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A Review of Radioactive Waste and its Safe Disposal

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***Abstract*: Byproducts of different nuclear processes or nuclear chain reactions, which are frequently employed for energy purposes, include radioactive waste. Nuclear waste is created by a variety of processes, including the mining of uranium ore, the synthesis of nuclear fuel, the creation and utilization of radionuclides, and the production of therapeutic byproducts. This waste's radioactive characteristics can change depending on its condition and can be in solid, liquid, or gas form. We will mostly discuss the following in this paper: 1) History of Nuclear power, 2) Uses across globe and its waste generation, 3) Types of Nuclear Waste, 4) Safe Storage and Treatment, 5) Formulating a synthesis and safe uses of nuclear waste.**

***Keywords*: Radioactive waste, nuclear power, spent fuel transportation cask, types of nuclear waste.**

1. Introduction

Radioactive materials are included in radioactive wastes, which are often leftovers from nuclear power production and other uses of nuclear fission or nuclear technology in industries like research and medicine. Governmental organisations control radioactive waste to safeguard public health and the environment since it is harmful to the majority of life forms as well as the environment. The main gist of the research is to cover the information on nuclear waste and to find the various ways to decompose the waste and some possible ways to use the by-products of nuclear waste.

2. History of Nuclear Power

Up to the 19th century CE, the nuclear power was a phenomenon that was mostly ignored. Antoine Becquerel makes the radioactive discovery in 1896. The first nuclear reaction that can last on its own is then produced by University of Chicago researchers. In 1951, a nuclear experiment in Arco, Idaho, generates enough electricity to light four lamps. The Atomic Energy Act of 1954 gives civilian nuclear energy development permission. In Shipping Port, Pennsylvania, the first commercial nuclear-powered generating plant is constructed in 1957.

At the Three Mile Island power facility, close to Middletown, Pennsylvania, coolant loss from the reactor core occurs in 1979 due to mechanical failure and human error. In Ukraine, which was then a part of the Soviet Union, the 1986 Chernobyl accident is the most well-known. 1996 In Spring City, Tennessee, Watts Bar-1, the final nuclear power facility in the United States, goes online. 2003 Exelon and Dominion Power submit proposals for nuclear facility construction in Virginia and Illinois, respectively. They would be the first brand-new reactors since 1996.

3. Uses Across Globe and its Waste Generation

Nuclear technologies harness the energy produced by splitting the atoms of certain elements. When it was first created, during the Second World War, research was initially geared toward making bombs. The pacific use of nuclear fission, which involved managing it for power production, came into focus in the 1950s. With 32 nations globally operating nuclear power plants, civil nuclear power can already claim more than 18,000 reactor years of experience. In fact, many more nations rely partially on nuclear-generated energy thanks to regional transmission lines; for instance, Italy and Denmark import about 10% of their electricity. Roughly 440 nuclear power reactors produce about 10% of the world's electricity. Around 55 more reactors, or 15% of the current capacity, are being built in 15 different nations. We can see that there was the rise of energy usage from 1965 to 2021 in the following graph. [1]

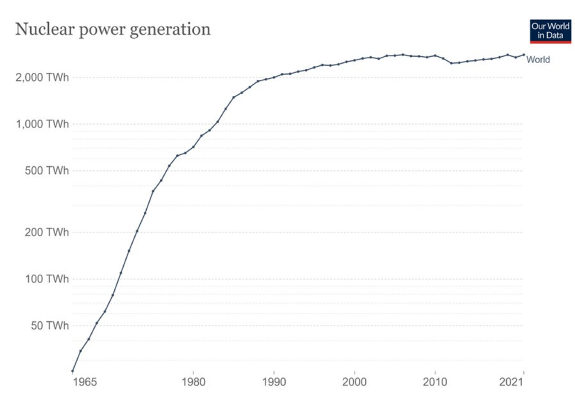

Fig. 1. Nuclear power generation

Nuclear fuel cycle, reprocessing of nuclear weapons, medical waste, industrial waste, and naturally occurring radioactive elements are only a few of the sources that produce radioactive waste (NORM). The majority of waste is produced by nuclear

