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A Study on Pipe-type Radioactive Wastes in the Iodine Ward

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Based on the fact that it is difficult to extract pure radioactive isotopes during the manufacturing process of the radioisotope, we conducted a study on the purity of 131I used in patients in clinical practice. Nuclear medicine treatment using ^{131}I is performed by being admitted to a dedicated ward. In the most commonly used method for producing ^{131}I, ^{129}I is present in 0.1 %. Therefore, the importance of the management of pipes arises. According to the calculation formula, in the case of ^{131}I, the radioactivity does not increase after 60 days. However, if ^{129}I is present in 0.1 %, the radioactivity increases after 6 months. A similar result was also obtained when the pipes in the treatment room used for 8 years were measured. Therefore, the development of a pure ^{131}I generation method is currently required, and a realistic radiation safety management system such as applying the extraction technology of ^{129}I or enacting the regulations for the follow-up management of sealed pipes should be constructed as auxiliary methods.

Keywords : iodine-131, iodine-129, pipe, iodine ward, radioactive waste

1. Backgrounds

Based on the fact that it is difficult to extract pure radioactive isotopes during the manufacturing process of the radioisotope, we conducted a study on the purity of 131I used in patients in clinical practice. The Department of Nuclear Medicine is a department for diagnoses and treatments using radioactive isotopes (RI) and is divided into three parts. In the case of in vivo and in vitro parts, radioactive isotopes such as ^{99m}Tc, ^{201}Tl, ^{123}I, and ^{125}I (hereinafter referred to as RI) are used less than 20 mCi of radioactivity for diagnoses. In this case, a separate hospitalization process is not required. However, in the case of the treatment part using RI, the treatment is performed while being hospitalized in a separate ward since high radioactivity is used for the tumor. In such RI treatment, the most common case is to treat metastasis of thyroid cancer. For the treatment of metastasis of thyroid cancer, 30-200 mCi of iodine-131 is used and the patient is hospitalized for 3-5 days in a dedicated ward. Since iodine is not naturally occurring RI, it needs to be produced according to a separate process. There are three main ways of producing iodine in a nuclear reactor. The first method is wet distillation, in which ^{130}Te or ^{130}Te compounds are irradiated with neutron irradiation, followed by reduction and distillation, and collected in an alkaline solution (Fig. 1). However, the wet distillation method has a few problems; complicated in operation, requires a lot of reagents, the inflow of impurities, and long chemical treatment time. The second method is dry distillation which was developed to solve the problems of wet distillation. In this method, $^{130}TeO_2$ irradiated with neutrons is mounted in a distillation vessel and heated to 760 °C for distillation. After reacting with the collection solution of the collector, the pH is adjusted with activated charcoal in the Na^{131}I state, and then it is eluted with ^{131}I gas through a distillation step in the solution withdrawer (Fig.

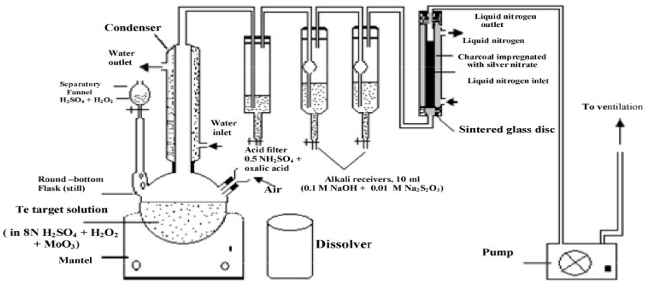

Fig. 1. Schematic diagram of the wet distillation method.

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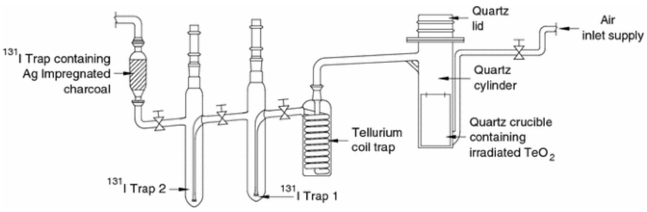

Fig. 2. Schematic diagram of the dry distillation method.

2). The dry distillation method has advantages such as high specific radioactivity, high Label synthesis yield, and the manufacturing of capsule formulation. However, this method also has some problems; the possibility of radioactive exposure during work, a relatively complicated procedure, requires various devices and samples although it's simpler than wet distillation. Above all, both wet and dry distillation methods have the same disadvantage: high production cost. For this reason, the nuclear fission method is mainly used. The nuclear fission method is a method that extracts ^{131}I by irradiating neutrons to ^{235}U or ^{238}U to cause nuclear fission. Although the yield of fission generation is about 3 %, the extraction of ^{131}I is possible at a low unit cost because the procedure is simple and the cost is low.

