Federal Ministry
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Climate Action, Environment,
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Nuclear Waste – An Intergenerational Issue

The world's first commercial nuclear power plant began feeding power into the grid in the Soviet Union in 1954. Exactly 70 years and close to 20,000 reactor operating-years later, the world has yet to see a functional final repository for the most hazardous radioactive waste.

The oldest Homo sapiens fossils, discovered in Africa, are 300,000 years old. That is roughly how long it takes for the plutonium isotope Pu-239 to largely decay. Plutonium is a heavy metal that basically does not occur in nature. It was mankind that brought large amounts of it into the world.

As with many other radioactive substances, plutonium is produced during the operation of nuclear power plants and serves as fuel at the same time. Once the nuclear fuel is used, it is unloaded from the reactor and stored underwater in a cooling pool. Without the shielding provided by the water, the high level of radioactivity emitted by the fuel elements would kill a human being within a minute.[1]

Still No Final Disposal Site for High-Level Radioactive Waste

After seven decades of nuclear power generation, as of mid-2024, there is still no safe final repository for highly radioactive waste available anywhere in the world. Only for low and intermediate level radioactive wastes final disposal sites have been implemented in most nuclear countries. In Europe alone, over 65,000 tonnes of highly radioactive spent

[1] GA Andrews GA, JA Auxier, CC Lushbaugh, "The Importance of Dosimetry to the Medical Management of Persons Exposed to High Levels of Radiation", In Personal Dosimetry for Radiation Accidents, International Atomic Energy Agency, 1965.

nuclear fuel are awaiting a destination for eternity.[2] Four fifths of the highly radioactive material is currently stored in swimming-pool-like cooling structures. The loss of the shielding water, e.g. through earthquakes, airplane crashes, acts of sabotage, a military or terrorist attack would cause the toxic waste to self-ignite and lead to the release of a large share of the radioactive inventory. The impact on densely populated regions would dwarf the disasters in Chernobyl or Fukushima.[3]

The generation of radioactive waste begins with uranium mining, then continues in conversion and enrichment plants, and during fuel element manufacturing. Irradiated and contaminated waste is also generated in nuclear reactors, and during plutonium separation in so-called reprocessing plants.[4] By far the highest levels of radioactivity are found in irradiated fuel elements and, if these have been processed, in canisters of vitrified waste destined for disposal. Low-level material, generated especially during uranium mining, dominate in terms of volume and weight.

100,000 Tons of Mining Waste Per Reactor Per Year

To operate a single 1000-MW nuclear power reactor for one year, over 100,000 tonnes of uranium ore must be extracted. The Wismut mine, located on the territory of the erstwhile German Democratic Republic (GDR) and operated until 1996, left behind over

300 million cubic metres of radioactive mining waste and 160 million cubic metres of contaminated sludges. Some 4,000 Wismut workers have died of lung cancer.[5]

Uranium concentrate is extracted from the ore and further processed via several conversion stages into fuel elements. Waste is produced at every step of the way. That

[2] Excluding Russia and Slovakia, derived from Manon Besnard et al., "World Nuclear Waste Report", 2019, see worldnuclearwastereport.org, accessed on 19 November 2020.
[3] Frank von Hippel and Michael Schöppner, "Reducing the Danger from Fires in Spent Fuel Pools", Science & Global Security, 2016, see scienceandglobalsecurity.org/archive/sgs24vonhippel.pdf.
[4] Reprocessing involves the shearing and dissolution of the highly active fuel elements in a chemical factory and filtering out plutonium and residual uranium. A reprocessing plant not only generates plutonium and uranium, but also large amounts of radioactive waste from a previously compact waste form. In the process, considerable amounts of radioactivity are released into the environment.
[5] Manon Besnard et al., "The World Nuclear Waste Report", November 2019, see worldnuclearwastereport.org/wpcontent/themes/wnwr_theme/content/World_Nuclear_Waste_Report_2019_Focus_Europe.pdf.

being so, the operation of a nuclear reactor results in the annual generation of around 1,400 cubic metres of waste when uranium concentrate is converted, 130 cubic metres during enrichment, 230 cubic metres during fuel element production, and 300 cubic metres during operation of the reactor. This totals over 2,000 cubic metres, in addition to the 25 tonnes of highly radioactive spent fuel and the mining waste at the beginning of the chain. The waste volume is reduced by incineration or compaction, but generally increases again with packaging for shipment and disposal.

A few countries, notably France, operate reprocessing plants that give rise to additional waste streams. Moreover, all these radioactive facilities will need to be dismantled at some point, resulting in even more waste streams. Out of a total of 213 nuclear power reactors that have been closed, only 22 have been technically decommissioned. Of these, only ten have been returned to “green field” status, free for any other use.

From Storage to Final Disposal: An Unresolved Problem

Radionuclides are unstable atoms. Depending on the degree of their instability, they decay at a faster or slower pace and emit potentially hazardous ionizing radiation in the process. Ionizing radiation can cause cancer and other serious illnesses. Long-lived, highly radioactive nuclear waste must be shielded permanently and reliably from the biosphere at least for tens of thousands of years. The term “storage” describes the handling of nuclear legacies over a certain period of time, whereas “final disposal” is the term used for emplacement in a facility without the intention of retrieval. Even in a “final repository” for highly radioactive waste – no such socially and scientifically accepted facility exists anywhere in the world, yet – nuclear waste remains a hazard over entire geological ages that span a million and more years.

A half-life is the duration of decay required for the activity of a given radionuclide to diminish by half. Only after ten half-lives has a radionuclide substantially decayed. Out of 1,000 kg, only 1 kg (= 0.1%) of the nuclide subsists, and yet it must still be safely contained.

Wanted: Radiological Safety for Eternity

During normal operation, a nuclear power plant produces a cocktail of radioisotopes in the reactor. Some are short-lived, i.e. radioactivity decays after a relatively short time. For example, half of iodine-131 transforms into other – usually more stable – isotopes within 8 days. Other radioisotopes take several years to decay. Heavy hydrogen tritium with a half-life of 12.3 years, for example, decays into helium. Other radionuclides have extremely long half-lives: Iodine-129 decays by half in 17 million years, plutonium-239 takes 24,000 years. Therefore, a final repository for highly radioactive waste must hold lots of different radioactive waste materials while guaranteeing safety over many half-lives, in other words, over time periods that are beyond the grasp of human imagination. One million years is three times as long as homo sapiens has been around. 5,000 years ago, the Egyptians built the pyramids. And the radioactive legacy of our generation is supposed to be kept safe underground for a period that is at least 200 generations long.

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