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Investigation of collection methods of At-211 used for targeted alpha therapy from the viewpoint of radiation management

Astatine-211 (^{211}At), with a half-life of 7.216 hours, which is produced via the ^{209}Bi(α,2n)^{211}At reaction using accelerator is one of the promising radionuclides for targeted alpha therapy. At the accelerator facilities, measurements of airborne radioactivity are required using an ionizing chamber or radioactive aerosol monitor to manage the risk of radiation exposure to workers. Alpha-emitting radionuclides such as ^{211}At contribute more to internal exposure than beta and gamma-emitting radionuclides, and the legal-airborne radioactivity concentration limit in Japan is set about two orders of magnitude lower than that of beta-emitting radionuclides. However, rapid and accurate detection is impossible with conventional methods due to the natural background caused by beta and gamma-emitting radionuclides. Therefore, in order to avoid internal exposure of workers, it is necessary to quickly and accurately detect the ^{211}At concentration in the atmosphere even under the influence of beta and gamma-emitting radionuclides. In this study, we investigated the optimal collection and measurement method of astatine using a radioactive aerosol monitor.
For the selection of suitable filters for the radioactive aerosol monitor, the ^{211}At collection efficiency of commercially available filters was evaluated experimentally. Three types of filters were selected: membrane filter, glass-cellulose fiber filter, and activated charcoal filter. Membrane filters, which are thin-film filters with a thickness of about 0.1 mm, are recommended for use in radioactive aerosol monitors for long-lived alpha-emitting radionuclides due to their high surface collection efficiency. The use of the thin filter prevents distortion of the alpha energy spectrum obtained by the radioactive aerosol monitor and provides a high accuracy in nuclide identification. Glass-cellulose fiber filters are about 0.4 mm thick and are commonly used as radioactive aerosol monitor filters in Japan. Activated charcoal filters are about 2.8 mm thick. It is usually used to collect radioactive iodine. Since astatine is also a halogen element, we also conducted a study using the activated charcoal filters.
Experiments were conducted using ^{211}At produced via the ^{209}Bi(α,2n)^{211}At reaction at the RIKEN AVF cyclotron. The ^{209}Bi target (> 99.999%, 20 mg/cm2), vacuum-evaporated on an Al plate, was irradiated with an alpha beam of 28.0 ± 0.2 MeV. After irradiation, ^{211}At is separated by dry distillation technique. The separated ^{211}At is dissolved in methanol, and the volatile components from the methanol are passed through a filter.
In order to evaluate the collection efficiency of the filter accurately, an experimental system was constructed using a plastic cylinder and a filter holder. The collection efficiency was evaluated using following equation.

\begin{equation}
ε={A_f}/({A_{bef}-A_{aft}-A_d})
\end{equation}

where A_f is the radioactivity of ^{211}At collected by filter. A_{bef} and A_{aft} are the ^{211}At radioactivity in a vessel before and after the experiments. A_d is the ^{211}At radioactivity which is deposited on the inner wall of cylinder.
First, ^{211}At was added in the vessel with methanol, and measured the radioactivity using Ge detector. Second, the vessel containing ^{211}At was set inside the plastic cylinder so as not to leak out the volatile components. The inner wall of the plastic cylinder was covered with a thin film to evaluate the astatine deposition on the wall. Using this system, a pump draws in air containing ^{211}At and a filter collects ^{211}At. This collection was carried out until the methanol evaporated. Third, after the collection, the ^{211}At radioactivity of the vessel, filter, and film was measured with a Ge detector. The experiments were conducted in a glove bag for safety. Moreover, two 20 mm thick activated charcoal cartridges were installed behind the filter holder to ensure that the ^{211}At in the exhaust air from the experimental apparatus was sufficiently reduced. A glove bag was

supplied with clean air through a HEPA filter.
Details of the results will be reported.
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