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# Inorganic chemical characterization of the Peña lagoon sediment by INAA

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## 1. Introduction

Lake systems are the continental environments most susceptible to climatic and anthropic action, whose physical, chemical, and biological changes that may have occurred are recorded in their sediments and can be detected, for example, by geochemical analysis [1]. The result of the interaction of all the processes that can occur in a lacustrine system is the sediment.
Lake sediments also constitute a potential ecosystem for the accumulation of trace elements that can be used in the study of pollution, as indicators of the presence and concentration of these elements [2,3].
For more than a decade, different areas of research have studied the lakes of Uruguay coast to better understand their history and origin [4-6]; one of these lakes is Peña Lagoon.
Peña Lagoon (Laguna de Peña) is a small freshwater lake of 5 ha in a watershed of 50 ha, with a maximum depth of 1.8m. The surroundings of this lake have been drastically modified since the creation of Santa Teresa National Park, where the lagoon is located [6].
The objective of this work was to perform the inorganic chemical characterization of the Peña Lagoon sediment determining the elements As, Ba, Ce, Co, Cr, Cs, Eu, Fe, Hf, K, La, Lu, Na, Nd, Rb, Sb, Sc, Sm, Tb, Th, U, Yb and Zn using Instrumental Neutron Activation Analyses (INAA) and verify the enrichment of these elements when compared to the reference values of the Upper Continental Crust (UCC) [7] and core base concentration values.

## 2. Methodology

Peña Lagoon (34º 00’ 13’’ S; 53° 33’ 10’’ O) is a small freshwater lagoon located on a narrow sedimentary fringe called "La Angostura", between the Atlantic Ocean and Black Lagoon [8]. According to Puerto [5] possibly the Peña Lagoon is part of a group of lakes that originated because of the damming of the waterways that move towards the Atlantic Ocean.
The chemical analyses were performed on a sediment core, collected in the center of the lagoon. The core was sectioned every 2 cm and the samples dried in an oven for 24h to eliminate moisture at 60ºC. After drying, the samples were ground using a glass mortar and pistil, homogenized, and packaged in polyethylene bottles.
INAA is a non-destructive analytical technique that allows to determine up to 40 chemical elements in a single sample. The precision and accuracy of the technique varies for each element [9]. Neutron activation analysis is a method for the qualitative and quantitative determination of elements. It is based on the measurement of characteristic radiation from radionuclides that are formed by irradiating materials by neutrons. [10].
The enrichment of the elements was calculated by two geochemical tools. The first tool was the enrichment factor (EF), a method that analyzes the anthropogenic influence in a given environment. The method determines whether a chosen normalizer element is enriched, by comparing sample values to reference values. This study uses the element Hf as normalizer element due to its little variation to weathering processes [9].
The second tool was the enrichment factor, using the base value of the core as a normalizer, BEF. Both the enrichment factor values, EF and BEF, were compared with the reference values proposed by Sutherland [12].

## 3. Results and Discussion

Table I presents the mean, minimum and maximum concentration values in mg $kg^{-1}$ of the inorganic chemical elements and the UCC reference values [7]. The elements As, Br, Cr, Sb and U presented mean concentration values higher than the UCC as well as the. The light rare earth elements Nd, Sc and Sm and the heavy rare earth elements, Tb, Yb and Lu.

Table I: Mean, minimum and maximum concentration values, mg $kg^{-1}$, of the inorganic chemical elements and reference values from UCC.

| Element | Mean | Min | Max | UCC | Element | Mean | Min | Max | UCC |
|---|---|---|---|---|---|---|---|---|---|
| | mg $kg^{-1}$ | | | | | mg $kg^{-1}$ | | | |
| **As** | 11.6 | 5.01 | 18.4 | 1.5 | **Na** | 4514 | 2491 | 5785 | 2560 |
| **Ba** | 478 | 255 | 999 | 668 | **Nd** | 11 | 27 | 53 | 26 |
| **Br** | 23.2 | 8.2 | 57.6 | 1.6 | **Rb** | 123 | 81 | 218 | 110 |
| **Ce** | 79 | 43 | 141 | 64 | **Sb** | 1.1 | 0.7 | 2.0 | 0.2 |
| **Co** | 21.4 | 7.6 | 46 | 10 | **Sc** | 19 | 8 | 41 | 11 |
| **Cr** | 64 | 41 | 153 | 35 | **Sm** | 8.9 | 5.6 | 21 | 4.5 |
| **Cs** | 13.3 | 4.3 | 30 | 3.7 | **Ta** | 0.2 | 0.57 | 1.1 | 2.2 |
| **Eu** | 1.8 | 0.64 | 4.3 | 0.9 | **Tb** | 1.1 | 0.61 | 1.8 | 0.7 |
| **Fe (%)** | 5.03 | 2.2 | 11.01 | 3.5 | **Th** | 10.6 | 7.9 | 18 | 10 |
| **Hf** | 4.6 | 2.7 | 7.9 | 5.8 | **U** | 4.8 | 2.9 | 9.7 | 2.5 |
| **K (%)** | 1.14 | 0.48 | 1.60 | 2.87 | **Yb** | 3.6 | 2.3 | 7.9 | 2.2 |
| **La** | 38 | 17 | 79 | 30 | **Zn** | 153 | 31 | 508 | 71 |
| **Lu** | 0.6 | 0.4 | 1.3 | 0.3 | | | | | |

