



## Determination of $^{210}\text{Pb}$ and $^7\text{Be}$ in Amazon Rainfall - site ATTO.

M.A. Tamires<sup>1</sup>, C.S.Paulo Sérgio<sup>2</sup>, Z.S.  
Guilherme<sup>3</sup> and G. Antonio Frederico<sup>4</sup>

<sup>1</sup>*tamires.mora@usp.br*, <sup>2</sup>*psscilva@usp.br*,

<sup>3</sup>*guilhermezahn@gmail.com*,

<sup>4</sup>*fredzini@ipen.br*

*Instituto de Pesquisas Energéticas e  
Nucleares (IPEN/USP-SP) Av. Professor  
Lineu Prestes 2242 05508-000 São Paulo,  
SP.*

### 1. Introduction

The Amazon region is one of the largest direct sources of organic aerosols into the atmosphere. The size and elementary composition of aerosols particle are important variables that influence its role as Cloud Condensation Nuclei. Although, aerosols are efficiently, removed by precipitation, the long distance transport of just small fraction of Amazonian aerosols may contribute greatly to the global balance of the free troposphere [1]. The research of atmospheric aerosol transport process can be, carried out using natural radionuclides. These radioactivity isotopes can be introduced into the atmospheric as emission from earth's surface, natural radioactivity produced by cosmic radiation; artificial radioactivity introduced by nuclear weapons test, nuclear incident or humanity activity. As radioactivity tracers, radionuclides quickly bind to the surface of aerosols and nuclei [2]. The removal rate of radionuclides from the atmosphere can be determined using aerosols deposition rate [3].

Considering that, the radioactive isotopes are, recognized as a good atmospheric transport tracers and deposition processes, among them stands out the  $^7\text{Be}$  and the  $^{210}\text{Pb}$ . The long term monitoring of radionuclides  $^7\text{Be}$  and  $^{210}\text{Pb}$  in atmospheric depositions, provides useful information of their sources, temporal and seasonal variation, deposition rates, atmospheric distributions and mechanism involved in their removal from the atmosphere. Although these radionuclides have distinctly different origins, they are, removed from the atmosphere by similar mechanisms mainly involving wet precipitation, dry precipitation, cosmic ray intensity, vertical and horizontal atmospheric transport, and radioactivity decay [4,5,6,7,8].

#### 1.1 Natural Radionuclides and Cosmogenic Radionuclides

The natural radioactive series of  $^{238}\text{U}$ ,  $^{235}\text{U}$  and  $^{232}\text{Th}$  are, composed by radionuclides that can be used to study environmental process. In the  $^{238}\text{U}$  decay series,  $^{210}\text{Pb}$  with a half-life of 22.6 years and transition gamma energy of 46,5 keV, is formed by the  $^{222}\text{Rn}$  decay, a noble gas that exhale from soil [9]. The formation of  $^{210}\text{Pb}$  in the atmosphere, allows the study of atmospheric transport and mixing process due to its distribution and variation in the air with [4,5,6].

The  $^7\text{Be}$  is a cosmogenic radionuclides with half-life of 55,3 days, it is produced by spallation nuclear interaction with cosmic rays on carbon, oxygen and nitrogen, that absorb neutrons and protons from the primary component of cosmic radiation [10, 11]. This formation happens in the stratosphere and upper layers of the troposphere and decay by electron capture, emitting gamma radiation with energy of 477.6 keV [7, 11].  $^7\text{Be}$  is, used in analysis of transport processes of soil particles [7], aerosol residence time in atmosphere processes, deposition dynamics, and as natural radiotracers in the study of atmospheric movements [8].

## 1.2 Amazon region

The Amazon Tall Tower Observatory (ATTO) is located in a region of untouched tropical forest in the center of the Amazon, at a distance of 150 km northeast of Manaus, a 325 m research tower that possibility the study in different areas. The forest Amazon has an important role in the climate change, and in direct sources of organic aerosols to the atmosphere. Significant changes related to human activities are occurring in the Amazon which can have global effects on the carbon balance, greenhouse gas concentrations, greenhouse effect and aerosol particles, and the oxidizing power of the atmosphere. The Amazon is one of largest direct sources of organic aerosols to the atmosphere [12, 13].

A large number of scientific articles have shown that air concentration and flow data depositional formation of  $^7\text{Be}$  and  $^{210}\text{Pb}$  provide important information about the origins and movements of air masses, as well as deposition processes and residence time of aerosols. This information is applied to atmospheric studies related to various areas ranging from meteorological studies to global climate change. One bibliographic review in 2021 [14], with the collection of global data available from 1955 to 2020, clearly indicates the lack of research and data collection on annual air concentration and fluxes depositional of  $^7\text{Be}$  and  $^{210}\text{Pb}$  in Brazil. Thus, the unprecedented contribution of this work is the collection of information relating to concentrations of  $^7\text{Be}$  and  $^{210}\text{Pb}$  in the Amazon rainforest, in a pristine region, which can contribute to the understanding of atmospheric and climatic processes that occur in the region. This study present the first preliminary results for  $^{210}\text{Pb}$  and  $^7\text{Be}$  activity concentration measured at in Amazon- site ATTO region rainfall during a short period from 2023 and 2024.

