Long-Term Variation of Atmospheric Beryllium-7 in Taiwan

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ABSTRACT

Taiwan Radiation Monitoring Center (TRMC) has measured the concentration of atmospheric ^{7}Be at the four stations on Taiwan for almost twenty years. Gamma emitting nuclides have been collected by air samplers and measured by gamma spectrometry. Cosmogenic ^{7}Be and other man-made radionuclides produced by Chinese nuclear weapon testings have been detected. Compared with ^{7}Be, man-made nuclides vanished quickly because of their short half life. The behavior of ^{7}Be in long-term concentration variation is different between northern and southern Taiwan because of local meteorological conditions. The results of Fourier analysis show that washout effect of rainfalls and transportation from stratosphere to troposphere are closely related to the variation of ^{7}Be concentration in near surface air. All the measured data of ^{7}Be show that the characteristic of yearly data coincides with the 11-year solar cycle.

INTRODUCTION

From the viewpoint of environmental preservation, it is very important to understand the short-term and long-term variation behaviors of radioactive or nonradioactive substances in the atmosphere. The understanding can provide valuable information of atmospheric changes from past to present, which may be used as baseline data for environmental monitoring. TRMC has monitored radionuclide concentrations in the atmosphere for the last twenty years. The measured data could help understanding the radionuclide distribution and determining the most important factors that affect atmospheric radionuclide transportation in the air. Fourier analysis can be used to check if the substance concentration varies periodically. In this paper we have analyzed the long-term data of radioactive substance concentration in the air by the Fourier method.

EXPERIMENT

Aerosol samples have been collected on the 0.8 μ m glass-fiber filters using constant flow-rate air samplers (Radeco HD-28) with pumping rate of 40 ℓ /min at four different sites in Taiwan. Filters were changed once a week. The sampling instrument on each site was setup in a weather house about 1 meter above ground. These filters were sent to laboratory and analyzed for gamma emitting nuclides by HPGe detectors.

In order to identify the reason for variation, a stainless water tray of 1 m^2 and gummed papers with 50×25 cm^2 were used to calculate deposition velocity in each station. A 1-m diameter pan for collecting rain water was set at station No.3 for calculating washout ratio.

RESULTS AND DISCUSSIONS

Results of measured gamma emitting nuclides show that cosmogenic ^{7}Be is the only nuclide found in the air of Taiwan. Some man-made nuclides such as ^{103}Ru, ^{106}Ru, ^{131}I, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{140}La, ^{141}Ce and ^{144}Ce produced by nuclear testings in China were detected. The consideration of variation behavior of these nuclides should be based on their production and removal processes. Man-made nuclides vanished within two months because of their short half life. Cosmogenic nuclides existing in the air are continuously generated.

The monthly average ^{7}Be concentrations measured in a 20-year period at four monitoring stations are shown in Figure 1. Spring peak and minima in fall and winter is a well known phenomenon.(1,2) However, in some areas of the world, two peaks may appear in spring and fall.(3,4) The northern part of Taiwan shows two peak during winter and spring while in the southern part two peaks appear in spring and fall. Both

demonstrates that these phenomena reveal two effects: one effect is with an obvious one-year cycle,and the other with a half-year cycle. In northern Taiwan, the one-year cycle is more notably than the half-year cycle.

The galaxy cosmic-ray dose is calculated by the CARI-2 computer program.(5) Input parameters include longitude and latitude of Taiwan, depth of atmosphere and heliocentric potential in each year.(6) The program calculates cosmic ray flux intensity and converts it into effective dose by conversion factors Based on ICRP No.60 table A-2. Correlation coefficients between ^{7}Be concentration and cosmic ray dose are listed in Table 1. Yearly average data have better, although weak, correlation with cosmic ray, but monthly data seem to have no correlation. This result indicates that the 11-year solar cycle of cosmic ray plays an important role of long-term variation of ^{7}Be concentration because of the change in production rate. However, for seasonal variation cosmic ray makes no obvious influence.

Transportation from stratosphere to troposphere has been shown to occur in spring and fall because of the direction change of the jet flow in stratosphere. This is the reason that half-year cycle variation exists. Deposition and washout by rainfall can be collected by water trays, gummed papers and a pan. Dry deposition is related with aerosol size that varies negligibly in natural environment. This can be proved by the result obtained from ^{7}Be on gummed paper. We could divide the lid height by residual time of ^{7}Be to estimate dry deposition velocity, which is 0.4 cm/s in Taiwan. That is quite close to the calculated value 0.45 cm/s obtained from monitored result of gummed paper. However, total deposition velocity is different as shown in Table 2. The 10-year's average washout ratio is 390. It means that after raining ^{7}Be in rain water is 390 times higher than in air. Washout effect by rainfall is the only reason for different deposition velocities and seasonal variations.

