Correlation between Yellow Dust and Radioactivity

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1. Introduction

The impact of severe dust outbreaks on airborne radionuclide concentration has been extensively studied in recent years. In East Asia, yellow dust or Asian Dust (AD) outbreaks are among the largest contributors of wind-blown dust that carry natural and anthropogenic radionuclides and subsequently alter their concentration and distribution throughout the environment. Although the Korean Peninsula has been experiencing AD events since ancient times, the research has tended to focus on the transport routes and characteristics of AD, rather than on its impact on radionuclide activity levels. This paper examines the relationship between radionuclide concentration in the air and the frequency of dusty days in South Korea during AD intrusion events. It also investigates whether increased radionuclide concentration is a function of either more mass or more dust contamination.

2. Data and methods

The data utilized in this study is obtained from the Radiation Monitoring Stations (RMS) of the Korea Institute of Nuclear Safety (KINS), where gross beta measurements are taken daily and gamma measurements are taken monthly. The data obtained covers a period of ten years, from 2004 to 2013, from monitoring stations of major South Korean cities.

Gross beta activities are measured in increments of five hours, in units of mBq/m^3. Gamma concentrations of anthropogenic ^{137}Cs and cosmogonic ^{7}Be are measured in units of $\mu Bq/m^3$ and mBq/m^3, respectively. In the case of gamma concentrations, the mass of the radionuclide-bearing dust in the filter was also measured in grams. Furthermore, data during AD days, as classified by the RMS, were obtained for each month at different cities of the country for the same ten-year period.

Statistical analysis of the data was carried out using OriginPro 8.5 software, as detailed below. Using descriptive statistics, the monthly mean value of each of the variables (gross beta activity, ^{137}Cs concentration, ^{7}Be concentration, mass of dust, and days of Asian dust) was calculated. The monthly mean value was used to avoid inconsistency caused by having multiple values of radionuclide concentration that correspond to only one value of AD days. Subsequently, in order to investigate whether a linear relationship existed between the variables, Pearson's correlation coefficients, r, were calculated, and their associated scatter plots were graphed.

The months of March and April were analyzed separately from the rest of the period in order to determine the possible effect of AD events in the spring season of each year. However, due to there being fewer data points present, the analysis was performed using the sum of March and April values for each year. Furthermore, to clearly visualize the effect of the Fukushima Daiiche nuclear accident on beta and gamma radioactivity levels, the concentrations of the year 2011 were treated separately and were analyzed using the monthly mean to obtain the correlation coefficients.

3. Results and discussion

3.1. Ten-year correlations

For the whole study period, gamma-emitting radionuclides were positively correlated with the mass of dust and the monthly frequency (days) of AD events, while gross beta was less associated and negatively correlated with AD, as seen in Table I. The correlation between the anthropogenic fission product ^{137}Cs and both mass of dust and days of AD tend to be about r = 0.88 and r = 0.79, respectively. This strong positive correlation implies that an increase in ^{137}Cs concentration is associated with more dust mass in the filter and the frequent arrival of long-transported air mass. Higher mass of dust is measured in the spring, when AD events are more frequent. Therefore, it is highly likely that ^{137}Cs was re-suspended into the troposphere from previously contaminated soil surfaces, transported for long distances along with the dust-bearing particles, and finally settled during AD events. An earlier study by Fujiwara [1] describes the contribution of AD to the atmospheric deposition of ^{137}Cs in Japan by observing the weekly atmospheric deposition in spring. The results of Fujiwara's study suggests that dust transported from the East Asian continent was the primary source of ^{137}Cs deposition in Japan during AD events.

Table I: Linear correlation coefficients (Pearson correlation, r) between activities, mass of dust, and days of AD for the whole study period (2004-2013).

	Excluding 2011			2011 only		
	^{137}Cs	^{7}Be	Gross beta	^{137}Cs	^{7}Be	Gross beta
Mass of Dust	0.88	0.61		0.51	0.31	
Days of AD	0.79	0.65	0.02	0.07	0.44	-0.18

^{7}Be also exhibited an almost equal correlation coefficient of about r = 0.6 with both mass of dust and days of AD, with the AD coefficient being slightly higher than that of dust mass. It is generally accepted that ^{7}Be is a cosmogenic radionuclide that is produced via cosmic-rays spallation reactions, which occur as result of stratosphere-troposphere exchange during late winter and early spring. However, it should be noted that the correlations point to the existence of secondary sources of ^{7}Be from soil dust or anthropogenic origins. The correlations obtained here are in agreement with the correlation obtained in the existing literature [2][3]. This indicates that AD is an important source of ^{7}Be in the atmosphere.

