in special containers which shield the radiation and which will not rapture in an accident. Whether used fuel is reprocessed or not, the volume of high-level waste is modest, about 3 cubic meters per year of vitrified waste, or 25-30 tons of used fuel for a typical large nuclear reactor [1].

Waste Management Principles

On a practical level, the activities necessary for managing radioactive waste properly can be categorized into the following steps:

A. Minimization

Existing facilities can, with foresight and good practice, reduce the amount of waste created. New technologies and plant designs also aim for waste reduction through such means as simplifying maintenance requirements.

B. Conditioning and Packaging

Solid LLW and ILW can often be super-compacted into much smaller volumes. Since liquid wastes cannot be disposed of, they need to be transformed into solids. Radioactive elements can be removed from the liquid by filtration or ion exchange and they dried, absorbed into a fixing medium, or solidified in concrete. After such conditioning, ILW and LLW can be packaged for interim storage or disposal in steel drums or containers. HLW produced during reprocessing emerges as a liquid and needs to be transformed into a solid for long term storage and disposal, normally by a process of vitrification.

C. Interim Storage

Interim storage facilities are generally used for intermediate-level waste (ILW) and high-level waste (HLW). Spent nuclear fuel that has not been reprocessed is initially stored underwater in a storage pool, usually at the reactor site. After some years it can be placed in specialized containers for interim storage or disposal. For HLW, a period of interim storage is always necessary to allow the initially very high level radiation and heat generation to fall.

D. Final Disposal

Disposal is the final step in radioactive waste management. Short lived ILW and LLW are disposed of routinely at numerous sites in many countries; some sites have already been filled and closed. It is expected that for a period of about 100 to 300 years following closure of an ILW/LLW disposal site active or passive controls will be applied, including groundwater monitoring, restrictions on access, periodic maintenance and restrictions on further land use. After this period the radioactive isotopes will have decayed to negligible levels [2].

Management of High-Level Waste

To generate commercial electricity, nuclear reactors are used in government-sponsored research and development programs, universities and industry; in science and engineering experimental programs; at nuclear weapons production facilities; and by the Navy and military services. The operation of nuclear reactors results in spent reactor fuel. The fuel for most nuclear reactors consists of pellets of ceramic uranium dioxide that are sealed in hundreds of metal rods. Certain changes take place in the ceramic pellet during their time in the reactor of the nuclear power plant. As the nuclear reactor operates, uranium atoms fission and release energy. When most of the usable uranium has fissioned, the “spent” fuel assembly is removed from the reactor. The particles left over after the atom has split are radioactive. Some of the fission products are various isotopes of barium, strontium, cesium and iodine. The spent fuel also contains plutonium and uranium remain within the spent fuel when it is removed from the reactor and are called high level waste as they are extremely hot and very radioactive. It contains the highly-radioactive fission products transuranic elements generated in the reactor core and some heavy elements with long-lived radioactivity.

A. Storage and Disposal

Since the spent nuclear reactor fuel is highly radioactive initially it is too dangerous to handle and thus it is very important to shield the radioactivity from humans and the environment. Following discharge from the reactor the fuel is required to be cooled, initially in a water filled pool. The water cools the radioactive isotopes and shields the environment from the radiation. Spent fuel cooling might be required for a period between 20-40 years before disposal. As the spent nuclear fuel ages the radioactivity decreases, reaching the point where it does not need to be water cooled and can be placed in dry storage facilities. After this ‘’cooling off’’ period the high level waste can be handled in different ways. It can be reprocessed then disposed of permanently or directly disposed permanently in a geological repository. Heat dissipation is an important factor that has to be taken into account in the design of geological disposal facilities [3].

