

Carbon Dioxide Concentration Changes Produced from Fossil Fuels at Gyeong-ju in 2020

Seung-Gyu Lee ^a, Yong-Ha Son ^a, Changgu-Je ^a, Ho-Won Kang ^a, Sae-Hoon Park ^a, Sang-Hun Lee ^a, Yu-Seok Kim ^{a*}
^a Department of Nuclear & Energy system Engineering, Dongguk University, 123, Dongdae-ro, Gyeongju-si, Gyeongsangbuk-do 38066, Republic of Korea
E-mail: unison@dongguk.ac.kr

1. Introduction

Throughout the current century, the $^{14}\text{C}/^{12}\text{C}$ ratio in atmospheric CO_2 ($\Delta^{14}\text{CO}_2$) will be determined by the increasing amount of fossil fuel combustion; the quantity of $\Delta^{14}\text{CO}_2$ will decrease because fossil fuels lose all ^{14}C from radioactive decay, hence none is released during combustion. ^{14}C is naturally produced in the atmosphere and decays with a half-life of 5700 ± 30 a. Therefore, fossil fuels, which are millions of years old, are devoid of ^{14}C , and their combustion adds only the stable isotopes ^{12}C and ^{13}C to the atmosphere as CO_2 [1].

During the process of photosynthesis, trees absorb CO_2 from the atmosphere to accumulate carbon and release oxygen. The accumulated carbon creates their branches and leaves, which have the same carbon isotope ratio as that of the carbon dioxide (CO_2) present in the atmosphere. Therefore, leaf or tree ring samples can be used instead of atmospheric samples to determine the percentage of CO_2 produced from fossil fuels in the atmosphere [2].

In 2020, the number of floating populations decreased due to the Covid-19 pandemic. As shown in Fig. 1, the number of tourists in Gyeong-ju, a tourist destination, decreased by 53% compared to that in 2018. As a result, the traffic in Gyeong-ju has decreased. To investigate the change of CO_2 produced from fossil fuels due to the decrease in traffic, *Prunus Sargentii* leaves were collected from four places (Hwango-dong, Hwangseong-dong, Jungbu-dong, and Bodeok-dong) with high traffic and another (Sannae-myeon) with less traffic.

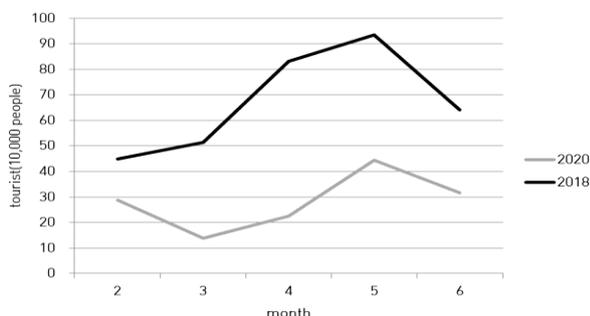


Fig. 1. Gyeong-ju tourist trend in 2018 and 2020.

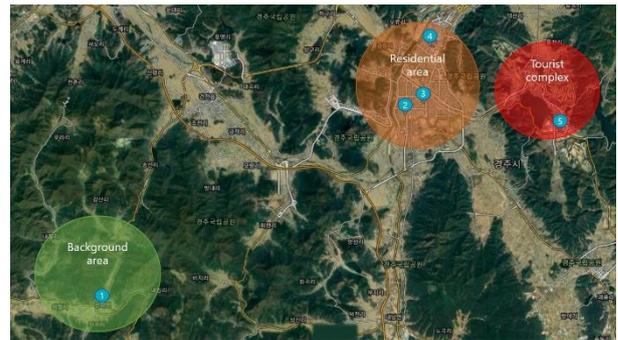
The $\Delta^{14}\text{C}$ data in 2020 were compared with those in 2018, which were measured by the accelerator mass spectrometry (AMS) facility at Dongguk University, to investigate the changes in the concentration of CO_2 from

fossil fuels in the atmosphere due to the decrease in tourists.

2. Methods

2.1 Detect samples

As displayed in Fig. 2, *Prunus Sargentii* leaves were collected on August 4 and 5, 2020, near the town offices located in three residential areas (Hwango-dong, Hwangseong-dong, Jungbu-dong), one tourist complex, (Bodeok-dong), and a small traffic point (Sannae-myeon) for use as the control sample.



