

6-2 Solutions for Problems of Waste with the Safety, Sustainability, and Economy — Development of Nuclear Systems using HTGR —

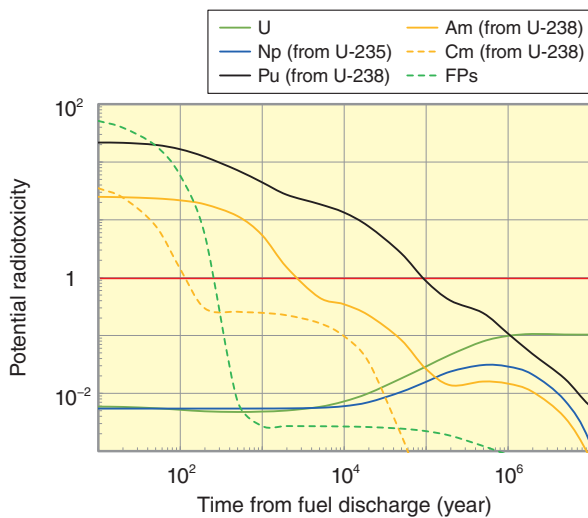


Fig.6-4 Potential radiotoxicity in spent fuels of light water reactors

The cooling time needed for the potential radiotoxicity of Pu to decline below that of natural U (—) is 100 thousand years, and that for Am is 3 thousand years. Np and Cm, which need shorter cooling times than those of fission products (FPs), are not problematic. With reprocessing, Pu is not problematic because it can be recovered and excluded.

The spent fuels (SFs) discharged from nuclear reactors are reprocessed, and high-level radioactive wastes (HLWs) are disposed of in a deep geological repository. The public exposure must be limited to below that of the natural environment. However, the Science Council of Japan has showed a new criterion whereby the total amount of radioactivity in HLWs should be controlled, and has recommended research into nuclear transmutation.

We have performed research on reducing radiotoxicity-generation using the high temperature gas-cooled reactor (HTGR) (which has outstanding inherent safety features and can supply both electricity and high temperatures) without nuclear transmutation.

In general, the toxicity hazard from radioactive nuclides is expressed in the potential radiotoxicity. Thus, it is supposed that a hazard must be controlled by managing the total amount of radiotoxicity. HLWs should be managed until the potential radiotoxicity decays below that of natural uranium (U).

Fig.6-4 shows the potential radiotoxicities of the SFs of light water reactors (LWRs). In particular, the radiotoxicity of plutonium (Pu) and americium (Am) is significant. These radionuclides are generated from U-238. The toxicity generation can be inhibited if the fuel contains only the fissile nuclide U-235. We propose the use of highly enriched U (HEU) with 93% enrichment, which is producible by practical means. To enhance proliferation resistance, the fuel is solidified by

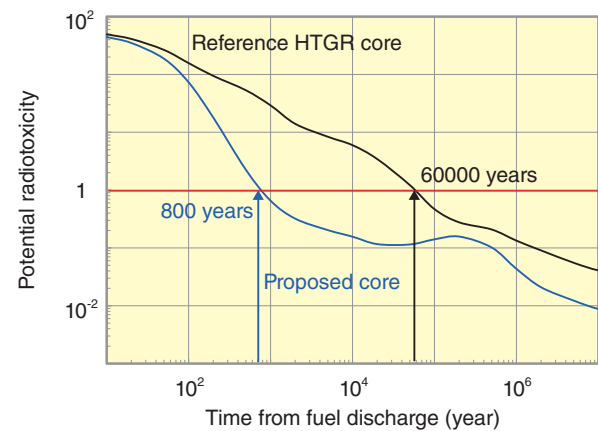


Fig.6-5 Potential radiotoxicity in spent fuels of a reference HTGR core and the proposed core (all nuclides)

In reference HTGR, the cooling time necessary for the potential radiotoxicity to decay below that of natural U is about 60 thousand years. In the proposed core, the cooling time is 800 years because the amount of U-238 in the fuel is reduced. If laser uranium-enrichment technology is developed, the cooling time can be reduced to about 500 years by higher U enrichment.

yttria-stabilized zirconia (YSZ), which is chemically inert, and fabricated as a coated particle fuel (CPF).

Fig.6-5 shows the potential radiotoxicities of the SFs of the reference HTGR core and the proposed U-YSZ-solidified CPF core. The cooling time necessary for the toxicity to decay below that of natural U is drastically reduced to about 800 years, over which time humanity could realistically manage the SFs.

The resistance of CPF against ground water is one million years, and the erosion rate of YSZ is 1/100 of that of vitrified wastes. The HTGR CPF with a YSZ kernel is suitable for direct disposal. The proposed core does not need any innovative technology to be developed. Cost-evaluation shows that the increase in the electricity-generation cost is within 5%.

Next, the sustainability of this system has been investigated. U exists inexhaustibly in the seawater, with an amount corresponding to the 70-million-year demand of electricity-generation. As the recovery cost has been evaluated to be about twice the present market price, the increase rate of electricity-generation cost using seawater U is only 6%. HTGR can achieve high economic efficiency with the simplicity of a direct gas turbine system. Even with the cost increase due to the proposed core and utilization of seawater U, the electricity-generation cost of HTGR will be cheaper than that of the LWR.

References

- Fukaya, Y. et al., Study on Reduction of Potential Radiotoxicity for Spent Fuel by using HTGR, Nippon Genshiryoku Gakkai Wabun Ronbunshi (Transactions of the Atomic Energy Society of Japan), vol.14, no.3, 2015, p.189-201 (in Japanese).
Fukaya, Y. et al., Sustainability and Economy of Energy Supply with HTGR Fueled by Uranium from Seawater, Proceedings of 2014 International Congress on Advances in Nuclear Power Plants (ICAPP 2014), Charlotte, North Carolina, USA, 2014, paper 14299, 7p., in CD-ROM.