B. Reprocessing

The spent nuclear fuel contains uranium and plutonium which are used as fuel in a nuclear reactor. Reprocessing is the chemical process where plutonium and uranium are separated from the fission products in the used fuel and then able to be recycled. If the used fuel is later reprocessed, it is dissolved and separated chemically into uranium, plutonium and high-level waste solution. About 97% of the used fuel can be recycled leaving only 3% as high-level waste. The recyclable portion is mostly uranium depleted to less than 1% U-235, with some plutonium, which is most valuable. After reprocessing the left over waste is largely liquid but reprocessing operations also generate solid and gaseous radioactive waste streams. Solid waste such as fuel element cladding hulls, hardware and other insoluble residues is generated during fuel dissolution. The principal liquid waste stream is the nitric acid solution, which contains both high levels of activity concentration of fission products and actinides in high concentrations. Liquid HLW is generally stored in tanks before its eventual solidification. The principal gaseous waste stream is the off-gas, which contains rare gases and volatile fission products that are released from the spent fuel during the dissolution process. Arising from a year's operation of a typical 1000 MWe nuclear reactor, about 230 kilograms of plutonium (1% of the spent fuel) is separated in for recycle. This can be used in fresh mixed oxide (MOX) fuel. If used fuel is not reprocessed, it will still contain all the highly radioactive isotopes, and then the entire fuel assembly is treated as HLW for direct disposal. It too generates a lot of heat and requires cooling.

C. Final Disposal

The nuclear waste will have to be stored indefinitely because of the long time it takes for some of the waste isotopes to decay to a safe level. Disposal in deep geological repositories is generally considered to be the best way to provide a permanent management solution for spent fuel and HLW. In doing so we must ensure that the radioactive waste does not move from its burial site or that it does not escape into the environment. If it does it could have dire consequences for future generations such as contamination of drinking water. To ensure that the radioactive waste is contained the current consensus is to use a multi-barrier system to store the waste. Those engineered barriers include the physical form of the waste, the waste containers and the geology of the disposal facility. Reprocessed waste is usually immobilized in a matrix such as borosilicate glass or ceramic (synroc) which has excellent resistance to radiation and leaching. Synroc is a ''synthetic rock'' invented in 1978 by Professor Ted Ringwood of the Australian National University. The main minerals in Synroc are hollandite, zirconolite and perovskite [4].

D. Vitrification

Vitrification is a proven technique in the disposal and long-term storage of nuclear waste or other hazardous wastes in a method called geomelting. Waste is mixed with the glass-forming chemicals in a melter to form molten glass that then solidifies in canisters, immobilizing the waste. Vitrification can greatly reduce the volume of the waste, and for some waste material can result in a reusable material. To produce the glass, the waste is dried, heated to convert the nitrates to oxides, and then mixed with glass forming chemicals and heated again to very high temperatures (approximately 1000°C) to produce the melt. This is then poured into a containment vessel where it cools to form glass. The containment vessel can then be sealed, decontaminated, and placed into a long-term or temporary storage facility [5].

Management of Low and Intermediate-level Waste

Low-level waste storage technology is well-established. Low-level waste is produced as a result of many commercial processes, and can be generated in solid, liquid and gaseous forms. It includes items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation. Low level radioactive waste is generated at facilities such as nuclear power plants, hospitals and research institution. Ion exchange resins and filter materials used to clean water at a nuclear power plant, contaminated hand tools, components, piping, valves and other equipment from nuclear power plants and other industries, research equipment from laboratories where radioactive materials are used, shoe covers, lab coats, cleaning cloths, paper towels and other supplies used in an area where radioactive material is present, containers, cloths, test tubes, bottles used in hospitals to diagnose or treat disease etc are the examples of Low-level waste [6]. ILW has a higher concentration of radionuclides, especially long lived radionuclides, than LLW; it may require shielding to provide adequate protection for workers and greater provisions ensure its isolation from the biosphere. ILW needs no or only limited provision for heat dissipation during its storage and disposal. ILW arises mainly from the reprocessing of spent fuel and from general operations and maintenance at nuclear sites, and can include metal items such as fuel cladding and reactor components, graphite from reactor cores and sludge from treatment of radioactive liquid effluents. The waste of this type is usually disposed of in the same way as Low-level waste. To provide for long term safety, disposal at greater depths than for LLW is normally considered to be appropriate. Low-level waste and Intermediate-level waste are known as reactor waste [7].

