NUCLEAR ENERGY AND TECHNOLOGIES

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Abstract- This study examined how radioactive materials are used around world for power generation and disposal of different categories of radioactive wastes. Now a days nuclear methods are gaining popularity for electric power generation since it is a clean and efficient way of boiling water to make steam, which turns turbines to produce electricity. Nuclear fission process is involved in plants where low - enriched uranium fuel is spent and thus splitting of uranium atoms is done in this process. This study also includes about nuclear technologies used in India.

1. INTRODUCTION

Radioactive Metals - Radioactive metals release alpha (α),Beta (β), and gamma rays (γ) because of unstable nucleus and this process is known as radioactivity. These rays carry significant energy and thus used for power generation, in field of material engineering and to treat cancer as well. Radioactive material loses its radioactivity through decay process over a period of time. Half-life of a nuclear material is time; it takes for 50% of its nucleus to decay.
Nuclear Materials - Special nuclear materials consists of plutonium, uranium-233 or uranium with
U233 or U235 content greater than that found in nature (i.e., >0.71 % U235).[1]

Nuclear Fuel - Uranium is used as a nuclear fuel by nuclear plants for the fission process.

Nuclear plant - Nuclear power plants use the process of nuclear fission to generate electricity. They do this by using nuclear reactors in combination of ranking cycle.

2. NUCLEAR FUEL CYCLE

Nuclear fuel cycle consist of processes (front end and back end) that describes uranium's life cycle i.e. from mining to its processing and thus its use for generating electricity and finally its reprocessing , waste storage and disposal.
Front End Cycle- It includes processes like mining and milling of uranium ore, conversion and enrichment to further remove impurities from mined uranium concentrate (u3o8), fabrication and plant operations.

Back End Cycle - It includes reprocessing also known as partitioning which separates spent fuel into
Uranium, plutonium and waste containing fission products and waste storage and disposal process.

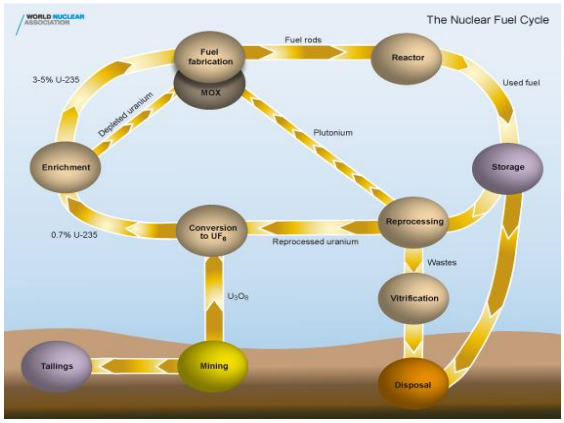

Figure- Nuclear Fuel Cycle (Source - Word Nuclear association).[2]

Nuclear Fission

Nuclear Fission is a process in which heavy nucleus such as uranium or plutonium subdivides into two fragments having almost equal masses and thus releasing a huge amount of energy as when bombarded with slow (low energy) neutrons.

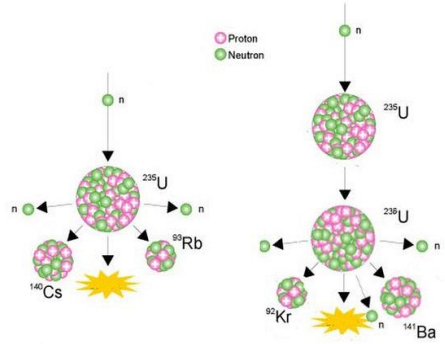

Figure - shows Nuclear Fission of U235 (Source- World Nuclear Association)

Nuclear Power Plant

Nuclear Power Plants use process of fission to generate electricity. They use nuclear reactors with combination of ranking cycle where reactor converts water into steam by generating heat which results in spinning of turbine and generator.

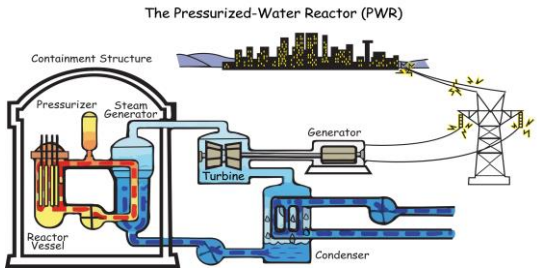

Figure - shows basic operations of a power plant (Source - US Nuclear Regulatory Commission).

