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One year of Be-7 measurement in rainfall collected in different points in the city of São Paulo, Brazil

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1. Introduction

Beryllium-7 (^{7}Be) is a cosmogenic radionuclide. Its production occurs from the interaction of cosmic radiation and nitrogen and oxygen atoms present in the upper atmosphere. It has a half-life of 53 days, decaying to ^{7}Li by electron capture and emitting a gamma ray with energy of 477.56 keV in the process. About 70% of the production of ^{7}Be occurs in the stratosphere and 30% in the upper troposphere, followed by rapid adsorption to sub-micron-sized particulate matter and subsequent deposition to the Earth's surface through wet and dry pathways [1][2].

Due to its relation to atmospheric movements and deposition processes, ^{7}Be exhibits evident variation in its concentrations depending on latitude, altitude, local meteorological conditions and because of these characteristics, it is widely used to understand various atmospheric movements, these include vertical and horizontal transport processes through the atmosphere, convective transport and studies of their accumulation and transport in coastal and estuarine systems. [3][4].

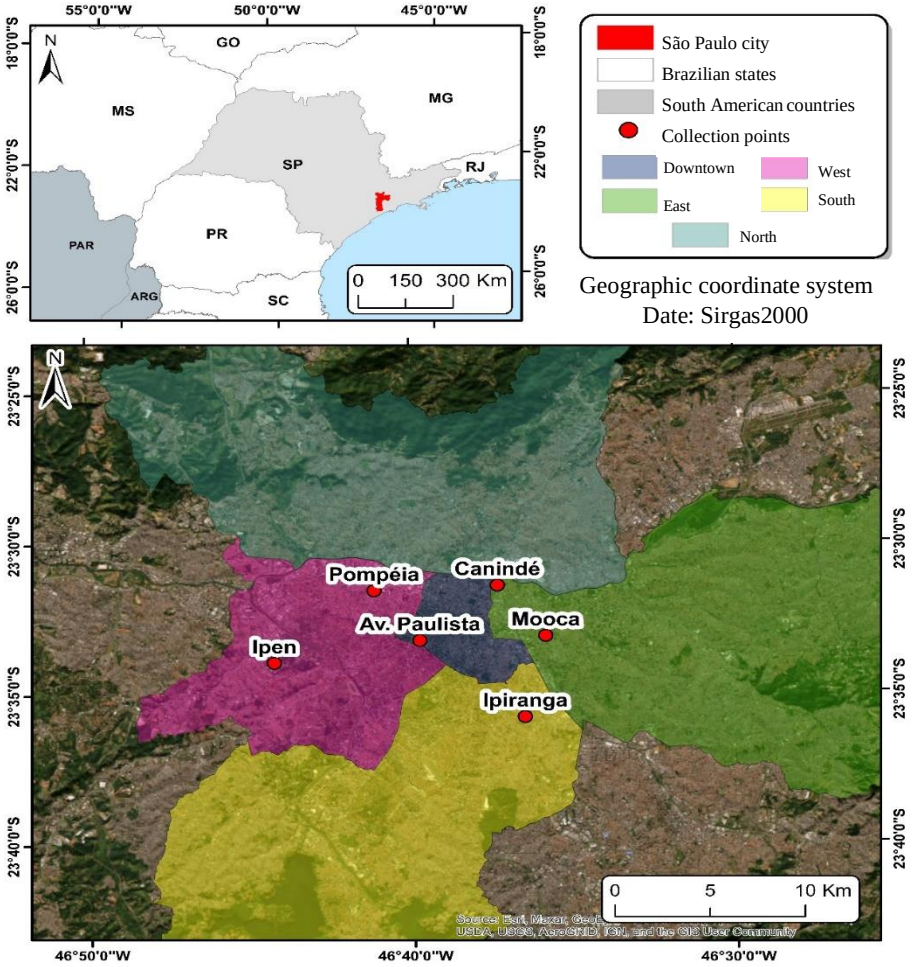
The objective of this study was to analyze and compare the activity concentrations obtained in rainfall collected at six different sampling points in the city of São Paulo, aiming to verify whether there is significant variation in ^{7}Be results within a megalopolis due to the different pollution concentrations observed within the same municipality and whether the values are consistent with observations already made in the literature. The results obtained were analyzed using descriptive statistics, the Shapiro-Wilk test and the non-parametric Krustal-Wallis test to verify if there were any significant differences in the results obtained.