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Treatment of Liquid Waste

According to the different types of reactors now operating commercially all over the world, different waste streams arises. These streams are different both in activity content and in the amount of liquid waste generated. The primary coolant in water cooled reactors and water from the fuel storage pools are major sources of liquid radioactive waste since some of their radioactive content may be transported to the liquid radioactive waste stream via process streams or leakages. Although the composition of the liquid radioactive waste may vary appreciably according to reactor type, contributions to the stream may derive from reactor coolant let-down, evaporator concentrates, equipment drains, floor drains, laundry waste, contaminated oil and waste arising from the decontamination and maintenance of facilities and equipment. Radioactive waste containing boric acid or organic matter may need special treatment. The treatment processes for liquid LLW are directed towards volume reduction and the removal of radionuclides from the bulk of the waste. Treatment processes for liquid waste are evaporation, cementation, bituminization, ion-exchange, and chemical precipitation.

A. Ion-Exchange

Ion-exchangers are insoluble solid materials which carry exchangeable ions. These ions can be exchanged by a stoichiometrically equivalent amount of other ions of the same sign when the ion-exchanger is in contact with an electrolyte solution. To remove radioactive metals from aqueous mixture, it is possible to use a ferric hydroxide floc. After the radioisotopes are absorbed onto the ferric hydroxide, the resulting sludge can be placed in a metal drum before being mixed with cement to form a solid waste form. In order to get better long term performance from such forms, they may be made from a mixture of fly ash, or blast furnace slag, and Portland cement, instead of normal concrete (made with Portland cement, gravel and sand). Ion-exchange properties of zeolites have received great attention for liquid waste treatment. The cationic radioisotopes, present in the liquid effluents of low and intermediate level wastes, can be removed by the ion-exchange with the Na^+ ions of zeolites [8].

B. Chemical Precipitation

Chemical precipitation methods based on the coagulation-flocculation separation principle are mostly used in nuclear power plants for the treatment of liquid effluents with low activity and high salt and mud contents. Their effectiveness depends largely on the chemical and radiochemical composition of liquid waste. Most radionuclides can be precipitated by barium chloride, sodium sulphate, potassium ferrocyanide, copper sulphate etc. The resultant sludge that contains the bulk of radioactivity requires conditioning [9].

C. Evaporation

Aqueous radioactive wastes are generated in many nuclear facilities e.g. nuclear power plants, research centers, waste conditioning facilities etc. When the concentration of soluble and/or insoluble solids in the waste stream is low, it is standard practice to concentrate the waste using an evaporator. It is used to concentrate the salt concentration in waste liquid about 50 times. In many cases, because the distillate must have a very high purity, two stage evaporation is necessary. Where the required decontamination factor is lower, a single stage evaporator can be used. Water is removed in the vapor phase of the process leaving behind non-volatile components such as salts containing most radionuclides. In this process, pretreatment of the waste is not required [10].

D. Cementation

Cementation is one of the most commonly used methods for conditioning radioactive wastes based on chemical reaction of mineral components, contained in cement, with water. It provides a cost-effective solution for encapsulation of various kinds of radioactive waste into a solid, safe form suitable for long term storage. Its high density provides the waste forms with a considerable degree of self-shielding thereby reducing requirements for additional package shielding. Water is chemically combined in the final product with a certain fixation ability for radionuclides contained in charge water. It is evident that the mass ratio of water to cement is not unlimited and the maximum for solid product is usually about 0.4.

E. Bituminization

Bituminization is a hot process which allows the wet stream to be dried off before being immobilized and packaged. Bituminization consists in fixing of contaminated salts into a water resistance matrix, using asphalt. During the process of liquid radwaste bituminization water evaporates with temperatures above 120°C and contained salts are homogenized with asphalt [11].

Treatment of Solid Waste

Solid waste arising from general nuclear power plant operation are composed of combustible waste, e.g. paper, clothing, plastics and non-combustible waste, such as scrap metal, rubble, and mineral insulating material. The non-combustible waste undergo high pressure compaction in metal cartridges and are collected as in containers as compacted pellets.

A. Incineration

Incineration is the only proven method providing the highest possible volume reduction factor for combustible waste from nuclear power plants, research centers and waste treatment facilities. The aim of incineration is to substantially reduce the volume of the combustible waste such as plastics, fabrics, wood and paper, which are radioactively contaminated, in compliance with the emission control requirements. Following the segregation of combustible waste from non-combustible constituents, the waste is incinerated in a specially engineered kiln up to around 1000°C. Gases produced during incineration are treated and filtered prior to emission into the atmosphere. In incineration process, the ash containing the radionuclides, may require further conditioning before disposal such as cementation or bituminization.

