Study for Quantitative Assessment of contaminated Uranium in Polyethylene using HANARO Neutron Activation Analysis

Seongpyo Hong [a*], Sung Hyo Lee [a], Kishore B. Dasari [a,b,c], Bo-Young Han [a], Gwang-Min Sun [a]
[a]*HANARO Utilization Division, Korea Atomic Energy Research Institute, Daejeon, Republic of Korea*
[b]*Research Institute of Natural Science, Gyeongsang National University, Jinju, Republic of Korea*
[c]*Inorganic Metrology Group, Korea Research Institute of Standards and Science, Daejeon 34113, Korea*
[*]*Corresponding author: hongsp@kaeri.re.kr*

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1. Introduction

Polyethylene (PE) is widely used as a neutron moderator and radiation shielding material in various applications, including nuclear facilities, radiation shielding structures, and space technology. The presence of trace uranium in polyethylene can lead to unintended radiation sources, necessitating precise contamination assessment and purity control. Additionally, uranium contamination in polyethylene-based storage containers for radioactive waste and radiation medical equipment poses potential long-term exposure risks, emphasizing the need for environmental and safety evaluations.

From an industrial perspective, uranium can be inadvertently introduced during polyethylene manufacturing through catalysts and additives, making strict quality control and compliance with international safety standards essential. Furthermore, in space applications, where polyethylene is studied for radiation shielding, even trace amounts of radioactive isotopes can contribute to secondary radiation exposure, necessitating precise material characterization.

Therefore, by utilizing highly sensitive analytical techniques such as Neutron Activation Analysis (NAA) for the quantitative assessment of trace uranium, the safety and reliability of polyethylene products can be ensured. Traditional INAA is primarily used to determine uranium concentration by detecting the medium-lived nuclide ^{239}Np (half-life: 2.35 days), which forms through neutron capture by ^{238}U and emits gamma rays at 106 keV, 228 keV, and 278 keV. [1]

However, gamma-ray interference and significant background noise in the low-energy region lead to inaccuracies in analytical results and increased uncertainty. Besides the ^{238}U(n,γ)^{239}U/^{239}Np reaction, the fission of ^{235}U generates various fission products, including ^{140}La, ^{140}Ba, ^{141}Ce, ^{99}Mo, ^{97}Zr, and ^{95}Zr, among others. These fission products can interfere with target nuclides directly formed in the sample. Several studies have experimentally determined correction factors to ensure accurate quantification of target elements in analytical samples. Among these fission nuclides, ^{140}La is particularly suitable for uranium quantification. This is because ^{140}Ba ($t_{1/2}$: 12.95 days) decays into ^{140}La ($t_{1/2}$: 40.28 hours), and the correction factor for ^{140}La depends on the decay time of the irradiated sample, affecting the analytical value of La. Therefore, ^{140}La can serve as a reference for determining uranium content.

The study was conducted by analyzing standard reference material (SRM) containing uranium to establish analytical criteria for optimizing the quantitative assessment of uranium in PE using HANARO's operational neutron activation analysis facility.

2. Methods and Results

2.1 HANARO neutron activation analysis facility

Neutron Activation Analysis (NAA) in HANARO uses a pneumatic transfer system (PTS) and the Rabbit to irradiate the sample with neutrons. The Rabbit is a capsule for transporting and retrieving prepared samples to and from the neutron irradiation point and is made of polyethylene, as shown in Figure1. The PTS consists of a loader, a receiver, a diverter, and a transfer line, which is a pipe with an inner diameter of 28 mm and an outer diameter of 34 mm and a length of approximately 60 m.

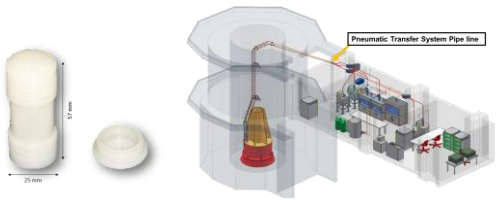

Fig. 1. Image of the Rabbit (left) and PTS in HANARO (right).

2.2 Sample preparation

To evaluate trace amounts of uranium, samples were prepared using SRMs from NIST SRMs 1633c and 2709 which contain uranium. Each sample was prepared in the form of a pellet containing 50 mg and placed in a rabbit.

Fig. 2. Image of prepared samples for irradiation

2.3 Neutron Activation Analysis

Samples packed in rabbits were irradiated with neutrons for 2 hours using Pneumatic Transfer System #2 (PTS#2) of the HANARO Neutron Activation Analysis Facility. The thermal neutron flux of PTS#2 determined using Fe flux monitor is approximately $2.3\times10^{13}n\cdot cm^{-2}s^{-1}$ at 27 MW thermal power.

3. Conclusions

To achieve more accurate quantitative analysis of trace uranium contamination in PE using neutron radiometric analysis, experiments were conducted to determine optimal analytical conditions and calibration functions using SRM. The findings of this study not only enhance the precision of uranium quantification in PE but also serve as a reference standard for analyzing trace uranium contamination in various sample types.

REFERENCES

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