The chemical the elements Ba, Ce, Co, Eu, Fe, La, Lu, Na, Rb, Sc, Tb, Th and Yb presented low enrichment (value < 2); the elements Cs, Sm, U and Zn moderate enrichment (values 2 to 5) and the elements As, Sb e Br were classified with high enrichment (values > 5 to 40). No element presented values above 40 (very severe enrichment). Fig. 1 shows the EF of the elements with moderate enrichment and Fig. 2 very high enrichment, both figures in log scale. The elements Nd and Ta are not represented because they presented detectable concentrations only in some slices of the core.

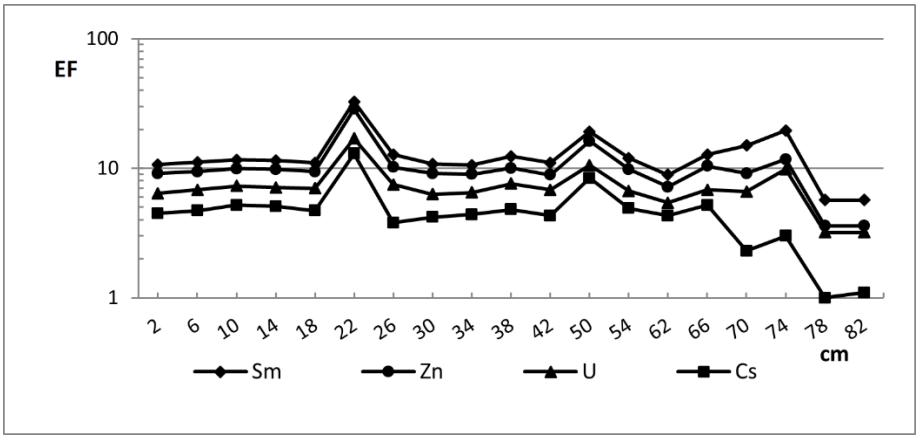


Figure 1: EF of the elements with moderate enrichment in logarithmic scale.

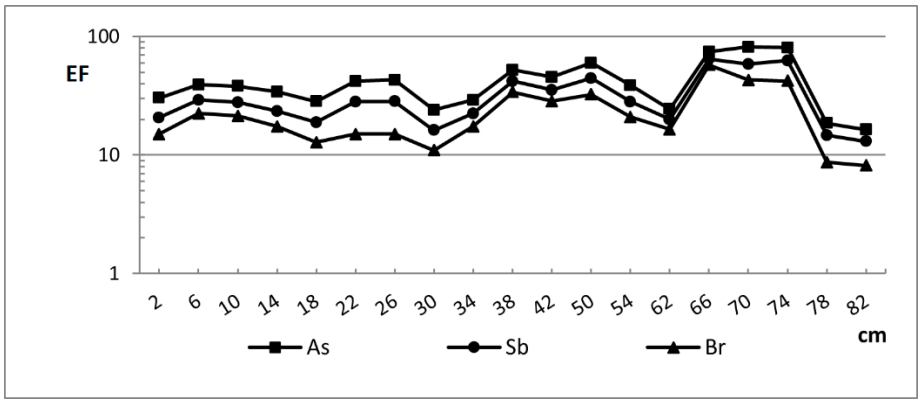


Figure 2: EF of the elements with very high enrichment in logarithmic scale.

In the case of BEF the elements Ba, Br, Ce, Co, Cr, Eu, Fe, Hf, La, Lu, Na, Nd, Rb, Sb, Sc, Sm, Ta, Tb, Th, U e Yb showed low enrichment and the elements As, Cs, K e Zn were classified as moderately enriched. None of the elements were measured presented very high or very severe enrichment. Fig. 3 shows the BEF, in log scale, according to the depth of the elements with moderate enrichment.