Number	Place	Location
1	Jungbu-dong	(35°50'49.0"N, 129°12'20.3"E)
2	Hwango-dong	(35°50'49.4"N, 129°12'57.6"E)
3	Hwangseong-dong	(35°52'20.1"N, 129°13'09.0"E)
4	Bodeok-dong	(35°50'05.4"N, 129°17'15.0"E)
5	Sannae-myeon	(35°45'27.9"N, 129°02'49.1"E)

Fig. 2. Map showing locations where leaf samples were collected.

2.2 Pretreatment

A pretreatment process of solvent extraction was performed on the collected leaves, as per the acid-alkali-acid pretreatment method used at the Oxford Radiocarbon Accelerator Unit [3]. The process involves three main steps: 1) Heating of 1 mol of HCl to 80 °C for

20 min with the leaves; 2) Heating of 1 mol of NaOH to 80 °C for 20 min with the leaves; 3) Heating of 1 mol of HCl to 80 °C for 1 h with the leaves. Following this step, the leaves were neutralized by washing with pure water and were left to dry overnight.

The target was placed into the reduction system, installed at Dongguk University, and measured using the AMS system [4].

3. Results and discussion

The quantities of ^{14}C in atmospheric CO_2 from fossil fuels, ff , in 2018 and 2020 were measured via an experiment and the results are shown in Table I. The value of $\Delta^{14}\text{C}$ was obtained using equations (1)–(4), considering the background levels measured by AMS and a graphitization system and sample (OX-II) using phthalic acid.

$$A_{on} = 0.7459A_{OxII} \left(\frac{1 - \frac{25}{1000}}{1 + \frac{\delta^{13}\text{C}_{OxII}}{1000}} \right)^2 \quad (1)$$

$$A_{sn} = \left(\frac{^{14}\text{C}}{^{12}\text{C}} \right)_{SN} = \left(\frac{^{14}\text{C}}{^{12}\text{C}} \right)_s \left(\frac{1 - \frac{25}{1000}}{1 + \frac{\delta^{13}\text{C}}{1000}} \right)^2 \quad (2)$$

$$A_{abs} = A_{on} e^{\lambda_c(y-1950)} \quad (3)$$

where λ_c
 $= \frac{1}{8267} \text{yr}^{-1}$ and y is the year of measurement

$$\Delta^{14}\text{C} = \left(\frac{A_{sn}}{A_{abs}} - 1 \right) \cdot 1000\text{‰} \quad (4)$$

The value of ff was obtained using equation (5).

$$ff = \frac{C_{ff}}{C_{site}} = \frac{\Delta^{14}\text{C}_{BG} - \Delta^{14}\text{C}_{site}}{\Delta^{14}\text{C}_{BG} + 1000} \quad (5)$$

Table I: Measurement results of $\Delta^{14}\text{C}$ (‰) and ff (%).

Place	2018		2020	
	$\Delta^{14}\text{C}$ (‰)	ff (%)	$\Delta^{14}\text{C}$ (‰)	ff (%)
Jungbu-dong	-28.33	1.79	-27.41	1.71
Hwango-dong	-32.97	2.26	-30.07	1.97
Hwangseong-dong	-28.32	1.79	-24.51	1.41
Bodeog-dong	-27.29	1.68	-18.04	0.76
Sannae-myeon	-10.65		-10.53	

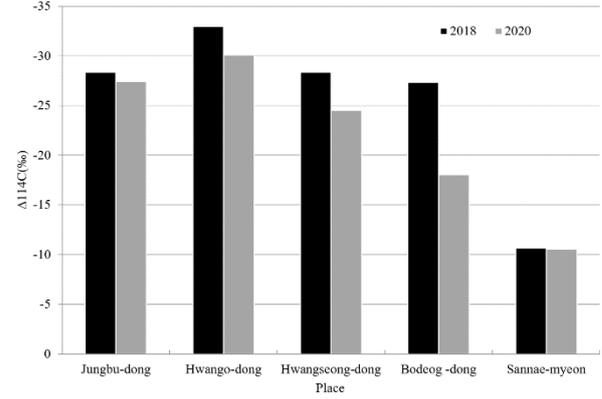


Fig. 3. $\Delta^{14}\text{C}$ values of leaf samples collected in Gyeong-ju.

