Treatment of Radwastes From Medical Radioisotope Production

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1. Introduction

Molybdenum-99 (Mo-99) and its daughter isotope technetium-99m (Tc-99m) has been the most commonly used medical radioisotope which covers 85% of overall nuclear diagnostics. Currently, majority of Mo-99 supplied in the market is fission-based Mo-99 produced by the fission of U-235 in research reactors. In spite of substitutive production schemes, reactor-based fission Mo-99 (FM) exhibits significant advantages with higher specific activity (~10^4Ci/g) with lower production cost. [1]

Historically, the most FM producers have been used highly enriched uranium (HEU) targets. However, to limit the use of HEU in private sector for non-proliferation, all producers are being forced to convert their HEU-based process to use low enriched uranium (LEU, 19.75% U-235 enrichment) targets by 2018.

Consequently, overall cost for the production of the FM increased significantly. It is not only because of the 50% less yield, but also because of the radioactive waste increase by 200%. Therefore, designing optimal radwaste treatment system for FM production is becoming more important. [2, 3]

2. Fission Mo-99 Production

2.1 Fission Mo-99 Target

Today, all industrial-scale FM producers use dedicated uranium targets optimized for the alkaline digestion. KAERI developed plate-type LEU target composed of UAl_3/UAl_4 meat dispersed in Al-6061 cladding. Each target plate contains 14.95g LEU and uranium density of the meat is 2.6 g U/cm^3. The targets are irradiated in the reactor, then transferred from the FM production facility for processing after cooling for 24 hrs.

2.2 Fission Mo-99 Process

The irradiated targets are dissolved in sodium hydroxide solution for processing. Fission products other than Mo-99 are removed from the solution using multiple separation steps, as shown in the Fig. 1. Then Mo-99 is eluted and purified to meet standard for international pharmacopoeia. [4, 5, 6]

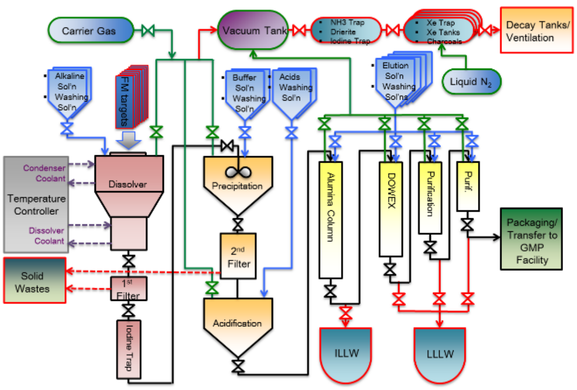

Fig. 1. Scheme for the FM process.

3. Radwastes in FM Production

As shown in the Fig. 1, solid, liquid and gaseous radwastes in various activity levels are produced during the FM production. In terms of radionuclides, isotopes of iodine, xenon, krypton, technetium and uranium are the major components in the waste stream.

3.1 Solid Radwastes

Uranium aluminide dissolved in the alkaline solution transforms to the insoluble oxide forms. The most of uranium and insoluble impurities containing transition metals, part of alkaline earth metals and transuranium elements forms colloidal particles. In alkaline solution, aluminum metal forms soluble sodium aluminides. But eventually, it transformed to insoluble aluminum oxides. Columns and consumables used in the separation and purification stages are also an origin of solid wastes.

3.2 Liquid Radwastes

Intermediate level liquid wastes (ILW) containing various fission products is generated from the separation of Mo-99 after alkaline dissolution of targets. KAERI developed new technology to facilitate waste treatment by converting sludge-type waste, which is difficult to handle, into independent solid and liquid wastes. Using this scheme, salt concentration in the ILW can be reduced significantly to make cementation much easier.

In the FM process with caustic digestion, most iodine remains in the liquid phase as negatively charged iodide form. Therefore, iodine can be separated using a dedicated column from to the ILW.

Low level liquid wastes produced during elution and washing for purification step can be treated by combination of ion-exchange and evaporation.

3.3 Gaseous Radwastes

Radioisotopes of xenon (Xe) and krypton (Kr) are generated from the fission of Uranium. Emission of radioxenon from the medical radioisotope production is controlled via delayed release through large charcoal beds.

KAERI developed compact xenon adsorption module with chilled carbon column to meet 5 GBq/day of CTBTO recommendation. It can satisfy the guideline with only 8.5 kg charcoal, instead of 32 tons of conventional system.

4. Conclusion

To achieve production objective (2,000 Ci/week) of Mo-99 in KJRR, KAERI is developing the FM production process with dedicated facility. Weekly production of 2,000 Ci (100,000 Ci/yr, 6-day calibration) Mo-99 will cover 100% domestic, as well as 20% of international demand. Every year, 3,000 L of ILW and 10 kg of spent uranium is expected to be treated.

Therefore, development of radwaste treatment program for the FM production is one of the most essential piece for the successful construction, licensing and operation of the new research reactor (KJRR), which is being constructed in Gijang, Busan, Korea.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF), funded by the Ministry of Science and ICT (NRF-2012M2A2A6009866).

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