B. Compaction

Compaction is aimed at reducing the volume and increasing the stability of solid waste for transport, storage and disposal, but its physical and chemical properties are not changed. The volume reduction achievable depends on the nature of waste and the equipment used. A part of solid radwaste generated during plant operation can be compacted up to various levels. Solid waste is collected in drums or other containers. Compaction can reduce the overall volume of drums containing solid waste and the technology is well proven. Compactors can range from low-force compaction systems (~5 tons or more) through to presses with a compaction force over 1000 tons, referred to as supercompactors. Volume reduction factors are typically between 3 and 10, depending on the waste material being treated. In the case of supercompactors, waste is sorted into combustible and non-combustible materials. Combustible waste is incinerated and whilst non-combustible waste is supercompacted. Sometimes, incinerator ashes are also supercompacted in order to achieve the maximum volume reduction.

Treatment of Gaseous Waste

Some airborne radioactive wastes are generated in either particulate or aerosol of gaseous form during normal operation of nuclear power plants. Gaseous radioactive waste is mainly generated from the degassing of the primary system and ventilation systems in the radiation controlled area of nuclear power plants. During reactor operation gaseous radioactive isotopes are created by neutron activation and fission and include tritium, carbon-14, argon-41 and radionuclides of xenon, krypton and iodine. All gaseous effluents at nuclear power plants are treated before discharge to the atmosphere to remove most of the radioactive components from the effluence. Gaseous wastes are filtered, compressed to take up less space, and then allowed to decay for some time period. After the required time has passed, the gases will be sampled. If the required limits are met, the gases will be released to the atmosphere, or sometimes the gases will be reused in specific areas of the plant. Gaseous waste from the primary system shall be treated by a gas decay tank or charcoal delay bed to reduce radioactivity, and released into the atmosphere through a radiation monitor. The usefulness of delay and decay as a means of reducing activity levels in gaseous wastes depends on the particular isotopes present. Gaseous waste from the building ventilation system is also to be discharged into the environment as well as through a high efficiency particulate air filter and charcoal filter under continuous monitoring into the environment. A high efficiency particulate air filter (HEPA) collects 0.3 µm particles at an efficiency of 99.97% or more at the rated air volume. Charcoal filter beds may be used to remove iodine [12].

Storage of Low and Intermediate-level Waste

Low-level radioactive waste is packaged in containers appropriate to its level of hazard. Some low-level radioactive wastes require shielding with lead, concrete or other materials to protect workers and members of the public. Workers are trained to maintain a safe distance from the more highly radioactive materials, to limit the amount of time they spend near the materials, and to monitor the waste to detect any releases. Nuclear power plants may store waste in special buildings that provide an extra degree of shielding. Safe distances must be maintained between the buildings containing radioactive material and the fence restricting public access to licensee property. Low-level waste may be stored to allow short-lived radionuclides to decay to innocuous levels and to provide safe keeping when access to disposal sites is not available. Options for storage of intermediate-level waste (ILW) are similar to those for low-level waste. Additional shielding may be required to limit radiation dose rates near ILW container.

Disposal of Low and Intermediate-Level Waste

The disposal facility shall be sited, designed and operated to provide features that are aimed at isolation of the radioactive waste from people and from the accessible biosphere. The features shall aim to provide isolation for several hundreds of years for short-lived waste and at least several thousand years for intermediate-level waste. Intermediate-level waste (ILW) needs to be managed and converted into a passively safe form as soon as reasonably practicable and placed into interim storage. ILW is packaged for disposal by encapsulation in cement-based materials within 500 liters stainless steel drums or $3m^3$ stainless steel boxes. Large items are packaged in higher capacity stainless steel or concrete boxes. Short-lived intermediate-level wastes are buried, while long-lived intermediate level wastes will be disposed of deep underground. Disposal in a facility at a depth of between a few tens and a few hundreds of meters is indicated for ILW. Again, LLW storage and disposal technology is well-established. LLW is suitable for near surface disposal. This is a disposal option suitable for waste that contains such an amount of radioactive material that robust containment and isolation for limited periods of time up to a few hundred years are required. LLW may have a wide range of activity concentrations and may contain a wide range of radionuclides, there are various design options for near surface disposal facilities. These design options may range from simple to more complex engineered facilities, and may involve disposal at varying depths, typically from the surface down to 30m. A near surface repository consists of reinforced concrete vaults established on the earth surface. Radioactive waste packages are placed into the vaults and covered with a layer of clay and soil. Reinforced concrete helps retard migration of radionuclides and prevents people or animals from intruding into the repository. Some countries prefer disposing of LLW in subsurface facilities or co-locating LLW with ILW or spent fuel in deeper facilities [13].

