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Measurement and analysis of Carbon-14 concentration in the air

*Jeong Min Park, Yi Sub Min, Ye Eun Lee, Sang Hoon Lee (KNU), Min Ju Kim (KNU)
Korea Multi-purpose Accelerator Complex, Korea Atomic Energy Research Institute
[*]*Corresponding author: jmpark027@kaeri.re.kr*

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1. Introduction

Carbon-14(^{14}C) is produced when cosmic rays, such as neutrons generated in space, react with nitrogen in the atmosphere, converting ^{14}N to ^{14}C. The generated ^{14}C reacts with oxygen in the atmosphere to become carbon dioxide (CO_2), and during this process, the amount of ^{14}C in the atmosphere is maintained constant.

In this way, ^{14}C occurs naturally and exists on earth, but it is also produced through nuclear reactions such as nuclear testing or nuclear fuel production. Artificially created ^{14}C is mostly contained in air or it can also seep into water and cause radioactivity then it affects people and the environment.

Carbon-14 is a low-energy beta emitter and a long-half-life nuclide approximately 5,300 years.

It accumulates in the body and causes internal radiation exposure mainly through the lungs, so it is one of the nuclides subject to monitoring in nuclear power plant. Generally, ^{14}C in air is absorbed and filtered through activated carbon filter or charcoal filters, and is mainly used in air purification facilities. [1]

In this study, in order to determine the amount of ^{14}C contained in the air, analysis was conducted on these filters.

2. Methods and Results

Carbon-14 analysis methods for solid samples are mainly divided into two types: high-pressure combustion and high-temperature combustion. In this experiment, the high-pressure combustion method was selected. Pretreatment of sample for analysis was conducted at Kyungpook National University (KNU),

2.1 Sample preparation

The samples to be used for analysis are activated carbon filter and charcoal filters, and the sample preparation sequence is as follows.

- Step 1. Classify the sample by type and use.
- Step 2. Disassemble the filter using an appropriate tool and pull out the material inside the filter and at this time, the internal material is used as a sample.
- Step 3. Homogenize the sample to a certain size.
- Step 4. Divide the sample and store it in a sample container.

2.2 Sample preprocessing

The homogenized sample is quantified and completely burned using a high-pressure combustion device. And CO_2 is generated by reacting acid with the gas generated as a result of combustion. The procedure is as follows and is shown in the schematic diagram in Fig 1. [2]

- Step1. Using a high-pressure combustion device, the sample is completely burned under high-pressure conditions.
- Step 2. The gas (CO_2) generated in the high-pressure combustion device is captured by flowing it into a mixed solution of equal amounts of distilled water and NH_4OH. (Primary capture)
- Step 3. Add $CaCl_2$ to the NH_4OH in which CO_2 is dissolved and heat it
- Step4. After heating is complete, wait until the supernatant and precipitate are separated.
- Step 5. Completely dry the sediment using an oven.
- Step 6. After homogenizing and quantifying the dried precipitate ($CaCO_3$), a diluted solution of HCl is added to generate CO_2
- Step7. CO_2 is captured in the carbon absorption solution using a collection device. (Secondary capture)
- Step8. The sample solution is measured using LSC.