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fuel cycles and nuclear weapons among all of these. In the nuclear fuel cycle, radioactive waste is produced both at the beginning and conclusion of the cycle. Waste from the uranium extraction process that emits alpha radiation typically comes from the front end of the nuclear fuel cycle. Whereas the spent fuel rod portion of the nuclear fuel cycle primarily consists of fission products that emit beta and gamma radiation, actinides that emit alpha particles, such as uranium-234, neptunium-237, plutonium-238, and americium-241, and occasionally even some neutron emitters, such as californium, it frequently contains radium and its decay products (Cf). Waste from the reprocessing of nuclear weapons is expected to include actinides that produce alpha rays, such as Pu-239, a fissile material used in bombs, as well as others with far greater specific activity, such Pu-238 or Po. Tritium and americium that release beta or gamma rays are also present, but in extremely minute amounts. Beta and gamma emitters are typically present in medical waste. Some of the isotopes used in medicine include Y-90 for the treatment of lymphoma, I-131 for the treatment of thyroid cancer, Sr-89 for the treatment of bone cancer, Ir-192 for brachytherapy, Co-60 for brachytherapy and external radiation, and Cs-137 for brachytherapy and external radiation. [2]

4. Types of Nuclear Waste

Low-level radioactive waste

Low-level waste is made up of items that have been polluted by radioactive chemicals and is mostly produced from the nuclear fuel cycle. It also covers things that develop radioactivity as a result of exposure to neutron radiation. Clothing, mop heads, cleaning rags, filters, reactor water treatment byproducts, tools, luminous dials, medical tubes, swabs, and injection needles are only a few examples of the low-level trash. The garbage is given special classification as mixed low-level waste when it is combined with hazardous waste (MLLW).

A. Nuclear waste of a middle level

Since the garbage has more radioactive components than low level rubbish, it needs further security. It consists of resins, chemical sludge's, contaminated reactor parts, and debris from decommissioned reactors. For disposal, the garbage at the intermediate level may be compacted in concrete. Long-lived waste is placed in a geological repository whereas short-lived waste, which mostly consists of reactor non-fuel components, is disposed of in shallow repositories.

B. High-level radioactive waste

After nuclear fuel is burned and removed from nuclear reactors, this kind of waste is created. Transuranic elements and highly radioactive fission products created in a nuclear reactor's core make up the waste. More than 95% of the radioactivity emitted throughout the nuclear power production process is a result of high-level waste. The high-level waste requires cooling since it generates a lot of heat. The trash should be protected during processing and transportation to prevent damaging exposure. Since high-level waste includes radioactive nuclear fuel rods, getting too near to the unprotected waste might cause immediate human death.

C. Uranium tailings

The waste byproducts produced when uranium is extracted from the ore are known as "tailings." They are radioactive sludge leftovers from the uranium-containing elements in the ore. Uranium is removed from the ore using a heap leaching method. Radom, one of the radioactive components in uranium tailings, decomposes to become radon. Uranium tailings are observed to preserve a significant amount of radiation levels inside the ore due to the existence of long-lived decay products. Due to the presence of many radioactive nuclides, including polonium-210, radium-226, radon-222, and the daughter isotopes of radon decay, the waste is regarded as harmful.

D. Rods of spent fuel

Ceramic uranium dioxide pellets are enclosed in a number of metal rods before being used as fuel in nuclear reactors. To create the fuel assembly, which is utilized to run nuclear reactors, the metal rods are bundled together. The spent fuel assembly is taken out after the fission reactor. Excessively hot spent fuel rods must be kept in water until they can be securely disposed of.

E. Transuranic nuclear waste

TRU waste is a byproduct of nuclear weapons production facilities, nuclear research facilities, and nuclear power plants.