Layers of Protection After Disposal

A ‘multiple barrier’ disposal concept is used to ensure that no significant environment releases occur over a long period after disposal. The principle barriers consist of a copper canister with a cast iron insert. This barrier is closed to the waste and its function is to isolate the fuel from the environment. The second layer consists of bentonite clay called a buffer. Its function is to protect the canister against small movements in the rock and keep it in its place. The clay also acts as a filter in case any radioactive particles escape from the canister. The third layer is the geological rock. The rock also stops leaking of radioactive particles into the environment but its main function is to protect the canister and buffer from mechanical damage and to offer a stable environment for the isolation of the waste.

Disposal Options

Disposal options are designed to contain the waste by means of passive engineered and natural features and to isolate it from the accessible biosphere to the extent necessitated by the associated hazard. The development of a disposal facility usually involves an extensive program of research, design and assessment work that may last for several years or decades. There have been several proposal for regional and international repositories for disposal of high-level waste and the concept received strong endorsement from the head of IAEA. Disposal facilities are not expected to provide complete containment and isolation of waste over all time; this is neither practicable nor necessitated by the hazard associated with waste, which declines with time. A 1983 review of the Swedish radioactive waste disposal program by the National Academy of Sciences found that country’s estimate of several hundred thousand years-perhaps up to one million years-being necessary for waste isolation ‘’fully justified’’. Aside from dilution, chemically toxic stable elements in some waste such as arsenic remain toxic for up to billions of years or indefinitely. As of 2009 there were no commercial scale purpose built underground repositories in operation. The countries that have made the most progress on final disposal are Finland, France and Sweden where facilities are scheduled to begin operation in 2020-2025 [14].

A. Near Surface Disposal

Near surface disposal facilities are on or below the surface where the protective covering is of the order of a few meters thick. These facilities will be affected by long-term climate changes and this effect must be taken into account when considering safety as such changes could cause disruption of these facilities. This type of facility is used for LLW and ILW with a radionuclide content of short half-life (up to about 30 years). Landfill disposal may be suitable for very low level waste with very limited amounts of long lived activity. These facilities contain no complex engineered barriers. For wastes with higher radioactive content, trench disposal has been often used. A trench can be divided into individual compartments to increase radionuclide containment and flexibility of operation.

B. Geological Disposal

Waste with higher contents of long lived radionuclides is usually disposed of at depth in appropriate geological formations. The depth of deep geological repositories ranges between some hundred and somewhat more than 1000 m. In some cases, certain categories of long lived waste can be disposed of at intermediate depth (up to some 100 m). With appropriate design, a geological disposal facility could receive all types of radioactive waste. This facility has the advantage of avoiding the need to separate short-and long-lived radioisotopes before disposal [15].

C. Deep Boreholes

For the deep borehole option, solid packaged waste would be placed in deep boreholes drilled from the surface to depth of several km with diameters of typically less than 1 meter. The waste containers would be separated from each other by a layer of bentonite clay or cement. The borehole would not be completely filled with wastes. The top two km would be sealed with materials such as bentonite, asphalt or concrete. This option is suitable where waste volumes are limited.

D. Disposal in Outer Space

The objective of this option is to remove the radioactive waste from the Earth, for all time, by ejecting it into outer space. The waste would be packaged so that it would be likely to remain intact under most conceivable accident scenarios. A rocket or space shuttle would be used to launch the packaged waste into space. Due to high cost of this option and the safety aspects associated with the risk of launch failure, this option was abandoned.

E. Rock Melting

The deep rock melting option involves the melting of wastes in the adjacent rock. The idea is to either produce a stable, solid mass that incorporates the waste or encases the waste in a dilutes form that cannot easily be leached or transported back to the surface. This technique has been mainly suggested for heat generating wastes such as vitrified HLW and host rocks with suitable characteristics to reduce heat loss.

