

Annual report: Measurement of radiocarbon using AMS in Gyeongju region

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1. Introduction

Human activities such as deforestation and use of fossil fuels have affected the global carbon cycle. Carbon dioxide (CO₂) emissions from fossil fuel combustion is increasing continuously due to human activities. Global CO₂ emissions reached an all-time high of 36.3 Gt in 2021 [1]. The measurement of CO₂ emissions using the radiocarbon dating method was developed by Willard Libby at the University of Chicago in the late 1940s. The method is based on the production of a certain quantity of radiocarbon (¹⁴C) throughout the Earth's atmosphere by the interaction of cosmic radiation and nitrogen; ¹⁴C combines with oxygen to form CO₂, which is absorbed by plants through photosynthesis. Then, plants absorb not only ¹⁴CO₂ but also ¹²CO₂ and ¹³CO₂ [2]. The isotopic proportion of carbon that plants absorb will be characteristic of the region. CO₂ emissions in each region can be compared using a proportion of radioactive carbon. Herein, leaves of the cherry tree were collected from six places in Gyeongju and measured using accelerator mass spectrometry (AMS) at the Dongguk University.

2. Methods and Results

2.1. Regional characteristics

The population density of Gyeongju is 188.40 persons/km². To clearly compare regional characteristics, the standard area representing population density was set as the housing site and the resident population of each region was identified. In addition, we compared and analyzed forest and farmland areas of each region. Table I contains

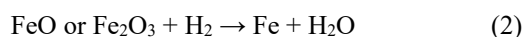
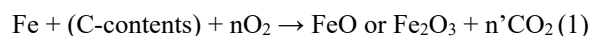
Table I. Sampling region and regional characteristics

	Sampling region	Regional characteristics	Population density (persons/km ²)	Housing site (%)	Forest area (%)	Farmland area (%)
Leaf 1	Sannae-myeon	Rural	2,955.88	3.07	67.93	11.51
Leaf 2	Bomon-dong	Tourist spot	10,041.67	3.63	44.90	40.59
Leaf 3	Hwango-dong	Residential area	20,092.72	44.01	0.25	5.96
Leaf 4	Hwangridangil	Tourist spot	21,054.19	24.57	6.12	22.49
Leaf 5	Hwangseong-dong	Residential area	30,857.30	23.15	8.30	14.62
Leaf 6	Dongcheon-dong	Residential area	21,002.88	19.82	40.27	13.14

information about each region. Among the sampling areas, Leaf 5 has a factory site, which accounts for 14.28%.

2.2. Sample preparation method

Precaution was taken during the sampling of leaves to avoid contamination by carbon-containing substances. Samples were washed with distilled water, and then washed again according to the acid-alkali-acid method [3]. Pure iron was obtained via a preheating process and was used as a catalyst for the reaction with the sample.



The sample was combusted through an Element Analyzer(FlashSmart™) to form CO₂. The generated CO₂ reacted with the catalyst through a reduction process to graphitize. The graphitized sample was ground and put in the cathode. The cathode was analyzed using AMS. Standard samples (phthalic acid, C4, C5, C8, and OX-II) were also investigated to verify the accuracy of measurements.

2.3. Results

In this experiment, AMS (MICADAS, Mini Carbon Dating System, 200keV model, Ionplus) of Dongguk University's WISE campus was used. The results are displayed in Tables II and III. Table III confirms that the experiment was successful and that sample data are relatively reliable.

Table II. Sample data

Sample	F ¹⁴ C	Δ ¹⁴ C (‰)
Leaf 1	0.9889	-19.7
Leaf 2	0.9874	-20.3
Leaf 3	0.9806	-27.0
Leaf 4	0.9852	-23.3
Leaf 5	0.9762	-32.3
Leaf 6	0.9849	-23.6

Table III. Standard sample data

Sample	Eigen value F ¹⁴ C	Measured value F ¹⁴ C
Phthalic acid	0	0.0037
IAEA C4	0.0020-0.0044	0.0032
IAEA C5	0.2305 (± 0.0002)	0.2244
IAEA C8	0.1503 (±0.0017)	0.1515
Ox-II	1.3408	1.3406

To analyze the sample data, we used Δ¹⁴C, which can be calculated using F¹⁴C. The smaller the value of Δ¹⁴C, the higher the CO₂ emissions.

$$F^{14}C = A_{SN}/A_{ON} \quad (3)$$

$$\Delta^{14}C = (A_{SN}/A_{abs} - 1) \times 1000 \quad (4)$$

$$A_{abs} = A_{ON}e^{\lambda(\text{year} - 1950)} \quad (5)$$

$$(F^{14}C / e^{\lambda c(\text{year} - 1950)} - 1) \times 1000 = \Delta^{14}C (\text{‰}) \quad (6)$$

In equation 6, the applied λc was 1/8267 yr⁻¹ along with considering the year in which the sample was collected. [4].

2.4 Discussion

Sample data in Table II show that regional characteristics are related to Δ¹⁴C. Rural areas represent the highest Δ¹⁴C, followed by tourist spots and residential areas. Leaf 6 has the characteristics of a residential area; however, its Δ¹⁴C is relatively high, indicating that it most likely corresponds to the large forest area and small housing site. Leaf 5 shows the lowest Δ¹⁴C in Gyeongju, probably because of the influence of the highest population density in Gyeongju and a factory site.

3. Conclusions

Samples were collected in six regions in Gyeongju, and their Δ¹⁴C amounts were calculated. An analysis of the difference in the emitted CO₂ according to regional characteristics confirmed that CO₂ emissions increased based on traffic volume. In addition, CO₂ emissions

were higher in the factory area. We propose to measure CO₂ emissions in industrial park areas and analyze the relationship with the number of adjacent factories in the future.

Acknowledgements

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