2. Introduction

When treatments are performed using RI in medical institutions, the most common cases are the metastasis of thyroid cancer treated with ^{131}I. Therefore, in terms of radiation safety management, radioactive wastes generated in the treatment room are also managed in consideration of ^{131}I. However, in the fission method, which is the most widely used one, ^{135}I, ^{133}I, ^{129}I, etc. are mixed at a ratio of 0.1 %. Most of iodine isotopes have half-lifes of less than a second, which is not a problem for use. But ^{124}I, ^{125}I, ^{126}I, ^{129}I, and ^{131}I have relatively long half-lifes, so they are subject to management (Table 1). In particular, ^{129}I requires special management for the disposal as radioactive wastes due to its very long half-life. The radiation wastes generated in the treatment room are divided into three types; gas, liquid, and solid forms. The gas type is managed using filters, while the liquid type is discharged after being stored for a certain period in storage tanks. The solid type is generally stored in radioactive waste rooms for a certain period of time and disposed of as general wastes. The pipes are regarded as solid radioactive wastes. However, long-term deposition occurs as they are installed in the treatment room. Accordingly, the pipes in the treatment room are evaluated from the perspective of radioactive wastes, and the changes in the pipes according to the application of ^{129}I are evaluated to find out possible problems and suggest improvements.

3. Measurements

The management of radioactive wastes according to the period of use of the ward was compared in the case of 100 % ^{131}I and 99.9 % ^{131}I with 0.1 % ^{129}I for the pipes in the treatment room. In addition, the strength of radiation safety management was evaluated by comparing the international and domestic standards of radioactive wastes. Radiation waste management is calculated up to a maximum of 9 years under the following assumptions; the dose administered to the patient is 200 mCi, the hospitalization period is 3 days, and there is no gap period. The results are shown in Fig. 3. The pipes are only deposited without emitting RI. However, in the case of 100 % ^{131}I, as the half-life is about 8 days, the amount of radioactivity is maintained and does not increase any

Table 1. Types of Radio-iodine and half-lifes.

Mass Number	Half Life	Mass Number	Half Life	Mass Number	Half Life	Mass Number	Half Life	Mass Number	Half Life
108	36ms	117	2.22m	124	4.17d	$130m_3$	315ns	136	83.4s
109	0.1ms	118	13.7m	125	59.4d	$130m_4$	254ns	136m	46.9s
110	650ms	118m	8.5m	126	12.9d	131	8.02d	137	24.13s
111	2.5s	119	19.1m	127	Stable	132	2.29h	138	6.23s
112	3.42s	120	81.6m	128	25m	132m	1.39h	139	2.28s
113	6.6s	$120m_1$	228ns	$128m_1$	845ns	133	20.8h	140	860ms
114	2.1s	$120m_2$	53m	$128m_2$	175ns	$133m_1$	9s	141	430ms
114m	6.2s	121	2.12h	129	1.5 E7y	$133m_2$	170ns	142	200ms
115	1.3m	121m	9μs	130	12.36h	134	52.5m	143	100ms
116	2.91s	122	3.63m	$130m_1$	8.84m	134m	3.52m	144	50ms
116m	3.27μs	123	13.22h	$130m_2$	133ns	135	6.57h		

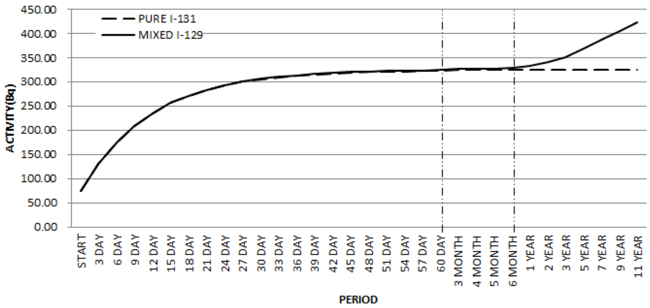

Fig. 3. Radioactivity of radioactive wastes according to the period of use.

Fig. 4. (Color online) Radioactivity measurement of pipes in the treatment room used for 8 years.

more from about 60 days. On the other hand, in the case of 99.9 % ^{131}I and 0.1 % ^{129}I, as the ratio of ^{129}I is very low, the radioactivity is maintained from about 60 days. However, about 6 months later, the amount of radioactivity increases as the deposition rate of ^{129}I increases. In reality, the measurement of the pipes in the treatment room, which has been used for about 8 years from 2011 to 2019, showed 420 cps.

