An Analytical Review on Radioactive Waste Classification

Rahul Pandey[1], Gaurav Kumar[2]

[1]Scholar,B.Tech IInd year, ME Dept, Amrapali Institute of Technology, Uttarakhand, India
[2]Associate Professor, ME Dept, Amrapali Institute of Technology, Uttarakhand, India

---

Abstract - *The global energy crisis along with environmental concerns have compelled researchers and scientists to look for a clean alternative source, Nuclear Power is one of the major upcoming high potent fuel sector which can be relied on in future. The most common nuclear fuel is Uranium U-235 and U-233 isotopes for power generations, whereas plutonium Pu-239 and thorium Th-232 (not self-fissile) are also used besides the Uranium Isotopes. It may prove to be very hazardous if handled improperly hence, its use was minimized and only a few countries in the world have access to this fuel. In this paper, a systematic analysis has been made on the different gradation of Nuclear Waste based on their irradiation factor, NWM methods which are mostly used and pertain scope have been approached. Also, an outlook on the rare element Protactinium has been done.*

Key Words: **NWM (Nuclear Waste Management), U-235, U-233, Pu-239, Protactinium.**

1. History of Evolution of Nuclear Source

The initial experiment was carried out by an Italian physicist Enrico Fermi in 1934, he proved that neutrons could split many kinds of atoms. The experiment results surprised him as he bombarded Uranium specimen with the neutrons and found the leftover material's mass was lighter than the Uranium.

Later in 1938, two German scientist Otto Hahn and Fritz Strassman conducted an experiment in which they fired neutrons from source containing beryllium and radium into uranium, the results were surprising as they were able to trace tracks of much lighter element i.e. barium in the leftover material. With the help of another German migrant Austrian scientist Lise Meitner they published their research and concluded that fission occurred using Einstein's theory of relativity. The oldest nuclear fuel discovered is regarded as Uranium U-235 isotope.

In 1941 Fermi and his associate, Leo Szilard developed a design for a self-sustaining chain reaction. The work on the concept began in 1942 in the University of Chicago. The design was such that Uranium was placed in stack of graphite to form a cube like frame of fissionable material. The model was named as Chicago Pile-1 which also contained control rods made of cadmium. When the rods were in the pile the neutrons would be less available and slow down the reaction, and when the rods are withdrawn the number of available neutrons significantly increases causing the reaction to speed up. On 2- December, 1942, 3:25 p.m., Chicago time, the reaction became self-sustaining and this marked the beginning of the nuclear era. This also gave birth to the concept of breeder reactors in which fissionable materials would be generated during the chain reaction, i.e. more fissionable material will be generated than consumed whereas some scientists started developing nuclear weapons for the WW-II. The only countries to have developed a fully functional breeder reactor are France and India.

II. Introduction to Radioactive Waste

Any nuclear materials or radioactive substances which cannot be further used are termed as radioactive waste. These compounds contain radionuclides at concentration rates higher than exempted limits by competent authorities and hence are separated from the general waste materials because, during their decaying process they continuously emit energy in the form of radiations which can cause severe acute life-threatening diseases. The radioactive waste occurs in three phases- solid, liquid and gases (Plasma state does not occur in this category).

The waste material separation intends to isolate it from the biosphere during its decaying process so as to prevent an interaction between the biosphere and the fuel. Some also are finding a way to utilize the waste materials to further reduce its half-life period. The current major use of this technique is to extract a rare element Protactinium(Pa). Pa_{91} is a rare shiny silvery color element. Analysis of the relative concentrations of various uranium, thorium and protactinium isotopes in water and minerals is used in radiometric dating of sediments which are up to 175,000 years old and in modeling of various geological processes.

III. Gradation of NWM along With Disposal Methods

Broadly the NWM are classified into six categories as per the IAEA:

Exempt waste (EW)

It is the lowest grade of radioactive material, they are not to be regulated by the authority as the radioactivity content is within compliance.

Very Short-Lived Waste (VSHLW)

These materials contain radionuclides of very short half-life's and are used for medical and research purposes. Under proper isolation for an adequate amount of time when allowed to decay they are good to be decomposed and need not require any further regulation.

Very Low-Level Waste (VLLW)

It usually has a higher radioactivity content than EW, but also may contain some long-lived radionuclides. These do not require high level isolation and hence are ideally decomposed in surface landfills under some regulation of the authorities.

Low Level Waste (LLW)

It has high amount of radioactivity content, isolation for about few hundred years is required before dumping them. They can easily be handled in an engineered near surface contamination facility. This category makes up a major amount of Nuclear Waste and contains large number of short lived radionuclides at high activity rate and some long-lived radionuclides at low activity rate.

Intermediate Level Waste (ILW)

It has higher radioactivity content than LLW, particularly the long-lived radionuclides concentration is high. It needs minimized provisions for heat transfer during its storage and contamination process. Waste of this class requires disposal at great depths (10-100m) because the activity concentration of long-lived radionuclides will not reduce to acceptable level in a time under institutional control for near surface contamination process.

High Level Waste (HLW)

They contain very high radioactivity and the amount of heat released is also very high. The design to hold and contaminate such waste is required to have heat exchanging ducts or vents or else the heat trapped will lead to an explosion. This Category of waste cannot be handled with reach of mankind and is dumped at least 700m below the surface depending upon the activity concentration of long-lived radionuclides.