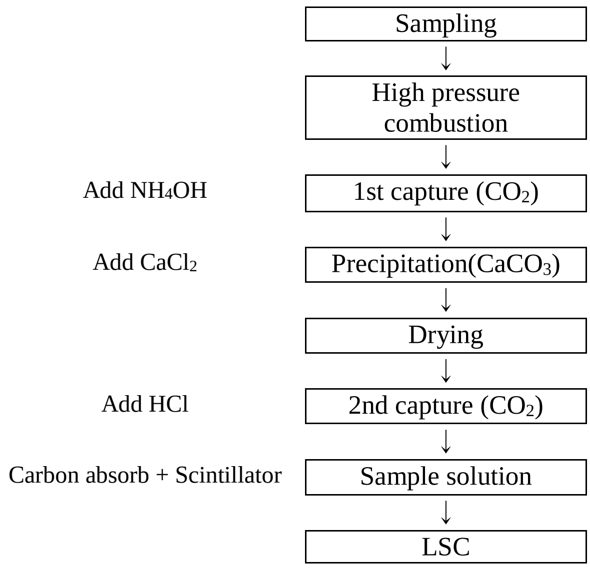

Figure 1. Schematic diagram of the analysis procedure

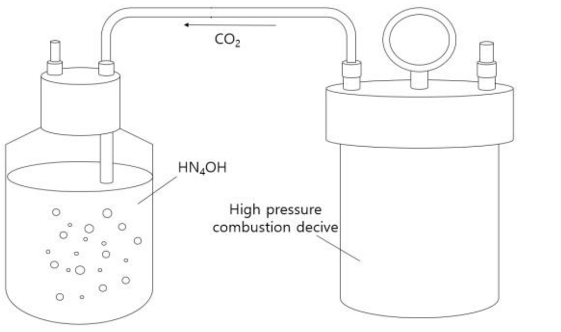

Figure 2. CO_2 primary capture device

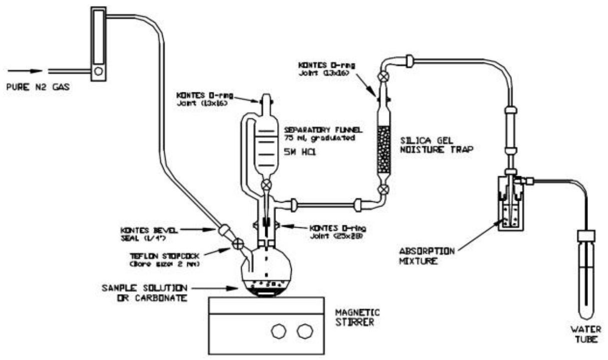

Figure 3. CO_2 secondary capture device

The blank sample was prepared in the same method as the sample vial by capturing the CO2 gas generated by burning the unused filter into a solution mixed with a carbon absorbent and scintillator of the same properties.

2.3 Measurement and Analysis

Confirm the net count rate (cpm) of the sample solution measured using a liquid scintillation counter (LSC). Specific Activity (A) is calculated from the net count rate and efficiency. The unit is expressed as the Specific Activity of ^{14}C in the sample. And is calculated as a value that reflects the carbon capture amount (A_C).

$$A = \frac{cpm}{eff \times 60 \times A_C}\,(Bq/g - C) - - - - - \; Eq1$$

The carbon capture amount (A_C) is calculated by reflecting the carbon atomic weight from the CO_2 capture amount as difference in sample weight before and after.

$$A_C = (S_b - S_a) \times \frac{W_C}{W_{CO2}}(g) - - - - - - Eq2$$

- S_b - S_a : Capture amount of CO_2
- S_b : Sample weight after CO_2 capture
- S_a : Sample weight before CO_2 capture
- W_{CO2} : Atomic weight of CO_2
- W_C : Atomic weight of C

2.4 Analysis Result

The results of the ^{14}C content analysis experiment for activated carbon filters and charcoal filters before (blank) and after use are shown in Table 1.

Table 1. Results of specific activity (^{14}C)

No.	Sample	CO2(g)	C(g)	Bq/g-C
#1	Carbon	2.22	0.605	>BKG
#2	Charcoal	2.21	0.603	0.261

As a result of analyzing the specific radioactivity of ^{14}C for two types of samples, the value of the carbon filter was lower than the background level, and the charcoal filter was 0.26 Bq/g-C. This is similar to the natural level of 0.23 Bq/g-C [3] in a general environment.

3. Conclusions

Carbon-14(^{14}C) is a typical low-energy beta emitter that is naturally generated by cosmic rays and is maintained at a constant concentration through repeated creation and decay in the atmosphere. However, it is also artificially generated during the operation of nuclear power plants, etc., and it can cause internal radiation exposure to people in a form contained in the air. ^{14}C is easily absorbed on filters such as activated carbon or charcoal filters, and using this property, an experiment was conducted to analyze the concentration of ^{14}C in the air using high-pressure combustion method on these filter samples in the facility.

As a result of the experiment, the activated carbon filter was lower than the background level, and the charcoal filter was confirmed to be at the level of a general environment. Therefore, it was confirmed that the concentration of ^{14}C in the air in the facility was maintained at the general environmental level.

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