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Berillyum-7 surface air concentration and rainfall influence

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1. Introduction

Beryllium-7 (^{7}Be) is a cosmogenic radionuclide produced in the atmosphere by cosmic ray spallation with nitrogen, oxygen and carbon [1, 2]. After production, these radionuclides are input to ecosystems through wet and dry deposition and proved t be powerful tools for studying dynamic processes that occur on the surface of the earth. The deposition of ^{7}Be on the earth's surface depends on its production rate (cosmic-ray intensity) which varies according to latitude, altitude and solar activity [3]. Factors that will influence concentration in the atmosphere include stratosphere–troposphere mixing, circulation and advection processes within the troposphere and the efficiency with which it is removed from the troposphere [3, 4]. In order to evaluate the potential of ^{7}Be as a tracer, it is necessary to know the seasonal and spatial variability and quantify the relationship between atmospheric content, deposition, precipitation and surface inventories [2, 5]. In this work the ^{7}Be air content from a 14-year period is analyzed and its relation with rainfalls evaluated.

2. Methodology

The used database corresponds to information provided for Station CN50 of the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty Organization. The CN50 station is one of the seventy-two stations of IMS network, where gamma radionuclides in air are monitored daily. CN50 station is located in Panama City (8°59′00.9″N; 79°31′59.1″W) at height of 90 m above the ground to minimize the resuspension from soil. The station consists of an air particle sampler (Senya JL900) with a 3M filter. The collection efficiency amounted to 99.99% for diameter particles equal or greater than 0.4 µm and 85% for diameter particles between 0.15 and 0.4 µm, at a flux of 980 m3 h-1. Accoupled to air particle sampler is a rain gauge Vaisala (QMR 102). The sampling period was 24 h each time. The filters were compressed (Karl Kolb press) and reserved 24 h to decay of short life radionuclides. The gamma radioactivity of the filters was measured by a gamma spectrometry system consisted of a high purity Ge detector (Canberra GC5020) with a 1.93 keV resolution and 56.1% relative at a 1.33 MeV gamma peak of ^{60}Co.

3. Results and Discussion

The database spans from 1 January 2006 to 8 July 2019 with 4600 data of ^{7}Be activity concentration in air, which ranged from 124 ± 4 µBq/m^3 to 7905 ± 152 µBq/m^3, with a mean value of 2368 ± 1467 µBq/m^3 (CV% 62). The data does not show normal distribution (Shapiro-Wilk test, $p < 0.001$, $\alpha = 0.05$), with major frequency of lower values of ^{7}Be in air (Figure 1).

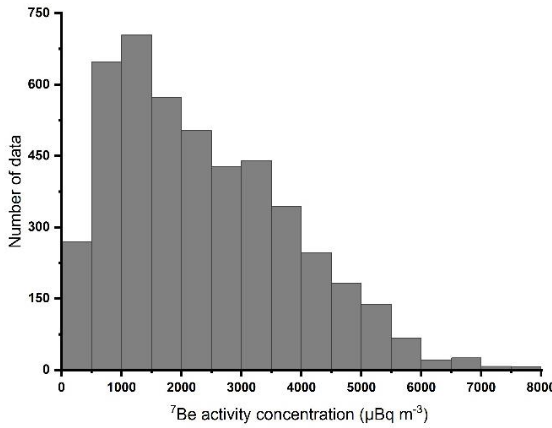

Figure 1: Histogram of the number of ^{7}Be activity concentration in air

Between years significant differences on ^{7}Be air concentration are found (Kruskal-Wallis test, $p < 0.001$, $\alpha = 0.05$), showing the year 2009 the higher values and 2012 the lower values (Figure 2). This result is expected and reported by other authors in several regions of the word; and could be attributed to changes of solar activity, following the solar activity cycle of 11-years [2, 6].

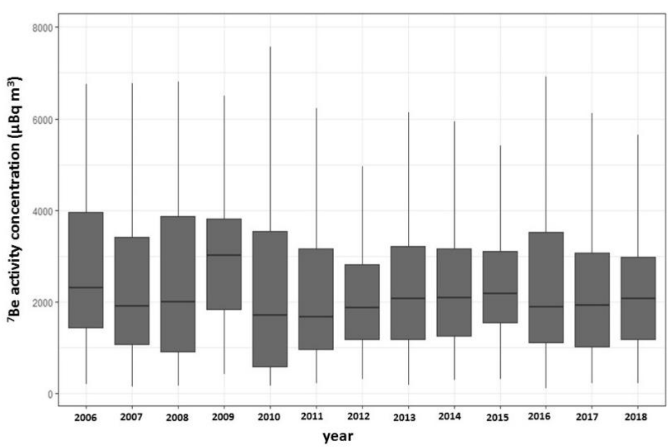

Figure 2: Box chart representation of ^{7}Be activity concentration in air for year (only complete years)

Mean annual ^{7}Be air concentrations shows high variability, with variation coefficients from 47% to 81%. With the aim to explore differences in ^{7}Be air concentration between months, data were clustered and analyzed. Significant differences are found between months of the year (Kruskal-Wallis test, $p < 0.001$, $\alpha = 0.05$), showing March month the higher ^{7}Be air concentration. The air concentration of ^{7}Be begins to increase in October, reaches maximal value in March and decrease reaching the minimum value in September (Figure 3). The ^{7}Be air concentration in March is 3.4 times that September. This behavior has been described in the bibliography and attributed to seasonal changes in solar activity [2, 4, 7].