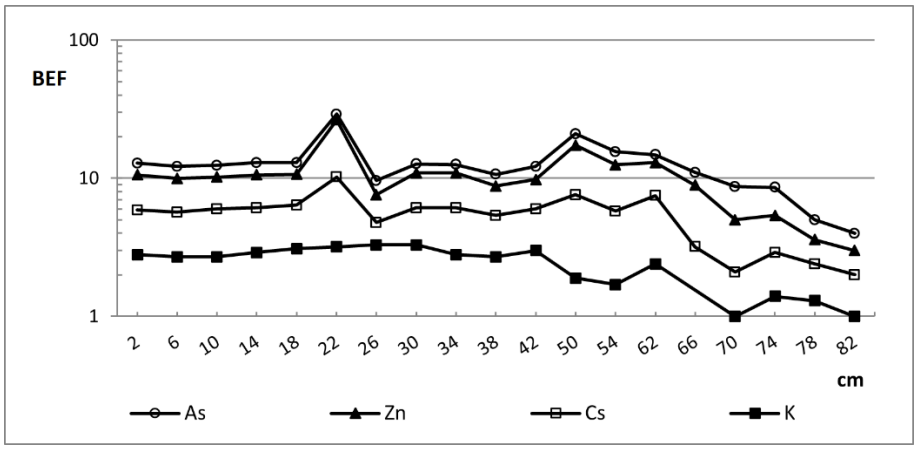


Figure 3: BEF of the elements with moderate enrichment in logarithmic scale.

## 4. Conclusions

The present work performed an inorganic chemical characterization of Peña Lagoon sediment using Instrumental Neutron Activation Analysis. Among all the elements determined, only the elements Nd and Ta were not detected throughout the core. Comparing the concentrations results obtained for the analyzed elements with values from UCC reference values, the elements As, Br, Cr, Sb, U, Nd, Sc, Sm, Tb, Yb and Lu presented concentrations higher than the reference values.

Two geochemical tools - EF and BEF - were used to evaluate the enrichment of determined chemical elements. With the enrichment results obtained, it was verified that the best enrichment factor used was the BEF, as it presented few enriched elements, since it uses the core base values as a normalizer, reflecting the natural concentrations of the studied environment.

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**References**

[1] Tundisi, J. G., & Tundisi, T. M. *Limnologia*, Oficina de textos (2016).

[2] Suguio, K. *Geologia sedimentar*. Editora Blucher (2003).

[3] Guerra, A. T., & Guerra. A. J. T, Dicionário Geológico-Geomorfológico, 9ª edição. Rio de Janeiro: Bertrand Brasil (2011).

[4] Inda, H. El Antropoceno en el sudeste del Uruguay: casas, indicadores y consecuencias (2016).

[5] Puerto, L. D. Interrelaciones humano-ambientales durante el Holoceno tardío en el este del Uruguay: Cambio Climático y Dinámica Cultural (2015).

[6] del Puerto, L., Bracco, R., Inda, H., Gutiérrez, O., Panario, D., & García-Rodríguez, F. Assessing links between late Holocene climate change and paleolimnological development of Peña Lagoon using opal phytoliths, physical, and geochemical proxies. *Quaternary International*, *287*, 89-100 (2013).

[7] Wedepohl, K. H. The composition of the continental crust. Geochimica et cosmochimica Acta, 59(7), 1217-1232 (1995).

[8] Cuña-Rodríguez, C., Piovano, E., del Puerto, L., Inda, H., & García-Rodríguez, F. On the relationship between holocene environmental variability and the diatom composition in the Pena Lagoon, Se Uruguay. *Ameghiniana*, *55*(4), 423-436 (2018).

[9] Damatto, S. R, Radionuclídeos naturais das series do $^{238}U$ e $^{232}Th$, elementos traço e maiores determinados em testemunhos de sedimento da Baixada Santista para avaliação de áreas impactadas. Tese de Doutorado, IPEN – USP, São Paulo (2010).

[10] Marques, L. S., Figueiredo, A. M. G., Saiki, M., & Vasconcellos, M. B. A. Geoquímica analítica dos elementos terras raras. Aplicação da técnica de análise por ativação neurônica (1989).

[11] Santos, L., DAMATTO, S. R., BARBIERO, L., FURIAN, S. M., & REZENDE FILHO, A. T. Fator de enriquecimento de elementos traço determinados em perfis de sedimentos do Pantanal da Nhecolândia-MS. INAC (2016).

[12] SUTHERLAND, R.A. “Bed sediment-associated trace metals in an urban stream, Oahu, Hawaii”. Environ Geo v. 39 n. 6, pp. 611-627, (2000).