Nuclear power plants are similar to coal-fired power Plants but since nuclear fuel is used in nuclear plants therefore different safety measures are used as properties of nuclear fuel differs from coal or other fossils fuels.

Nuclear Reactor
The main component of a nuclear Power plant is Nuclear Reactor because it contains nuclear fuel along with nuclear waste products. Also nuclear chain Reaction takes place inside the reactor only, thus it is called as heat source for the power plant. The fission of uranium fuel takes place in nuclear reactor which produces heat within the reactor.
Along with reactor, Power Plants are also comprised of turbines, Generators, Cooling Towers and some safety systems as well.

Rankine Cycle
Rankine vapour cycle is process used by nuclear power plants. In this process, fuel is used to produce heat within Boiler, which results conversion of water into steam, which further gets expanded with help of a turbine thus producing useful work.

Radioactive Wastes and Disposal
Fuels used for the thermal generation of electricity produce wastes. But since wastes produced by nuclear fission are radioactive in nature therefore should be managed safely and in an environment friendly manner.

Radioactive Wastes, In general are categorized as -

- Low - Level Wastes (LLW)
- Intermediate Level Wastes (ILW)
- High Level Wastes (HLW)

NOTE - In India Radioactive Waste is categorized as-

- Low and Intermediate Level (LIL)
- High Level Wastes (HLW)[3].

Low and Intermediate Level (LIL)
These can be further divided into 3 categories,

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Solid Waste
Significant amount of solid (LIL) waste is generated while doing different nuclear installations. These are of two types-
Primary Wastes -These include spent radiation sources, radioactively contaminated equipment etc.
Secondary Wastes - These are resulted from different operational activities, organic ion exchange filter cartridges etc.

Liquid Wastes
These are in high volumes and have low levels of radioactivity.

Gaseous Waste
These include radiations which contaminate air in the working area. But to deal with these gaseous waste, off gas ventilation system play an important role.

LLW disposal
LLW are easy to dispose of. Radioactivity of LLW is relatively small. If they are stored for about 10 to 50 years then most of the radioactive isotopes present in LLW will decay. Hence after that LLW are disposed as of Normal Refuse.

High Level Waste (HLW)
High level waste is produced in the reprocessing stage of spent fuel, constituting most (almost 99%) of radioactivity in entire nuclear fuel cycle. These wastes are comprised of material obtained from the core of nuclear reactor, i.e. uranium -235 and plutonium239. Most of the radioactive present in HLW emit large amount of radiation having half-lives of the order 500 - 100000 years or even more. Thus, this period of time is much long for waste to settle at safe level of radioactivity.

HLW disposal
HLW waste is vitrified first with boron forming borosilicate glass as it is an effective neutron absorber. Note - But it is difficult to effectively vitrify Plutonium. Then these vitrified wastes are stored in steel – canisters for cooling and surveillance over a long period of time. Finally vitrified waste is disposed - off in a deep geological depository.

India's Nuclear Technology Scenario
Indian Scientists formulated India's 3 stage nuclear Programme in 1950's. In India both uranium and thorium reserves are present but uranium reserves are little as compared to thorium. India has the largest share of global Thorium Reserves i.e. about 25% of global reserves [4]. The 3 stage Programme describes about different technologies to be used and how nuclear fuel and wastes can be effectively utilized and managed.

3 stages are:

- Stage 1 - Use of PHWR (Pressurised Heavy Water Reactor) Technology in which natural uranium is

used as Fuel. At present reactors are operating effectively in India based on this technology and progressively their design has improved.

- Stage 2 - FBR (Fast Breeder Reactor) technology to be used so that Plutonium and depleted uranium from PHWRs can be utilized. Constructions of FBRs are due and will begin soon. Only a Prototype of this reactor is working at IGCAR (Indira Gandhi Centre of Atomic Research), Kalpakkam.[5]

- Stage 3 - This stage focuses on the development of Technologies, which will use Thorium. At present only one research reactor (KAMINI) is operating, which use U-233 as fuel (produced by thorium fuel cycle).

3. RESULT

Hence we have studied the role of radioactive materials and technologies in the field nuclear sector and how nuclear wastes are managed by applying certain methods and techniques.

Acknowledgement

We would like to thank our Research Guide Assistant Prof. Monika Bazzad.

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