Other recognized factor to affects ^{7}Be air concentration has precipitations. In the study period, rainy days represents the 47% of the days and 65% of the rainfalls have a precipitation volume lesser than 10 mm and the 90% of the rains have a precipitation volume lesser than 35 mm. Extreme rainfall volumes were registered, reaching to 1559 mm. Significant differences have found in ^{7}Be activity concentration in air between days without rains (0 category in Figure 4) and days with different ranges of rainfall amount (Kruskal Wallis test, $p < 0.001$, $\alpha = 0.05$), indicating that amount of precipitation have effect over the ^{7}Be air content, due to washing effects of the rain on the atmosphere [2, 8].

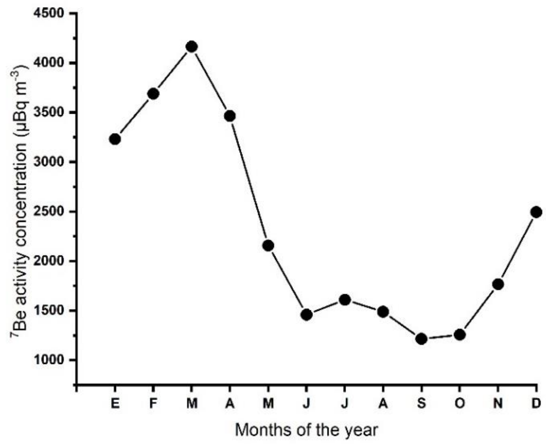

Figure 3: Mean monthly ^{7}Be activity concentration in air

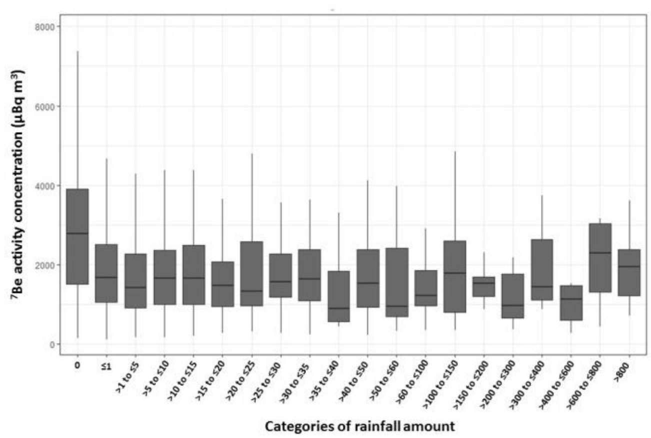

Figure 4: Box chart representation of ^{7}Be activity concentration in air clustered according to amount of precipitation.

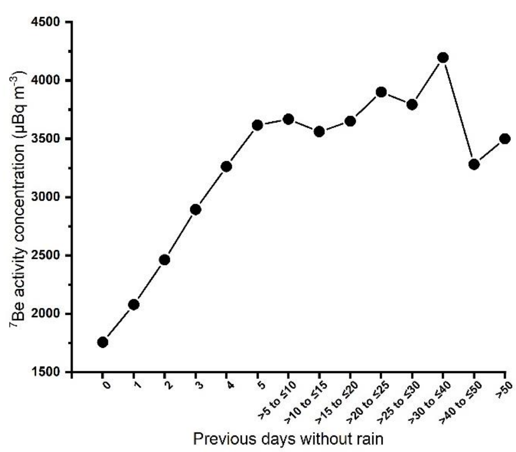

Figure 5: Mean ^{7}Be activity concentration in air clustered according to previous days without rains

When atmosphere is washed of ^{7}Be by rains, a reload time from atmospheric ^{7}Be is expected to occurs. If the ^{7}Be activity concentration in air are clustered according to previous days without rains significant differences are found between categories (Kruskal Wallis test, $p < 0.001$, $\alpha = 0.05$), the ^{7}Be air content increments to day 5 and remains constant for more days without rains (Figure 5). This result indicates a reload rate of 5 days for the region. For other regions, analyzing ^{7}Be rainwater content, a reload rate of 1 day has been reported [8].

4. Conclusions

Daily ^{7}Be activity concentration in air from 1 January 2006 to 8 July 2019 was analyzed, showing changes between year and months of the year. The relation between annual and monthly oscillation with solar activity must be explored with the aim to explain these patterns.
When changes in ^{7}Be activity concentration are explored in relation with precipitations two main outputs are found. The amount of precipitation has effects over ^{7}Be air content, higher ^{7}Be content in air seem to be related to days without rains or lower rainfalls, this could be attributed to the washing effect of the rain on the atmosphere. Furthermore, this might mean that after an intense rain, a reload time of the atmosphere with new ^{7}Be could expected to occurs, available for the next rains. The preliminary results indicates that the reload rate is about of 5 days. More exhaustive analysis is needed to confirm this.

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