The domestic and international standards for self-disposal of radioactive wastes are shown in Table 2, and the results of comparing standards by types are shown in Fig. 5.

4. Evaluation

Unlike other radioactive wastes, pipes are wastes that

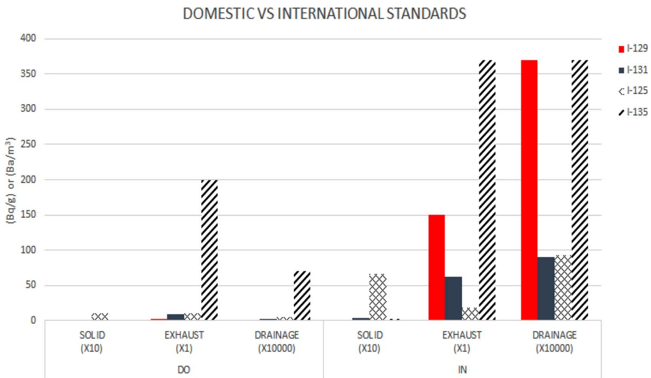

Fig. 5. (Color online) Comparison of domestic & international standards for self-disposal of radioactive waste.

cannot be replaced every time a patient changes, so deposition occurs continuously. In the case of ^{131}I, since the half-life is short, the radioactivity increases for about 60 days and then is maintained even in the most severe case. However, when ^{129}I is mixed with 0.1 %, the radioactivity of the pipes continues to increase after about 6 months. As a result of actually measuring the pipes in the treatment room used for 8 years, it was confirmed that similar values were obtained. However, when considering the reduction of the pipe itself and the type of the pipe compared to the set conditions, it seems that there will be some differences for each treatment room.

The results of comparing the domestic and international standards for self-disposal of radioactive wastes are as follows. In Korea, the radioactivity levels are restricted mainly, and minimum standards are applied for mixed components. On the other hand, the international standard is based on absorbed dose and suggests a more gentle standard by applying a mixing ratio to mixed components. As the intensity of domestic radiation safety management is high, there's an advantage of pursuing safer radiation safety management. However, an intensity exceeding the acceptable level can rather cause an accident and increase the probability of a radiation safety accident. Therefore, it is necessary to present the regulations for radiation safety

Table 2. Comparison of domestic and international standards for self-disposal of solid type radioactive wastes.

Division	Standard
Domestic	– INCLUDE ONLY NUCLIDES WITH A HALF-LIFE OF 5 DAYS OR LESS – 0.4 Bq/cm^2 OR LESS AT 10 cm FROM THE WASTE SUFACE – ^{129}I : 0.01 Bq/g – $^{126, 130, 131, 132, 134, 135}$I : 10 Bq/g – $^{123, 125}$I : 100Bq/g
International	– CAN'T EXCEED 1 μSv/h OF DOSE RATE ON THE SURFACE – CAN'T CONTAIN α-SOURCES

management that can be realized through appropriate exchanges with the practice.

5. Conclusion

In the case of pipe-type radioactive wastes in the treatment room, it can be said that the problem caused by ^{129}I is the biggest. If the general standards are applied, it is estimated that it will take more than 280,000 years for self-disposal, while 102,000 years are required according to the international standards. Therefore, the first thing to consider is to develop a method to produce 100 % ^{131}I at a low cost. However, this process can only be achieved through long-term research, so it needs to be improved with auxiliary methods. To store pipe-type radioactive wastes for a long time, inefficiency of cost and space occurs. If only the extracted ^{129}I is stored by applying the technology that can extract ^{129}I in the pipes, the cost will be reduced and the efficiency of the space will increase. The pipes in the treatment room are usually managed by removing or sealing the pipes. To remove the pipes, professional technicians are needed. But the technicians have limited knowledge and experience in radiation safety management. Therefore, they must wear protective clothing and install a HFC(Hand, Foot, Cloth) monitor. However, it is practically difficult to purchase expensive equipment for temporary work, so most of the pipes are sealed to block the discharge of RI. The problem is that there is no follow-up care after sealing. If the pipes are sealed while converting a treatment room to a general room, the room becomes a general area and is excluded from the management of the Nuclear Safety Committee. After a certain period, when the construction of the ward is carried out due to a disaster or extension, there is no information about the radioactivity, and the workers may be exposed to radiation. Therefore, regulations for separate follow-up management should be prepared when pipes are sealed. The efficient radiation safety management should be realistic, not just strong. Effective radiation safety management not only understands the work environment and process in the field but also finds and fixes gaps there, rather than simply lowers the permissible standards.

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