CONCLUSION

From the results of analysis mentioned above, we conclude that:

1. Concentration of ^{7}Be in air has minor difference between northern and southern Taiwan, with respective value of about 4 mBq/m^3 in the north and 3 mBq/m^3 in the south.
2. Seasonal variation of ^{7}Be concentration behavior is different between northern and southern Taiwan. One year cycle in Northern Taiwan is apparent.
3. Seasonal variation is due to different deposition velocities caused by washout effect of rainfalls.
4. Half-year cycle may be due to air transportation from stratosphere to troposphere.
5. Variations of yearly average data are almost consistent with the 11 years' solar cycle.

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Table 1. Average ^{7}Be concentrations and their correlation coefficients with cosmic ray.

Station Number	Longitude (degree)	20 years Average (mBq/m^3)	Yearly data Correlation Coefficient	Monthly data Correlation Coefficient
1	25.30 N	3.89±2.04	0.43	0.25
2	25.20 N	3.85±1.95	0.81	0.40
3	22.67 N	2.74±1.59	0.37	0.08
4	21.95 N	2.78±1.55	0.20	0.24

Table 2. Total deposition velocity and average total flux of ^{7}Be.

Station Number	Deposition velocity (cm/s)	Total flux by water tray method (Bq/m^2 • M)	Corresponding residual time (day)
1	0.95	103.8	17.1
2	0.87	80.0	18.6
3	0.69	32.8	23.5
4	0.66	31.3	24.6

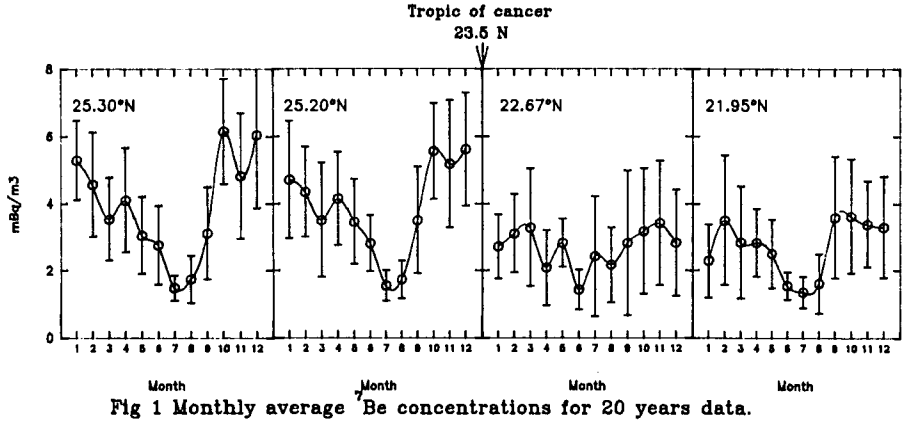

Fig 1 Monthly average ^{7}Be concentrations for 20 years data.

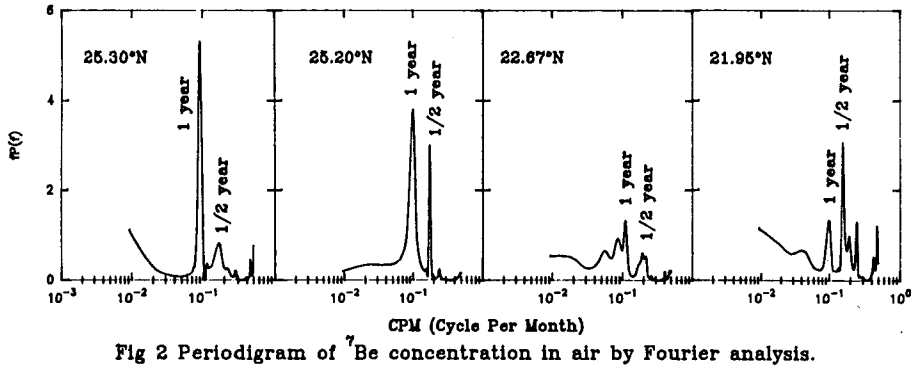

Fig 2 Periodigram of ^{7}Be concentration in air by Fourier analysis.