2. Methodology

Rainfall samples were collected from January to December 2023 at six different sampling points in the city of São Paulo, covering the four regions of the city (north, south, east, and west), downtown, and a collection point located at Ipen campus (Fig. I), using polypropylene collectors and a catchment area of 0.19 m^2, installed in the selected points.

The collections were performed weekly, and after each collection, the samples were concentrated by evaporation to a final volume of 100 ml. Subsequently, the activity of ^{7}Be was determined through high-resolution gamma spectrometry using hyperpure germanium (HPGe) detectors with a beryllium window model GX 2520 from Camberra, associated with an electronic system; the measurement time of each sample ranging from 80,000 to 300,000 s. The radionuclide concentration in the samples was calculated using the gamma spectrum analysis program, Interwinner (version 6.0).

Figure I - São Paulo Map with the sampling points.



3. Results and Discussion

Throughout the year 2023, a total of 174 rainfall samples from the six sampling points were collected and analyzed. Monthly rainfall collected ranged from 5 mm to 430 mm, the activity concentration varied from 0.21 Bq L^{-1} to 3.64 Bq L^{-1} and the mean values ranged from 1.42 to 1.53 Bq L^{-1} (table I). For the activity concentration values, the Shapiro-Wilk test was applied with a significance level of 0.05, and all points showed $p > 0.05$ (Normal distribution), except for the CN sampler, which showed $p < 0.05$ (Non-normal distribution). Thus, the non-parametric Kruskal-Wallis test was applied, which showed that there is no significant difference between the results obtained for ^{7}Be at the different collection points in the city of São Paulo ($H(2) = 1.13$; $p = 0.95$).

Table I shows the linear correlation values between ^{7}Be activity and rainfall, with strong and directly proportional correlation values for all collection sites. This is due to rainfall being the main deposition mechanism for ^{7}Be, and therefore a strong correlation between the two is expected [5].

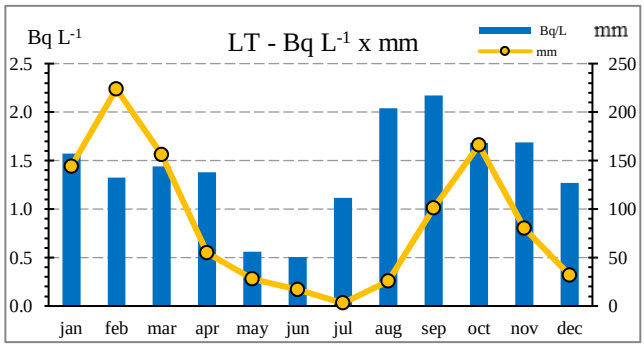
Table I – Mean concentration, Bq L^{-1} and correlation with rain water.

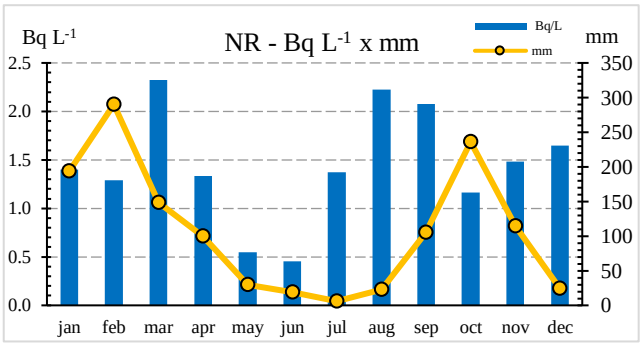
Collector	Mean Concentration Bq L^{-1}			Correlation with rainwater
	Mean	Maximum	Minimum	
CN	1.48	3.39	0.49	0.76*
IP	1.53	3.61	0.42	0.74
LT	1.52	3.20	0.50	0.76
NR	1.48	3.64	0.21	0.79
UL	1.42	3.23	0.38	0.74
WE	1.47	3.32	0.40	0.80

*When performing linear correlation with rainfall, Pearson correlation was used because all points have a normal distribution, except for this point CN, requiring Spearman correlation for non-parametric samples.

