International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 5 (June 2014) http://ijirae.com

Nuclear Waste: Introduction to its Management

Snehjit J. Kumbhar
Civil Department& Mumbai University

Piyush K. Jaybhaye
Electrical Department &Mumbai University

Abstract— ***Nuclear waste is a waste product containing radioactive decay 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. 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. The main objective in managing and disposing of radioactive (or other) waste is to protect people and the environment. This study initially focused on how nuclear power affects the surrounding environment. Also this paper presents various types of waste generation, storage and transportation. Finally this paper demonstrates that the treatment options for nuclear waste.***

Keywords— nuclear, radioactive, environment, treatment, management;

I. INTRODUCTION

RADIOACTIVE WASTES ARE THE LEFTOVERS FROM THE USE OF NUCLEAR MATERIALS FOR THE PRODUCTION OF ELECTRICITY, DIAGNOSIS AND TREATMENT DISEASE, AND OTHER PURPOSES. THE MATERIALS ARE EITHER NATURALLY OCCURRING OR MAN-MADE. CERTAIN KINDS OF RADIOACTIVE MATERIALS, AND THE WASTES PRODUCED FROM USING THESE MATERIALS, ARE SUBJECT TO REGULATORY CONTROL BY THE FEDERAL GOVERNMENT OR THE STATES. NUCLEAR HERE IS THE TRUTH ABOUT NUCLEAR POWER AND SEVEN REASONS WHY NUCLEAR POWER IS BAD FOR THE ENVIRONMENT AND FOR THE NATION.

- Nuclear power is extremely costly. Building or restarting the number of nuclear power plants that the industry is pushing for would cost trillions of dollars. For example, there was an estimate created by the Florida Power and Light Company to create a new reactor plant with a price tag of between $12 and $18 billion dollars for a single project. This sticker shock would be passed on to consumers already struggling in a weak economy.

- Nuclear Power will not reduce our Dependency on Middle East Oil Supplies: One of the arguments used to support nuclear power is that it will reduce our oil use. This is simply not true because most of the oil that we use is for gas in our automobiles and nuclear power has nothing to do with that since it is producing electricity not fuel.

- Nuclear Power Contaminates Water Supplies: Cases of water contamination with radioactive substances has occurred around over a dozen different nuclear sites around the country. The process of mining materials used in nuclear power plants such as uranium and titanium run a very high risk of water contamination to nearby rivers and streams as well as ground water supplies.

- There is No Safe Way to Mine, Store, or Process Nuclear Materials: Even though energy moguls claim that nuclear energy is safe, the truth is that there is no guaranteed safe means for containment of nuclear materials. The risk of an accident and exposure increase exponentially through each step in the process of mining, transportation, storage, refinement, and use or nuclear power which then leaves you with enormous amounts of nuclear waste that must be contained and disposed of. Every step of this process carries great risk for the environment and the community.

- Nuclear Power Will Not Reduce Carbon Emissions: While the plant itself at the point of producing energy may not be emitting as much carbon pollution as a coal plant, it does create equal or greater amounts of carbon emissions during the entire process leading up to that point.
- Exposure to the Radioactive Material Can Be Deadly, Causing Health Problems and Cancer: Through the history of nuclear disasters we have had a living lab to see the numbers of deaths caused by nuclear power plants along with infertility, health problems, and deadly cancers among people in communities even far away from the original site.
- Viable Sources of Clean Renewable Energy Already Exist: We already have the technology available for clean and renewable forms of safe energy that have lower costs than nuclear power including wind and solar which could create thousands of new jobs, boost the economy, and give us a safer solution for the future.

II. TYPES OF NUCLEAR WASTE

A. *Exempt waste & 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 the surrounding environment. It consists mainly of demolished material (such as concrete, plaster, bricks, metal, valves, piping *etc*) produced during rehabilitation or dismantling operations on nuclear industrial sites.
Other industries, such as food processing, chemical, steel *etc* also produce VLLW as a result of the concentration of natural radioactivity present in certain minerals used in their manufacturing processes (see also information page on Naturally-Occurring Radioactive Materials). 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 and industry, as well as the nuclear fuel cycle. It comprises paper, rags, tools, clothing, and filters *etc*, which contain small amounts of mostly short-lived radioactivity. It does not require shielding during handling and transport and is suitable for shallow land burial. To reduce its volume, it is often compacted or incinerated before disposal. It comprises some 90% of the volume but only 1% of the radioactivity of all radioactive waste.

C. *Intermediate-level waste*

Intermediate-level waste (ILW) contains higher amounts of radioactivity and some requires shielding. It typically comprises resins, chemical sludges and metal fuel cladding, as well as contaminated materials from reactor decommissioning. Smaller items and any non-solids may be solidified in concrete or bitumen for disposal. It makes up some 7% of the volume and has 4% of the radioactivity of all waste.