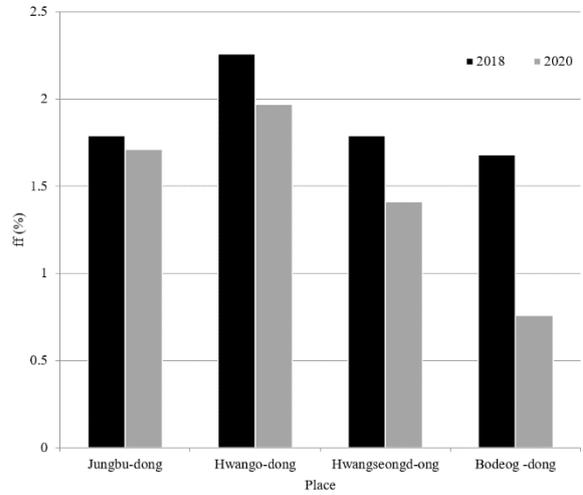


Fig. 4. Total CO_2 produced from fossil fuels in atmosphere in Gyeong-ju in 2018 and 2020.

As shown in Fig. 3, the value of ff in Sannae-myeon, selected as the control group, decreased by 1% in 2020 compared to 2018, and was the lowest measured average value out of Hwangseong-dong, Hwango-dong, and Jungbu-dong, which are densely populated areas in the city. The difference in the value of $\Delta^{14}\text{C}$ in Sannae-myeon proves that the intervention of other variables, excluding the flow rate of the population, was insignificant.

Further, the data from Hwangseong-dong, Jungbu-dong, and Hwango-dong, as residential areas, can represent the flow of Gyeong-ju citizens. The result of ff shown in Fig. 4 shows an average decrease of 12% in 2020 compared to that in 2018. Thus, the flow of citizens affected the change in the CO_2 concentration from fossil fuels. However, each region has a large deviation in its data values. Other factors affecting such deviations should be considered to achieve more accurate values. The representative tourist complex of Gyeong-ju is located in Bodeok-dong; hence, it is observed that the flow rate is more influenced by tourists here than in

other regions. Therefore, this region can represent the flow of tourists. As shown in Fig. 1, the number of tourists decreased by 53% in 2020 when compared to that in 2018. Furthermore, the ff % decreased by 54% in 2020 when compared to that in 2018, as shown in Fig. 4.

This indicates that the decrease in tourists due to the pandemic significantly impacted the change in the CO₂ concentration from fossil fuels in Gyeong-ju.

4. Conclusion

The ff value of Bodeok-dong given in Fig. 4, which represents the effect of tourists on the CO₂ concentration, decreased by 53% compared to that in 2018. This is similar to the result shown in Fig. 1. As 54% of the total number of visitors to major tourist destinations is based on data, the drop in the value of ff is not equal to the decrease in tourists; whereas, the difference in the value of ff in Bodeok-dong suggests that the decrease in tourists greatly affects the change in the CO₂ concentration from fossil fuels in Gyeong-ju. However, it is necessary to investigate the ff value of a popular tourist area to achieve more accurate values. In addition, due to the large variation in the data from the residential areas, an investigation into the causes for such deviations in each region is necessary.

REFERENCES

- [1] H. D. Graven, Impact of fossil fuel emissions on atmospheric radiocarbon and various applications of radiocarbon over this century, Proceedings of the National Academy of Sciences, Vol. 112(9491), No. 31, pp. 9542-9545, 2015.
- [2] J. H. Park, Distribution of CO₂ produced from fossil fuel by accelerator mass spectrometry: in Daejeon, Analytical Science & Technology, Vol. 21, No. 1, pp. 9-13, 2008.
- [3] K. E. Stenström, A guide to radiocarbon units and calculations, Division of Nuclear Physics Interracial Report LUNFD6(NFFR-3111), pp. 1-17, 2011.
- [4] S. H. Lee, A new compact AMS facility at the Dongguk University, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, Vol. 465, Feb. 15, pp. 15-18, 2020.