Plutonium is a significant component of the TRU waste. Although this kind of trash does not contain a significant amount of radiation, breathing in the waste's microscopic particles can be dangerous. The radiation the particles generate may harm people's lungs.

5. Safe Storage and Treatment

Since the 1950s, scientists have proposed a new type of geologic repository known as a deep borehole, which has recently attracted a lot of interest due to advancements in drilling techniques. A hole is dug to a depth of around 4000 - 5000 meters in deep boreholes, where spent fuel assemblies are piled before being shut off. By descending about ten times deeper than standard repository designs, the material is expected to be farther segregated from the biosphere for a longer length of time. The wasted fuel is never unprotected in real life. In order to allow for the cooling of the spent fuel without the use of water, it is maintained submerged (water is a great shield) for 7-10 years. Nuclear waste is either recycled or transferred into enormous concrete containers known as dry casks after cooling in spent fuel pools. Each of these barrels contains a number of used fuel assemblies.

Dry cask storage is a safe place to keep high-level radioactive waste, including used nuclear fuel that has been previously cooled in the spent fuel pool for at least a year and occasionally for up to ten years. Casks are typically steel cylinders with a bolted or welded closure. The fuel rods within are surrounded by inert gas. The steel cylinder should have no trouble holding onto the spent fuel. Each cylinder is surrounded by additional steel, concrete, or other materials in order to shield workers and members of the public from radiation. [5]

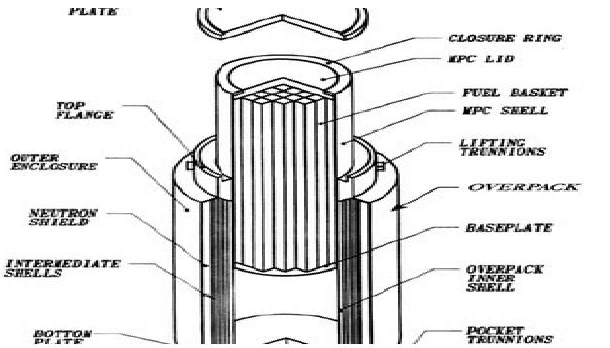

Fig. 2. HOLTEC HI-STAR 100 Spent Fuel Transportation Cask [4]

Although above-ground dry cask storage is highly stable, both proponents and opponents of nuclear power may agree that there are good reasons to strive to move it even more away from the biosphere.

Thermally controlled water is used in spent fuel pools because it functions as a natural and dependable radiation barrier. As a result, these pools are utilized to store spent nuclear fuel. The spent fuel must be stored in the spent fuel pool for a period of time before being removed from the reactor and replaced with new fuel. The spent fuel must be kept submerged due to the heat created by the breakdown of fission products, which helps to minimize radiation levels surrounding the spent fuel pool. Wasted fuel produces less heat over time.

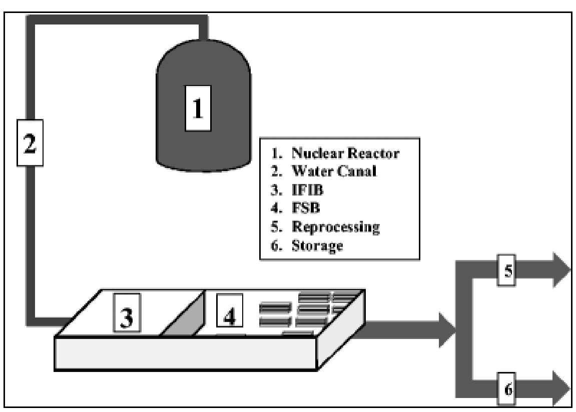

Fig. 3. A schematic outline of spent nuclear fuel pool facility. IFIB, irradiated fuel inspection bay; FSB, fuel storage bay [6]