D. *High-level waste*

High-level waste (HLW) arises from the 'burning' of uranium fuel in a nuclear reactor. HLW contains the fission products and transuranic elements generated in the reactor core. It is highly radioactive and hot, so requires cooling and shielding. It can be considered as the 'ash' from 'burning' uranium. HLW accounts for over 95% of the total radioactivity produced in the process of electricity generation. There are two distinct kinds of HLW:

- Used fuel itself.
- Separated waste from reprocessing the used fuel (as described in section on Managing HLW from used fuel below).

III. STORAGE & TRANSPORTATION

The production of waste from nuclear power, its storage and handling are the great concern to public. There are three levels of nuclear waste, low activity or low level, intermediate activity or intermediate level and high activity or high level wastes.

A. *STORAGE LOW LEVEL WASTE*

Low level waste includes materials that are used to handle nuclear material such as radiation suits and laboratory equipment. They are normally stored for up to 15 years in secure storage and then, after careful packaging they can be disposed of as normal waste.
However, there is disagreement over the way the waste is disposed. For example, The British and Irish Governments do not agree on the disposal of low level radioactive material in the Irish Sea.

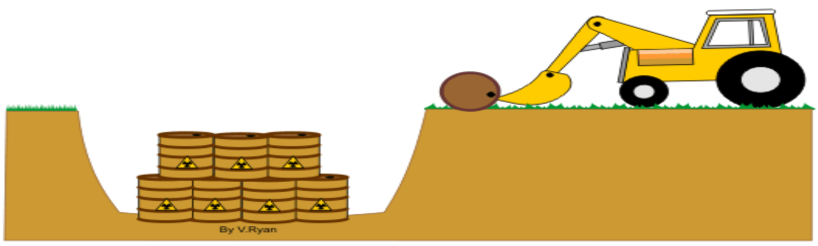

Fig. 1 Storage of low level waste

B. *STORAGE INTERMEDIATE LEVEL WASTE*

These are much bulkier materials and are characterised by low heat emission. They contain metal fuel cladding, chemical sludge's and other radioactive wastes. The waste is first encased in resin or concrete and sealed in steel drums. The drums are then packed into concrete casks and placed in concrete trenches up to 18 metres deep. When completely filled the trenches are covered with a concrete slab, a layer of compacted clay and a reinforced concrete intrusion shield and a final layer of clay. Deep disposal of intermediate wastes also takes place, storing the wastes in a suitable geological formation at a depth of at least 100 metres

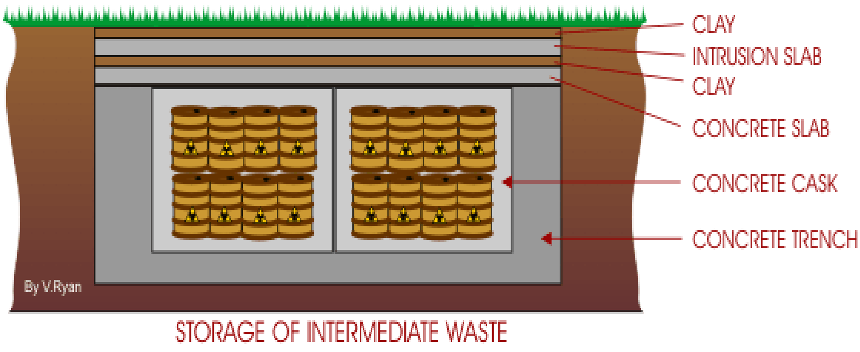

Fig. 2 Storage of Intermediate waste

C. *STORAGE HIGH LEVEL WASTE*

High level waste is extremely radioactive and remains in this state for thousands of years. Safe and stable storage of this type of waste is of great concern. Modern storage methods include the use of glass vitrification. This involves combining the radioactive liquid waste with glass to form a solid compound. Because of the solid nature of the waste it is much less likely to contaminate the surrounding area. Unlike liquid waste, it cannot leak into the ground if the stainless steel container it is in becomes faulty. In theory, the highly radioactive waste can be stored indefinitely in deep stable formations such as caves and caverns.