Transport of Radioactive Materials

The transport of radioactive material includes the carriage of radioisotopes for industrial, medical and research uses, and the shipment of radioactive waste and of consignments of nuclear fuel cycle material. For the transport of radioactive material, the carrier should ensure that its personnel are adequately trained and know the regulatory requirements applicable to the modes of transport to be used, and how to comply with them. The handling, storage and shipment of materials, parts, components, etc., require proper planning and control. This applies not only to initial delivery, but also to use in transport operation. Prior to the dispatch of any item containing radioactive material, the package is monitored to determine the transport index and to assign the category label. Nuclear materials have been transported since before the advent of nuclear power over fifty years ago. About 20 million shipments of all forms of radioactive materials and waste now take place worldwide each year, of which only about 5% relates to the nuclear fuel cycle. In the USA one percent of the 300 million packages of hazardous material shipped each year contain radioactive materials. Of this, about 250000 contain radioactive wastes from US nuclear power plants, and 25 to 100 packages contain used fuel. The IAEA published its first regulations for the safe transport of radioactive material in 1961 [16]. For transportation purposes, radioactive material is defined as any material which has a specific activity greater than 0.002 micro curies per gram. This definition does not specify a quantity, only a concentration. Since transport accidents cannot be prevented, so when radioactive materials are transported, it is important to ensure that radiation exposure of both those involved in the transport of such materials and the general public along transport routes is limited. In case of fresh fuel assemblies, the radiation levels are negligible and no shielding is required. But used fuel and high-level waste are highly radioactive and proposed designed containers with integral shielding are used. To limit the risk, two types of packages called Type A and Type B are used. Packages of radioactive materials are labeled in accordance with the requirements of national and international regulations. Type ‘A’ container is designed to survive normal transportation handling and minor accidents. Type B containers must be able to survive severe accidents. A Type ‘A’ package may be a cardboard box, a wooden crate, or a metal drum, based on performance requirements. A Type B package may be a metal drum or a huge, massive shielded transport container. Both packages are tested and certified to withstand fire, impact, pressure, liquid ingress, heat and cold. For Type ‘A’ packages, which must pass stringent tests, only 1% of those involved in accidents have failed. Of those, 39% have released their contents. For Type B packages, which must pass the most rigorous tests, several have been involved in accidents. There has never been any accident in which a Type ‘B’ cask containing radioactive materials has been breached or has leaked [17].

Results and Discussions

This research is completely a theoretical framework. The objective of this study 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. Nuclear energy offers the opportunity of meeting a significant part of the anticipated increase in electricity demand whilst reducing the potential environmental and economic concerns associated with fossil fuels. It is more able than oil or gas to provide security of supply because the fuel uranium comes from diverse sources. But the main problem of thinking nuclear power is radioactive waste. Spent nuclear fuel is highly radioactive and potentially very harmful. Standing near unshielded spent fuel could be fatal due to the high radiation levels. Ten years after removal of spent fuel from a reactor, the radiation dose 1 meter away from a typical spent fuel assembly exceeds 20,000 rems per hour. A dose of 5,000 rems would be expected to cause immediate incapacitation and death within one week. Besides, the danger of exposure to radiation in LLW varies according to the types and concentration of radioactive material contained in it. LLW from processing water at a reactor may be quite hazardous. LLW could cause exposures that could lead to death or an increased risk of cancer. But radioactive materials from medical research are not particularly hazardous unless inhaled or consumed, and a person can stand near it without shielding. For this reason, radioactive waste must be managed so as to reduce any associated risks to acceptable levels.

Bangladesh has been considering embarking on nuclear power for 50 years and the latest attempt is expected to come from 2 GW of nuclear provided by Russian reactors. The nuclear power plant will be built at Ruppur, 200 km north-west of Dhaka, in the Ishwardi sub district of Pabna district. It will go into operation by 2020. The government has given top priority to ensure the highest level of safety. All fuel is being provided by Rosatom and processes its spent fuel in Russia. Russia has agreed to accept the waste to bury in their country.

Conclusion

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled. Nuclear safety is a global issue. A serious event in one country may have an impact on its neighbors. So, governments and the nuclear industry must work together to deliver safe disposal. Besides, generation of radioactive waste shall be kept to minimum practicable.

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