



The importance of moisture content in Pb-210 dating in sediments – Case study of the Fundão dam – Mariana (MG)

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Abstract. The Fundão dam, in Mariana, broke in November 2015, releasing more than 59 million m³ of tailings that reached almost 700 kilometers along the river, crossing the states of Minas Gerais and Espírito Santo, reaching the estuary and reaching the Atlantic Ocean. After the accident, several environmental impacts were recorded along the path affected by the tailings mud. IBAMA requested a historical survey of contamination, due to the burial process, layer by layer of sediments. Because there are no bathymetric surveys, the changes that occurred in these places are unknown. To obtain this information, Pb-210 dating will be applied. In the present study, nine sediment cores were collected in different locations in the states of Minas Gerais and Espírito Santo. Based on the moisture profile, it was possible to identify the cores that had the potential to provide a Pb-210 profile that could be dated. After this analysis, three cores showed behavior within the expected range for Pb-210 dating.

1. Introduction

On November 5, 2015, one of the biggest and most impactful accidents in Brazilian mining happened: the rupture of the tailings containment structure of the Fundão dam in the municipality of Mariana - MG [1]. This accident dumped approximately 59 million m³ of iron mining tailings that reached rivers, lakes, vegetation, in addition to burying homes in the district of Bento Rodrigues [2]. The impacts generated by this rupture extended from the accident site, in the municipality of Mariana, to the Doce River, reaching the state of Espírito Santo, covering 700 km in length [3].

After the accident, several environmental impacts were recorded along the path affected by the mud, such as contamination by heavy metals and chemical compounds in the water and sediments along the basin, the loss of biological diversity, in addition to the deposition of waste in the affected areas [4, 5, 6].

As the tailings end up being deposited in the sediments, these accumulated sediments contain a historical record of the changes caused as a result of anthropogenic processes. Therefore, the use of the analysis of the superimposed layers of the sediments is a way of studying the history of a region.

To identify the extent of residue contribution in sediment profiles Pb-210 dating will be applied. Therefore, it is important to verify which cores have the potential to provide a datable Pb-210 profile. This identification was made from the moisture content, as it is used to help the decision process to qualify a core. Only testimonials that behave as expected are qualified. Durham and Joshi (1980)

comment that the graph of moisture with depth must present an exponential decrease, according to equation 1. This exponential behavior is observed when there are no factors that cause mixing of the sedimentary layers [7]. In equation (1) below, y_0 , a and b are constants.

$$y = y_0 + a \cdot e^{-b \cdot z} \quad (1)$$

Thus, this work proposes to identify, from the calculation of moisture content, the testimonies with the best profile to perform dating.

2. Methodology

2.1. Study area

The first place hit by mining waste, in the form of mud, was the Santarém stream. The water contaminated by the mud flowed down the Gualaxo do Norte River, found the course of the Carmo River and then were transported by the Doce River to its mouth in the Atlantic Ocean, in the municipality of Linhares, state of Espírito Santo.

This work approached nine collection points to cover the widest possible variety of representative sedimentary environments along the water course belonging to the Rio Doce basin, which was affected by the rupture of a dam that occurred in Mariana, in 2015.

The study was carried out in partnership with the Renova Foundation, which is an entity responsible for mobilizing to recover the environment and repair the damage caused to residents affected by the rupture of the Fundão dam, in Mariana (MG).

2.2. Sampling

Sedimentary cores were collected in nine different locations in the states of Minas Gerais and Espírito Santo, with the points named: BAG, AIM, MAS, LNV, LJP, LAL, LAO, ERD and ERD02 (figure 1).

