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Major Source of Plutonium Isotopes in the Environment and Assessment of the Internal Radiation Dose from Discharge of Plutonium from the Sellafield Reprocessing Plant

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Introduction

Anthropogenic radionuclides of plutonium (Pu) have been released into the environment because of atmospheric nuclear weapons testing. In addition, Pu can be used as fuel after reprocessing the spent nuclear fuel. Therefore, Japan plans to reprocess nuclear fuel; hence, it is important to investigate the behavior of Pu in the environment. The purpose of this study was to review the existing literature related to the fate of Pu in the environment and to estimate the internal exposure dose of residents living near the Sellafield reprocessing plant. In particular, the study focused on internal radiation exposure based on the consumption of seafood.

Sources of Pu in the environment

The principal source of Pu in the environment is the fallout caused by atmospheric nuclear weapons testing. Pu can be released from other sources including nuclear fuel reprocessing plants, falling satellites, accidents during nuclear weapon transportation, and during nuclear facilities accidents. Pu has been distributed throughout the world because of atmospheric nuclear testing. Other sources have a more localized affect and can be distinguished according to the differences of $^{240}Pu/^{239}Pu$ atom ratios.

Estimating internal radiation dose from the Sellafield reprocessing plant

The Sellafield site consists of various nuclear facilities that have discharged radioactive materials into the Irish Sea since the 1950s. Discharge of Pu from reprocessing plant operations and the total discharge amounts of $^{239, 240}Pu$ and ^{238}Pu were 587 TBq and 144 TBq, respectively. The environmental monitoring of radionuclide levels around the Sellafield reprocessing plant was performed by a U.K. government agency. The present study estimates the internal exposure dose of residents by determining Pu concentrations in seafood and the average yearly seafood consumption of residents. Figure 1 shows that the internal radiation dose from Pu was up to 10 mSv in the late 1970s, which was approximately 1/10 lower than the internal radiation dose from ^{137}Cs. Moreover, the global average dose was 290 mSv. Thus, the internal radiation dose from Pu near the Sellafield reprocessing plant was considerably lower than that from other sources such as ^{137}Cs and the global average.

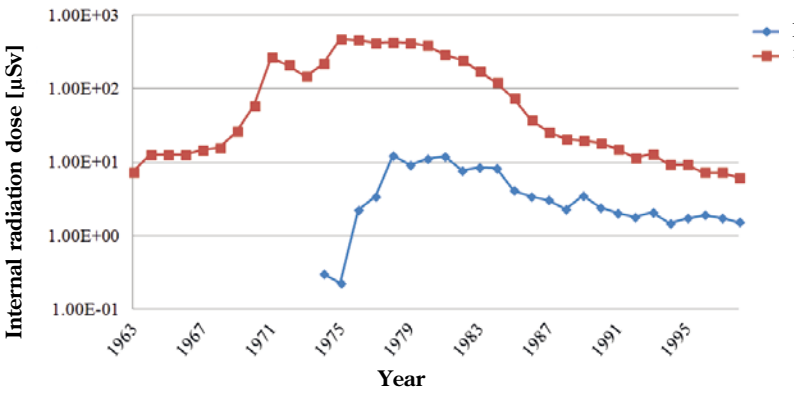

Fig. 1. The annual internal radiation dose by Pu and ^{137}Cs from the Sellafield reprocessing plant.

Conclusion

This study summarizes the literature related to the behavior of Pu isotope in the environment. In addition, the study estimates the average Pu internal dose of the Sellafield residents based on the consumption of seafood. These results are expected to be useful for understanding the fate of Pu isotopes associated with nuclear fuel reprocessing in Japan.

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Correlations between Thyroid Radiation Dose and Thyroid Cancer Risk.

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After the atomic bombings in 1945, the incidence of thyroid cancer increased among residents of Hiroshima and Nagasaki, Japan. Similarly, the incidence of thyroid cancer substantially increased among the exposed children or adolescents in Belarus, Ukraine, and the four other affected regions of the Russian Federation after the Chernobyl disaster. This trend has been maintained even 20 years after exposure, with 5127 cases (among those aged < 14 years in 1986) and 6848 cases (among those aged < 18 years in 1986) of thyroid cancer have been reported between 1991 and 2005 in Belarus, the Ukraine, and the affected regions in the Russian Federation.

The average thyroid radiation dose, mainly due to consumption of milk contaminated with I-131 during the first few weeks following the accident, was estimated be approximately 490 mGy. There is no doubt that this increased exposure to radioiodine due to the Chernobyl disaster has substantially contributed to the increase in the incidence of thyroid cancer. Therefore, the possible health risks in the evacuees of the Fukushima disaster is of concern, particularly those of infant thyroid cancer due to the release of radioactive iodine ^{131}I into the environment. Local health authorities measured thyroid activity of 1149 children aged <15 years in Iwaki City, Kawamata Town, and Iitate Village, Japan, from March 24–30 in 2011. The maximum dose was considered to be equivalent to a thyroid dose of 35 mSv. ^{131}I activity measurements in the thyroids of residents and evacuees in Namie Town during the period from April 12–16 were also conducted. The Tsushima District of Namie Town is located within a 30-km radius of the reactor. ^{131}I activity in the thyroids of 46 out of the 62 residents and evacuees were measured. The median thyroid equivalent dose was estimated to be 4.2 mSv and 3.5 mSv in children and adults, respectively. The maximum thyroid doses for children and adults were 23 mSv and 33 mSv, respectively. Considering the relatively low levels the present estimated thyroid gland equivalent radiation dose, an increased in the incidence of thyroid cancer among Fukushima disaster survivors is less likely.

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Investigation of the Medical Effects of Functional Food Materials for Radioprotection

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Radiation and radioactive materials are generally used in various medical fields for diagnostic imaging or blood inactivation for blood transfusion. Furthermore, they are useful in non-destructive tests, growth inhibition of agricultural products, and industrial sterilization. Despite their useful applications in specific fields, their influence on human health cannot be neglected. Although radiotherapy is one of the most typical therapeutic methods for cancer treatment, side effects generally follow each treatment in many clinical cases. Therefore, mitigation methods are required to alleviate the side effects of radiotherapy for achieving optimum therapeutic effects of cancer treatment. To this end, many studies have been performed to reduce the side effects of radiations and to protect human bodies from the radiations. There are several types of medicines known as typical radiation protective agents such as amifostine (WR-2721), which exhibits radioprotective effect by radical elimination or low oxygen action, and it can improve the production of hematopoietic cell growth factors such as G-CSF and GM-CSF. Other medicines include Prussian blue, a chelating agent, and stable iodine, which promote the excretion of radioactive materials induced by internal contamination. However, no radioprotective medicine for clinical usage has been approved in Japan so far. Therefore, the development of a new material for radioprotective medicine is in urgent need. In the development of radiation-protective agents, not only drug development processes but also the search for functional food materials has been performed. However, very little knowledge about the medical effects and toxicity of the food material with radiological protection function has been accumulated. In this review, medical data about radioprotective functional foods reported from 1990 to 2012 has been verified and medical verification about the validity of the data and the data-analysis method has been performed. A structured abstract of about 88 archived research reports extracted from PubMed is created. The analytical result suggested that most of the reports about radioprotective functional food material were at rudimentary medicine level. Furthermore, standardization of medical evidence data has not been performed to date; and it is difficult to compare the effect of each type of material objectively. Therefore, the development of standardized models consisting of safety assessment and further data verification models is needed. However, since some materials have been followed until the clinical trial stage, the application of radiation-protective agents that utilize functional natural food materials is expected.