D. *TRANSPORTATION OF NUCLEAR WASTE*

Section 2 of the Nuclear Energy Act (990/1987) defines the transport of nuclear materials and nuclear waste as the use of nuclear energy, thus constituting operations subject to licence. Furthermore, the requirements for export and import licences laid down in the Nuclear Energy Act shall be taken into consideration in international transports. The Nuclear Liability Act (484/1972) is also applied to the transport of nuclear materials and nuclear waste. Council Directive 92/3/Euratom contains regulations for transports of radioactive waste (including nuclear waste) between the Member States of the EU and across the EU borders. Council Regulation 1493/93/Euratom contains regulations for transports of radioactive materials between the Member States of the EU. Guide ST 5.4 deals with the advance description, notification and approval procedures required by the above regulations. Guide YVL 6.21 issued by the Radiation and Nuclear Safety Authority deals with the physical protection of the transports of nuclear fuel. An international agreement named “The Convention on the Physical Protection of Nuclear Material (IAEA INFCIRC/274)” has been concluded to protect nuclear materials from illegal acts. The IAEA has issued a recommendation for the security arrangements of nuclear facilities named “The Physical Protection of Nuclear Material (INFCIRC/225)”, and it is applied to transports as well.

The regulations concerning the transport of dangerous goods require that the following requirements be fulfilled:

- The competence of the transport staff and the transport equipment meet the requirements laid down in the regulations for the transport of dangerous goods.
- The transport documents have been drawn up and the radioactive material has been packed in accordance with the transport mode-specific regulations for dangerous goods.
- The package used for transport has been fitted with labels, and the package design is approved (when this is required) by the Radiation and Nuclear Safety Authority or another authority that complies with the same regulations.
- The advance notification to be supplied to the Radiation and Nuclear Safety Authority has been given. (The regulations require an advance notification when the activity of the transported material exceeds the value of 3000 A1 or the value of 3000 A2 and whenever the activity exceeds 1000 TBq.)

Furthermore, the rules and regulations concerning the use of nuclear energy or radiation require the following:

- A license approved by the Radiation and Nuclear Safety Authority for the transport of nuclear material or nuclear waste;
- Sufficient security and emergency arrangements;
- Arrangement of the liability for nuclear damage;
- An import and/or export license for nuclear material or nuclear waste for transports across Finnish borders (including transit);
- An advance description from the authority of the receiving country for transports of radioactive material within the EU;
- For transports of radioactive waste, an approval by the competent authorities of the country of origin and the receiving country of the waste as well as of the transit countries.

Fig. 3 Transportation of Nuclear waste

The transport of nuclear material or nuclear waste shall not begin without a transport plan approved by the Radiation and Nuclear Safety Authority. However, a transport plan is not required for such nuclear materials or nuclear wastes that have been exempted from a licence for the transport.

In the transport plan, the licence-holder shall explain in which way the requirements stated in Section 4.2 above are fulfilled. The plan consists of a report to be submitted to the Radiation and Nuclear Safety Authority for approval together with appendices to be included for information. The documentation supplied for information includes, for instance, frequently changing data such as schedules and contact information on the persons involved in the transport.

The decision of approval for the transport plan may include conditions, which may relate, for instance, to the transport routes or to the handling of packagings. Outside nuclear facilities, the packages of nuclear materials and nuclear waste can be handled in the same way as normal goods, unless otherwise required by the licences and approvals for the transport. The equipment used for handling packages shall be overhauled and inspected appropriately.

The application for the approval of a transport plan shall contain the following information:

• the name and address of the consignor and the consignee;

• general information on the package, the number and issuer of the approval certificate, description of the packaging and contents, the permitted number of packages, the estimated transport index and the criticality safety index, and the estimated class;

• general information on the transport, such as the transport mode, the means of transport, alternative routes, the carrier, and potential stops and temporary storages;

• a list of the documents accompanying the transport;

• information on potential exclusive use of the means of transport;

• special safety measures (speed limits, restrictions on other traffic, special equipment);

• a reference to a separately approved physical protection plan for the transport and, if necessary, an emergency plan in case of an accident;

• a description of any necessary special arrangements (or a reference to a separate approval certificate concerning them);

• a description of the nuclear liability insurance;

• Transport equipment and special equipment used for the transport, also including communication and radiation control equipment.

IV. TREATMENT OF NUCLEAR WASTE

A. *VITRIFICATION*

Long term storage of radioactive waste requires stabilization of the waste into a form which will neither react nor degrade for extended periods of time. One way to do this is through vitrification. Currently at Sell afield the high-level waste (PUREX first cycle raffinate) is mixed with sugar and then calcined. Calcination involves passing the waste through a heated, rotating tube. The purposes of calcination are to evaporate the water from the waste, and de-nitrate the fission products to assist the stability of the glass produced. The 'calcine' generated is fed continuously into an induction heated furnace with fragmented glass. The resulting glass is a new substance in which the waste products are bonded into the glass matrix when it solidifies. This product, as a melt, is poured into stainless steel cylindrical containers ("cylinders") in a batch process. When cooled, the fluid solidifies ("vitrifies") into the glass. Such glass, after being formed, is highly resistant to water. After filling a cylinder, a seal is welded onto the cylinder. The cylinder is then washed. After being inspected for external contamination, the steel cylinder is stored, usually in an underground repository. In this form, the waste products are expected to be immobilized for thousands of years. The glass inside a cylinder is usually a black glossy substance. All this work (in the United Kingdom) is done using hot cell systems. The sugar is added to control the ruthenium chemistry and to stop the formation of the volatile RuO_4 containing radioactive ruthenium isotopes. In the West, the glass is normally a borosilicate glass (similar to Pyrex), while in the former Soviet bloc it is normal to use a phosphate glass. The amount of fission products in the glass must be limited because some (palladium, the other Pt group metals, and tellurium) tend to form metallic phases which separate from the glass. Bulk vitrification uses electrodes to melt soil and wastes, which are then buried underground. In Germany a vitrification plant is in use; this is treating the waste from a small demonstration reprocessing plant which has since been closed down.