Radioactive waste transmutation, to put it simply, is the process by which radioactive isotopes are changed into non-radioactive isotopes. The long-lived radioactive isotope of iodine-129, which necessitates complex disposal methods, is one example of radioactive waste transmutation. Iodine-129 is bombarded with neutrons to destroy its radioactivity; once the neutron is absorbed, it is transformed into a non-radioactive isotope of xenon. [2]

6. Formulating a Synthesis and Safe uses of Nuclear Waste

There are several beneficial fission products in high level radioactive liquid waste, including 137Cs, 90Sr, 106Ru, etc., which have many industrial and medical uses. These isotopes' energy can be utilized for blood irradiation, food preservation, sewage treatment, medical procedures, brachytherapy, and a number of other industrial uses. The waste becomes a resource when these beneficial isotopes are extracted from radioactive waste, recovered, and used for societal purposes.

A. Irradiation ^{137}Cesium glass pencils

For a variety of uses, including the irradiation of food, sewage sludge, and blood, ^{137}Cs can be employed as a notable substitute irradiation source to 60C°. The necessity for replacement of the radiation sources is reduced because ^{137}Cs has a longer half-life than ^{60}Co. Radioactive waste contains a significant amount of ^{137}Cs, one of the main fission products. The majority of the ^{137}Cesium was recovered from waste thanks to the creation of selective extract ants by internal researchers and their utilization. To be employed as a blood irradiator, the recovered ^{137}Cs solution is transformed into a non-dispersible cesium glass pencil. At the Waste Immobilization Plant Trombay, a small number of lac Ci of ^{137}Cs have been successfully collected and transformed into Cs glass pencils, each of which has an activity of 2.0 to 5.0 Ci/gm of ^{137}Cs. These pencils were given to several hospitals through BRIT after being subjected to stringent quality control. The usage of Cs glass pencils for other irradiation processes, like food irradiation, is being researched and developed.

B. Radiopharmaceutical of ^{90}stronium in the milking of ^{90}yttrium

Another isotope found in trash, ^{90}Sr, decays to ^{90}Y by beta decay and is used as a radiopharmaceutical for medicinal usage when treating cancer. Strontium from HLW was effectively recovered and converted into an yttrium generator using an internal-developed strontium selective extracting. Using proprietary membrane technology, ^{90}Y is extracted from pure 90Sr and given for radiopharmaceutical usage.

C. ^{106}Ru for the treatment of eye cancer

As a brachytherapy, ^{106}Ru has a significant role to play in the treatment of eye cancer. ^{106}Ru plaques are still imported. Technology for recovering ^{106}Ru from nuclear waste and creating silver plaque with ^{106}Ru in it has been successfully established as an effective import replacement for treating eye cancer. For the treatment of eye cancer, BRIT produces and distributes Ru plaques to various eye hospitals. These plaques contain between 300 and 600 micro curries of Ru-106 activity. The locally created Ru-106 eye plaques perform on par with global standards and are reasonably priced. [7]

D. Disinfection of waste water

Disinfection of drinkable water and wastewater offers some protection from harmful organisms, such as those that cause cholera, polio, typhoid, hepatitis, and a range of other bacterial, viral, and parasite diseases. A considerable portion of harmful organisms are either eliminated or managed during the process of disinfection. We can use it to disinfect city wastewater. Without the use of chemical sterilizers like bleach, radiation can sterilize. However, the risk is not worth the possibility of it being stolen, catching fire, or something else.

7. Conclusion

The safe management of radioactive waste has always been a top objective for our nuclear energy program. Identification, classification, storage, transportation, and disposal of radioactive waste must be done carefully. The production of radioactive waste has significantly increased due to the expansion of nuclear reactors and the mass manufacturing of nuclear weapons around the globe. Nuclear transmutation can be used to lower the radioactivity of high-level waste, which is crucial. In a similar vein, alternative reprocessing techniques include incorporating low level radioactive waste into products like discrete and vitrified goods must be made feasible.

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