IV. Experimental Observation

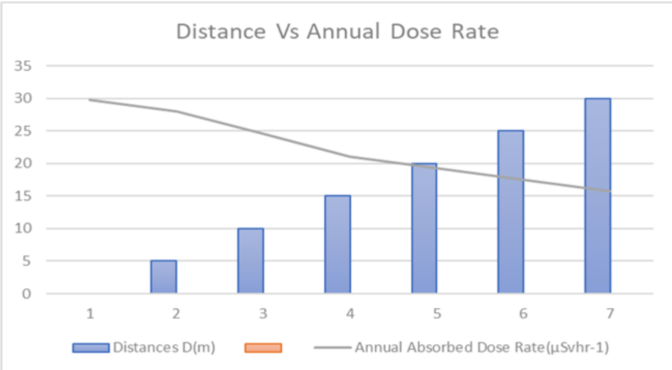
The following experiment was conducted by scholars- Akinnagbe O B, Adekoya O at Lagos State of Nigeria. The radiation survey meter used was RADALERT50 to measure the radiation exposure rate in micro sievert per hour (µSvhr)

The procedure followed was as: Readings were obtained by placing the detector at gonad level i.e. about 1 meter above the ground level in the sampling location. This was done at a regular interval of 5meters away from the point of reference up to 30 meters. The results obtained revealed that the annual absorbed dose rate measurements taken inside the dumping pit was 28.05µSvhr-1 which is far lower than the average of 70µSvhr-1 recommended by UNESCO on effect of Atomic Radiation.

The readings obtained during the measurements are as follows:

Location No.	Distance meters	Absorbed Dose Rate ($\mu Svhr^{-1}$)	Absorbed Dose Rate ($\mu Svhr^{-1}$)	Absorbed Dose Rate ($\mu Svhr^{-1}$)	Average Absorbed Dose Rate ($\mu Svhr^{-1}$)	Annual Absorbed Dose Rate ($\mu Svhr^{-1}$)
1	5	0.017	0.016	0.017	0.0166	29.8
2	10	0.016	0.016	0.017	0.0163	28.05
3	15	0.013	0.014	0.014	0.0136	24.54
4	20	0.012	0.012	0.011	0.0116	21.04
5	25	0.010	0.010	0.010	0.0106	19.29
6	30	0.009	0.009	0.009	0.009	15.78

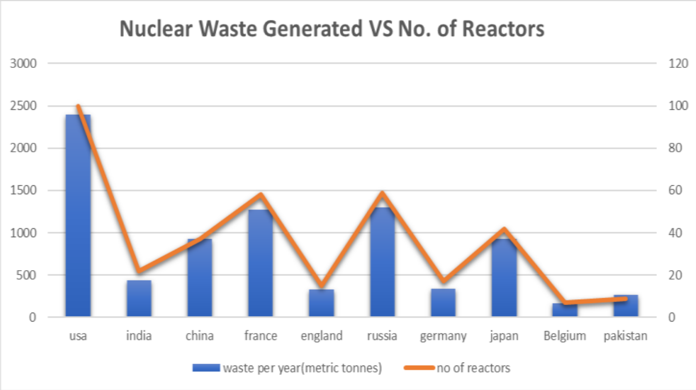
Graph Plotted on the above obtained data is as follows:



An Estimated Approximate Nuclear Waste Generated among the top nuclear powers in the world is as tabulated below with a graph showing the ratio of Waste generation per reactor for different countries.

Countries	Waste generated per year (Metric tons)	Number of reactors
USA	2400	100
India	440	22
China	925	37
France	1276	58
England	330	15
Russia	1298	59
Germany	340	17
Japan	924	42
Belgium	168	7
Pakistan	270	9

Graph Based on the above tabulated data is as:



V. Protactinium: an outlook

Protactinium represented by Pa, is an element found one part per trillion parts in the earth, although it is found part per million in uraninite ores. Its atomic number is 91 and it readily reacts with oxygen, water vapor and inorganic acids. It is physically described as a dense metal with silver-grey color. The element is classified as highly radioactive, its longest lived naturally occurring isotope Pa-231 has a half-life period of about 32760 years and is a decay product of U-235. Also, Protactinium-233 results from the decay of thorium-233 as part of the chain of events used to produce Uranium-233 by neutron irradiation of thorium-232. Pa is an undesired intermediate product obtained in thorium-based nuclear reactors during power generation process. Therefore, it is removed from the active zone of the reactor during the breeding process. Due to its high radioactivity and less availability currently there is no commercial use of Pa.

VI. CONCLUSION

We on the basis of above tabulated data and grading classification can come to a conclusion that high power generation should be done with minimizable amount of waste generated, like the development of the RMBK, VVER type reactors.The waste disposal on onsite, i.e. the interim dry used fuel storage facilities should be replaced by pitted structures with fins for heat structure as it is dangerous to store HLW in facilities. The security measures been the highest in the world yet the tragic incident of Japanese Fukushima Nuclear accident happened in 2011. The pitted measures are safe as the nuclear matter remains isolated even in most of the natural calamities except earthquake and lack of human causalities is also very less in these cases. It is easy or the waste to exchange heat beneath the surface as it can be used to heat certain water sources as per requirement of the industry which will decrease the labor to heat water and make the process a bit cheaper.

REFERENCES

[1]. Luís Paulo Sant'ana,Taynara Cristina Cordeiro, Proceedings of the International Academy of Ecology and Environmental Sciences, 2016

[2]. US Department of Energy DOE/NEE-0088.

[3]. IAEA-TECDOC-1183-November 2000

[4]. US department of Energy, DOE O 435.1, 1999 Issue.

[5]. Assessment of Radiation Emission from Waste sites in Lagos state of Nigeria- Akinnagbe O B, Adekoya O, 2012 edition – Schematic scholar

[6]. A review of radioactive waste management-Nikunnj Khelurkar, Sunay Shah, IEEE Explore.