B. *Ion exchange*

It is common for medium active wastes in the nuclear industry to be treated with ion exchange or other means to concentrate the radioactivity into a small volume. The much less radioactive bulk (after treatment) is often then discharged. For instance, it is possible to use a ferric hydroxide floc to remove radioactive metals from aqueous mixtures. 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 (mechanical stability) 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).

C. *Synroc*

The Australian Synroc (synthetic rock) is a more sophisticated way to immobilize such waste, and this process may eventually come into commercial use for civil wastes (it is currently being developed for US military wastes). Synroc was invented by the late Prof Ted Ringwood (a geochemist) at the Australian National University. The Synroc contains pyrochlore and cryptomelane type minerals. The original form of Synroc (Synroc C) was designed for the liquid high level waste (PUREX raffinate) from a light water reactor. The main minerals in this Synroc are hollandite ($BaAl_2Ti_6O_{16}$), zirconolite ($CaZrTi_2O_7$) and perovskite ($CaTiO_3$). The zirconolite and perovskite are hosts for the actinides. The strontium and barium will be fixed in the perovskite. The caesium will be fixed in the hollandite.

D. *Re-use of waste*

Another option is to find applications for the isotopes in nuclear waste so as to re-use them. Already, caesium-137, strontium-90 and a few other isotopes are extracted for certain industrial applications such as food irradiation and radioisotope thermoelectric generators. While re-use does not eliminate the need to manage radioisotopes, it reduces the quantity of waste produced. The Nuclear Assisted Hydrocarbon Production Method, Canadian patent application 2,659,302, is a method for the temporary or permanent storage of nuclear waste materials comprising the placing of waste materials into one or more repositories or boreholes constructed into an unconventional oil formation. The thermal flux of the waste materials fracture the formation alters the chemical and/or physical properties of hydrocarbon material within the subterranean formation to allow removal of the altered material. A mixture of hydrocarbons, hydrogen, and/or other formation fluids is produced from the formation. The radioactivity of high-level radioactive waste affords proliferation resistance to plutonium placed in the periphery of the repository or the deepest portion of a borehole.Breeder reactors can run on U-238 and transuranic elements, which comprise the majority of spent fuel radioactivity in the 1000-100000 year time span.

E. *Space disposal*

Space disposal is attractive because it removes nuclear waste from the planet. It has significant disadvantages, such as the potential for catastrophic failure of a launch vehicle, which could spread radioactive material into the atmosphere and around the world. A high number of launches would be required because no individual rocket would be able to carry very much of the material relative to the total amount that needs to be disposed of. This makes the proposal impractical economically and it increases the risk of at least one or more launch failures. To further complicate matters, international agreements on the regulation of such a program would need to be established. Costs and inadequate reliability of modern rocket launch systems for space disposal has been one of the motives for interest in non-rocket space launch systems such as mass drivers, space elevators, and other proposals.

V. CONCLUSION

We have quite a good mastery of that technology and we are getting better at keeping the genie in the bottle, although accidents do and will happen. The problem is that as more accidents occur we take the risk of affecting our DNA and this can affect generations down the line. As computer control systems become more reliable then the theory is that it will get safer. BUT the biggest problem is the Bi product and how it is used. - The fast breeder reactor produces weapons grade plutonium. This wouldn’t be a problem but humans seem to be hell bent on finding and using ways to destroy other humans more efficiently. So in the political climate that the world is in at present nuclear energy is not safe, not because of leaks but because it produces weapons at the same time. It’s a bit like giving a baby a gun. We are not yet intelligent enough as a species to control ourselves when it comes to dealing with conflicts.

References

[1] Natarajan, R., in IANCAS Bull., July 1998, p. 27
[2] Kumra, M. S. and Bansal, N. A., in Facets of Nuclear Science and Technology, Department of Atomic Energy, Mumbai, 1993.
[3] www.hse.gov.uk/foi/internalops/nsd/tech_asst_guides/TAST0.pdf
[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, IAEA Safety Standards Series No. GSG-1, IAEA, Vienna (2009).