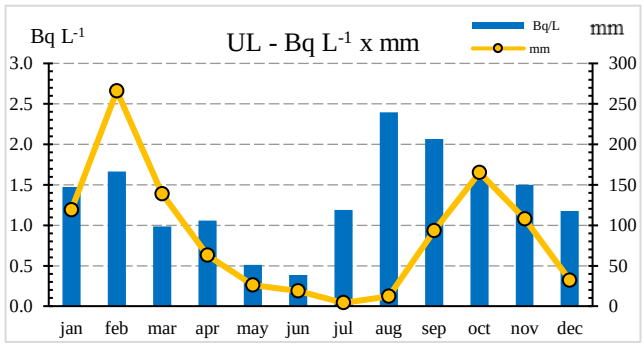
Figures 2 to 7 show the monthly mean of the concentration of ^{7}Be activity and the monthly rainfall, showing the variation in the results obtained and the relationship between the variables presented.

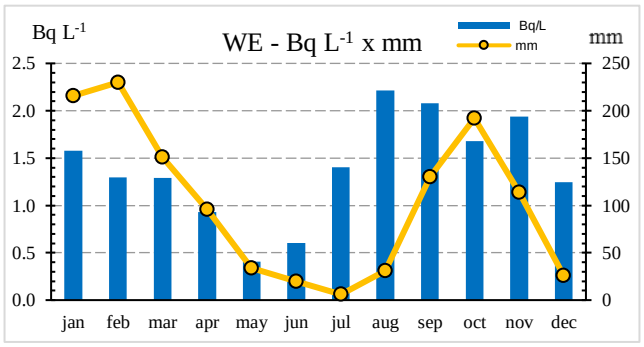
Figures 2 and 3 - Monthly mean of ^{7}Be activity concentration and rainfall at points LT and NR, respectively.



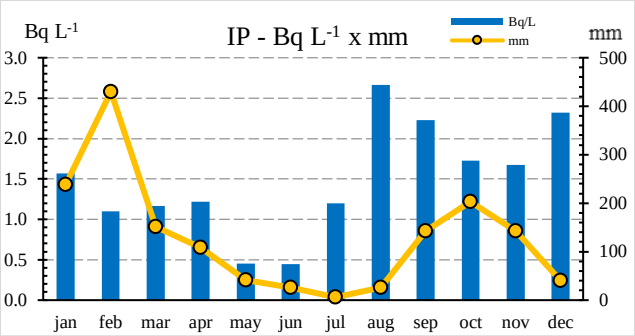


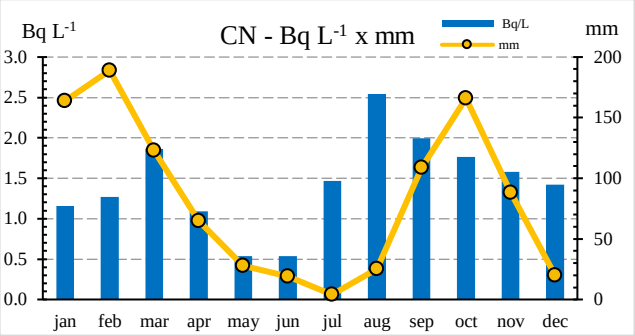
Figures 4 and 5 - Monthly mean of ^{7}Be activity concentration and rainfall at points UL and WE, respectively.





Figures 6 and 7 - Monthly mean of ^{7}Be activity concentration and rainfall at points IP and CN, respectively.





When analyzing figures 2 to 7, all the collection points showed similar behavior in their ^{7}Be results, with ^{7}Be varying as the amount of rainfall changed (strong correlation show in table I) and consequently, with a strong seasonal variation. At all the collection sites, the highest ^{7}Be activity values were obtained during the summer and spring, these being the wettest seasons in the city of São Paulo.

4. Conclusions

The ^{7}Be results obtained in 2023 demonstrated that the concentration mean values for this radionuclide in the city of São Paulo was 1.48 Bq L^{-1}, with seasonal variation in ^{7}Be results and a strong correlation between ^{7}Be and rainfall. The Shapiro-Wilk and Krustal Wallis statistical tools showed that the results obtained at the six collection points did not differ significantly from each other.

Acknowledgements

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