## 2. Methodology

### 2.1. Sample preparation for rainwater test

The samples were collected in 2023, December, to 2024, January, periods in the Amazon region at the ATTO site located in São Sebastião do Uatumã municipality, a sustainable development reserve. This periods, correspond summer season. One sample location, named Campina (Figure 1) has a white sand soils and short vegetation species and the Plateau region (Figure 2) is in a dense forest location with different types of soil (sandy to clayey) [15].



Fig. 1: Sample collector from Campina region.  
Source: Owner authorship.



Fig. 2: Sample collector from Plateau region (From The IPEN/USP). Source: Owner authorship.

After collection, the samples were acidulated with 2 mL of concentrated HCl to pH1. The walls of the collection containers were washed 3 times with 1 mol L<sup>-1</sup> HCl, to completely remove  $^7\text{Be}$ , which, when in contact with the bottle, tends to remains impregnated on the walls. The rainwater samples were pre-concentrated to 100 mL on a hot plate at a temperature close to 150 °C. The aliquots were, transferred to a f-100 flask with washing the sides of the beaker with HCl 1M. The measurement was carried out by gamma-ray spectrometry for a period of 24 hours. It was used a HPGe detector (Canberra). From the gamma counts

obtained, the activity concentration was estimated using a punctual calibration using the ISOCS software from Mirion Technologies. The decay during counting can be considered negligible if the half-life of both radionuclides is much longer than the duration of the count (~24h).

### 3. Results and Discussion

The activity concentration values found are in Table I.

TABLE I- Activity concentration (mBq/L) of  $^7\text{Be}$  and  $^{210}\text{Pb}$  in rainwater from the Amazon region – site ATTO. All the samples were pre concentrated to 100 mL and they were measurement by gamma spectrometry.

| Sample<br>(Lat/Log)     | M(L) | Sample period | $\Delta t$ | A(f)- $^7\text{Be}$<br>(mBq/L) | A(f)- $^{210}\text{Pb}$<br>(mBq/L) |
|-------------------------|------|---------------|------------|--------------------------------|------------------------------------|
| P1A (2,14°S, 59,0° O)-P | 4,75 | December      | 74         | 468±32                         | 221±68                             |
| P1B (2,14°S, 59,0° O)-P | 4,75 | December      | 78         | 609±42                         | 165±51                             |
| P2 (2,14°S, 59,0° O)-P  | 3,0  | January       | 16         | 381±26                         | <LID                               |
| C (2,12°S, 58,74°O)-C   | 5,0  | December      | 77         | <LID                           | <LID                               |
| T (2,15°S, 59,0° O)-C   | 4,25 | January       | 13         | 356±25                         | 308±96                             |

Subtitle – Lat/Long: Latitude/Longitude; -P: Plateau region; -C: Campina region;  $\Delta t$  : Time in days elapsed from collection to counting – This parameter is important because  $T_{1/2}$  of  $^7\text{Be}$  is short; A(f) -  $^7\text{Be}$  and  $^{210}\text{Pb}$  : Sample activity concentration measured on the f-100 flask; <LID: less than the limit of detection.

In rainfall Amazon samples the activity concentration to  $^7\text{Be}$  varied from 356±25 mBq/L to 609±42 mBq/L and the activity concentration of the  $^{210}\text{Pb}$  ranged from 165±51 mBq/L to 308±96 mBq/L. Values close observed in this work to  $^{210}\text{Pb}$  were obtained in rainfall collected in São Paulo region with estimated values between 4.9 mBq/L to 1408±43 mBq/L where highest concentration were obtained in months of winter and the lowest in summer [16]. Also studies show values to  $^7\text{Be}$  varied from 0,12±0,15 Bq/L to 1,96±0,23 Bq/L in Rio de Janeiro in Niteroi City , Brazil [17] and in rainfall events from South American a mean value of  $1,7 \pm 0,6$  Bq/L[18].

### 4. Conclusions

In this study the gamma-ray characterization of rainfall collected in the Amazon – site ATTO was performed. To quantify the values of  $^7\text{Be}$  and  $^{210}\text{Pb}$  in rain water samples, it was necessary pre concentration the samples and after it was used the gamma-ray spectrometry analyze, where to  $^{210}\text{Pb}$  was used the transition gamma energy of 46,5 keV and for  $^7\text{Be}$  used the energy of 477.6 keV, that decay by electron capture. The preliminary results of  $^7\text{Be}$  and  $^{210}\text{Pb}$  activity concentrations from Amazon rainfall showed significant values. The activity concentration of  $^{210}\text{Pb}$  and  $^7\text{Be}$  are almost uniform throughout the rainwater analyzed.  $^{210}\text{Pb}$  was found in Campina and Plateau region while activity concentration of  $^7\text{Be}$ , just appear in Plateau region. This preliminary results are good agreement with studies data from South American and a long term observation is planned for the next two years.