The correlation of gross beta with the frequency of AD was nearly zero (r = 0.02), indicating a positive but insignificant relationship with AD. As a result, a relationship between these two variables could not be established using only monthly data.

Figure 1 illustrates the positive linear correlations found between: (a) ^{137}Cs concentration and days of AD, (b) mass of dust and days of AD, and (c) ^{137}Cs concentration and mass of dust.

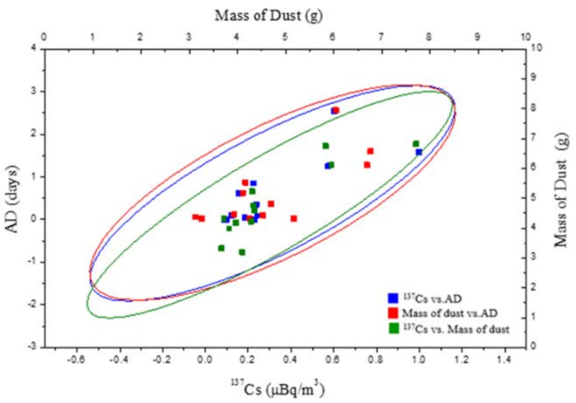

Figure 1: ^{137}Cs concentration versus days of AD and mass of dust, and mass of dust versus days of AD.

The coefficients of these correlations are summarized in Table II. It can be observed that the three variables are strongly intercorrelated, indicating that they overlap to a significant extent. These strong positive intercorrelations infer that AD occurrence frequency and mass of dust are indicators of ^{137}Cs concentration levels.

Table II: Linear correlation coefficients between ^{137}Cs concentration, days of AD, and mass of dust.

	^{137}Cs	Mass of Dust
AD	0.79	0.74
Mass of Dust	0.88	1.00

3.2 2011 correlations

A separate correlation analysis was carried out to evaluate the effect of the Fukushima Daiiche nuclear accident on the concentrations of gamma-emitting radionuclides and gross beta in 2011. As can be seen in Table I, overall, the correlations in 2011 were considerably lower than the correlation obtained for the whole study period. In particular, ^{137}Cs exhibited little or no correlation (r = 0.07) with the frequency of AD, compared to the strong correlation observed previously for the whole study period. By contrast, the correlation with the mass of dust remained moderately positive (r = 0.51). The observed decrease in the correlation coefficients implies that the concentration level in 2011 may not be attributed to the occurrence frequency of AD events. Hence, it could be assumed that in 2011, other sources of dust contamination existed.

3.3 Correlations during spring season

A striking difference was noted when similar correlations were carried out for the same variables mentioned above during the spring season. As shown in Table III, the majority of correlations with the mass of dust were even lower than previously predicted, except for ^{7}Be correlation coefficient that remained about r = 0.6.

Table III: Linear correlation coefficients (Pearson correlation, r) between activities, mass of dust, and days of AD during March and April of each year.

	Excluding 2011			2011 only		
	^{137}Cs	^{7}Be	Gross beta	^{137}Cs	^{7}Be	Gross beta
Mass of Dust	0.47	0.63		0.43	0.28	
Days of AD	-0.05	0.29	0.27	-0.19	0.06	0.37

However, the correlations with the days of AD were slightly biased downward in the case of ^{137}Cs and weakly correlated in the case of ^{7}Be. Moreover, marginally higher correlations of gross beta with days of AD were observed, contradicting the correlations in Table I. The results here suggest that a distortion of the correlations occurred upon the arrival of long-range transported AD during spring.

4. Conclusion

In this study, significant linear correlations of gamma-emitting radionuclides were found with mass of dust and occurrence frequency of AD. Regardless of the source origin of the dust, ^{137}Cs and ^{7}Be concentration primarily depended on dust mass in the filter. Nonetheless, the correlations were greatly distorted in 2011 and in the spring season, particularly the correlations with AD days that were far below that of the correlations obtained for the whole study period. A possible explanation of these conflicting results is that a change in the dust source could appreciably alter the concentration, deposition, and distribution of airborne radionuclides. This study concludes, therefore, that ^{137}Cs and ^{7}Be deposition is usually uniform in South Korea, and the noted distortion of the correlations is attributed to the change of the source origin of the dust.

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