### Acknowledgements

Authors thanks the Institute of Energy and Nuclear Research (IPEN-CRPq)/USP for the study opportunity, the doctoral scholarship financed by CAPES, the INPA for the opportunity to visit ATTO in Amazon region and the ATTO resident employees.

## References

- [1] M. O. Andreae, AND P. J. Crutzen, "Atmospheric Aerosols: Biogeochemical Sources and Role in Atmospheric Chemistry", *Science*, vol. 276, pp. 1052-1058 (1997).
- [2] M. Baskaran, "Po-210 and Pb-210 as atmospheric tracers and global atmospheric Pb-210 fallout: a Review", *Journal of Environmental Radioactivity*, vol. 102, pp. 500-513 (2011).
- [3] A. Camacho, I. Valles, A. Vargas, M. Gonzalez-perosanz, X. Ortega, "Activity size distributions for long lived radon decay products in aerosols collected in Barcelona (Spain)", *Applied Radiation and Isotopes*, vol. 67, pp. 872-875 (2009).
- [4] M. I. Savva *et al.*, "Applied Radiation and Isotopes", vol. 87, pp. 361 (2014).
- [5] M.I. Savva, M.J. Anagnostakis, "Applied Radiation and Isotopes", vol. 109, pp. 555 (2015).
- [6] J. M. Godoy, "<sup>210</sup>Pb Sediment Dating: Redeeming the History of Environmental Pollution in the
- [7] D. E. Walling, Q. He, W. Blake, "Use of <sup>7</sup>Be and <sup>137</sup>Cs measurements to document short – and medium – term rates of water-induced soil erosion on agricultural land", *Water Resources Research*, vol. 35, pp. 3865-3874, (1999).
- [8] I. Sykora, K. Froehlic, "Chapter 3 Radionuclides as Tracers of Atmospheric Processes", *Radioactivity Environment*, vol. 16, pp. 51 -88, (2009).
- [9] N. Preiss, M-A. Mélières, M. Porchet, "A compilation of data on lead 210 concentration in surface air and fluxes at the air-surface and water-sediment interfaces" *Journal of Geophysical Research*, vol. 101, pp. 28847-28862 (1996).
- Anthropocene", *Revista Virtual de Química*, vol. 10, pp. 1733-1757 (2018).
- [10] J. Masarik, J. Beer, "Simulation of particle fluxes and cosmogenic nuclide production in the Earth's atmosphere", *Journal of Geophysical Research*, vol. 104, pp. 12099-12111 (1999).
- [11] D. Lal, P. K. Malhotra, B. Peters, "On the production of radioisotopes in the atmosphere by cosmic radiation and their application to meteorology", *Journal of Atmospheric and Terrestrial Physics*, vol. 12, pp. 306-328 (1958).
- [12] M.O Andreae, ET AL, "The Amazon Tall Tower Observatory (ATTO): overview of pilot measurements on ecosystem ecology, meteorology, trace gases, and aerosols", *Atmospheric Chemistry and Physics*, vol. 15, pp. 10723-10776 (2015).
- [13] C.A. Nobre, M. A. S. Dias, A. D. Culf, J. Polcher, J. H. C. Gash, J. A. Marengo, AND R. Avissar. *The Vegetation, Water, Humans and the Climate*, Springer, Berlin (2004).
- [14] F. Zhang, j. Wang, M. Baskaran, Q. Zhong, Y. Wang, J. Paatero and, J. Du, "A global dataset of atmospheric <sup>7</sup>Be and <sup>210</sup>Pb measurements: annual air concentration and depositional flux", *Earth System Science Data*, vol. 13, pp. 2963-2994, (2021).
- [15] Secretaria do Meio Ambiente – Amazonas. Disponível em : <https://meioambiente.am.gov.br/rds-do-umatuma/>. Acesso em: 01/03/2024.
- [16] S. R. Damatto, J. V. Frujuele, J. M. Souza, L. F. Santos. "Pb-210 Deposition measured in rainfall in São Paulo, SP – BRAZIL". *International Nuclear Atlantic Conference – INAC, ABEN*, (2013).
- [17] R. P. Cardoso, M. C. Muniz, J. J. Ayub, B. Fagundes, R. M. Dos Anjos, A. S. Cid, H. V. F. Lohaiza, "<sup>7</sup>Be content in rainfall and soil deposition in South American coastal ecosystems", *Proceedings of Science - Proceedings of XXXIV edition of the Brazilian Workshop on Nuclear Physics* (2011).
- [18] J. J. Ayub, F. Lohaiza, H. Velasco, M. Rizzotto, D Di Gregorio, H. Huck, "Assessment of <sup>7</sup>Be content in precipitation in a South American semi-arid environment", *Science of the Total Environment*, vol. 441, pp. 111-116 (2012).