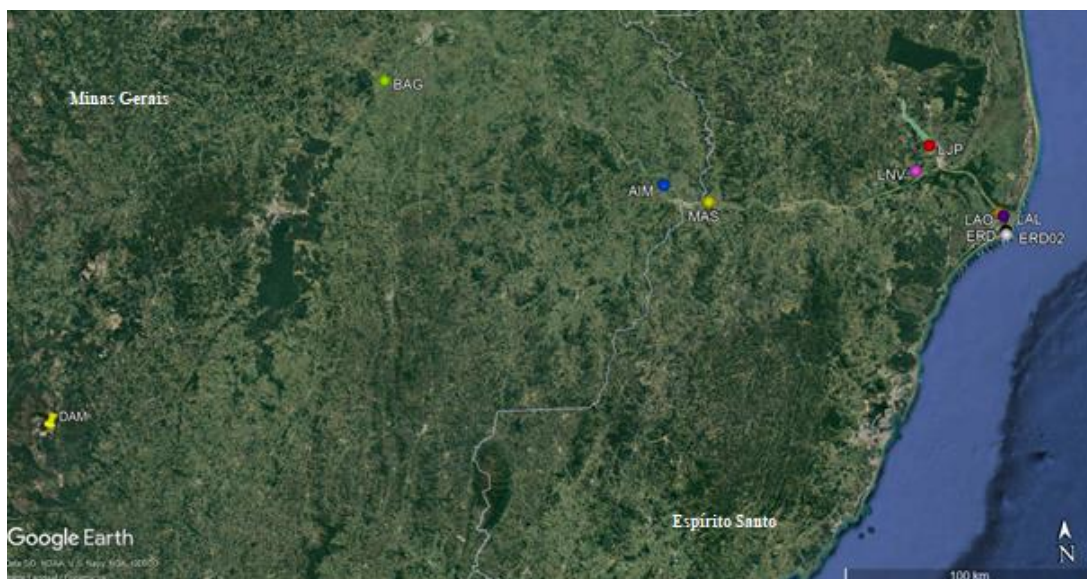


Figure 1. Geographical distribution of the location of the dam and the points sampled in the states of Minas Gerais and Espírito Santo (prepared by the author – Google Earth Pro).

The first campaign to collect sedimentary profiles was carried out in September 2022 at points BAG, AIM, MAS, LJP and ERD. There was a need to carry out a new collection in April 2023, at points LNV, LAL, LAO and ERD02. The cores were sampled and their data were tabulated, such as the geographic coordinates of the points and the depths of the water column at each point (table 1).

Table 1. Geographic coordinates of the sampling points of the sediments core samples and water column depth.

Sampling Point	Longitude	Latitude	Water depth (m)
UHEBAG	42°07'34.76" W	19°01'36.05" S	2.2
UHEAIM	41°06'07.00" W	19°26'13.00" S	4.2
UHEMAS	40°56'12.86" W	19°30'03.84" S	2.0
LVN	40°09'18.83" W	19°24'59.28" S	5.0
LJP	40°05'59.83" W	19°19'44.37" S	2.5
LAL	39°50'31.57" W	19°34'29.61" S	2.8
LAO	39°49'39.64" W	19°35'08.00" S	3.1
ERD	39°49'10.00" W	19°38'21.00" S	0.15
ERD02	39°49'09.08" W	19°39'05,06" S	2.6

In the first collection, a simple manual collector was used, a stainless steel tube with a diameter of 7.5 cm and a length of 100 cm, at the BAG, AIM, MAS, LJP and ERD points.

The second sampling was performed employing a Uwitec gravity sampler equipped with a transparent PVC tubes of 6 cm in diameter and 120 cm in length, was used at points LNV, LAL, LAO and ERD02. The lengths of the collected sediment cores varied between 18 and 40 cm.

The cores were subdivided immediately after sampling into 2 cm layers. Subsequently, the samples were sent to the Division of Radioprotection (DIRAD) at the Institute of Radioprotection and Dosimetry (IRD/CNEN).

2.3. Calculation of moisture content in the sediment

After sectioning, the samples were weighed as soon as possible in order to avoid mass loss due to evaporation. Then, each sample was taken to the oven for 48 hours at approximately 100°C and after this drying time, the samples were weighed.

Moisture content was determined by dividing the dry and wet mass of each sample.

3. Results and discussions

As the ERD profile, from the Rio Doce estuary, was collected in a sand bank and because it only contains sand, the core was discarded because Pb-210 is present in the fine material. It is possible to observe the characteristic of this profile in figure 2.



Figure 2. ERD profile composed only of sand.

3.1. Moisture content

The analysis carried out on the cores collected in September 2022 qualified one of the four cores sampled, as it presented a variation that is closer to an exponential referring to moisture with depth and was submitted to the dating technique with Pb-210, as can be seen in figure 3. This being the LJP profile.

From the preliminary analyses, the testimonies identified as BAG, AIM and MAS were discarded due to the existing current in the Doce River, thus avoiding the homogeneous deposition of sediments in the collected places. It is possible to observe that the BAG profile graph presents results that mirror what was visualized in the first layers on the metallic aspect of the sample. AIM presented an irregular profile and the MAS profile presented an opposite behavior to the expected one.

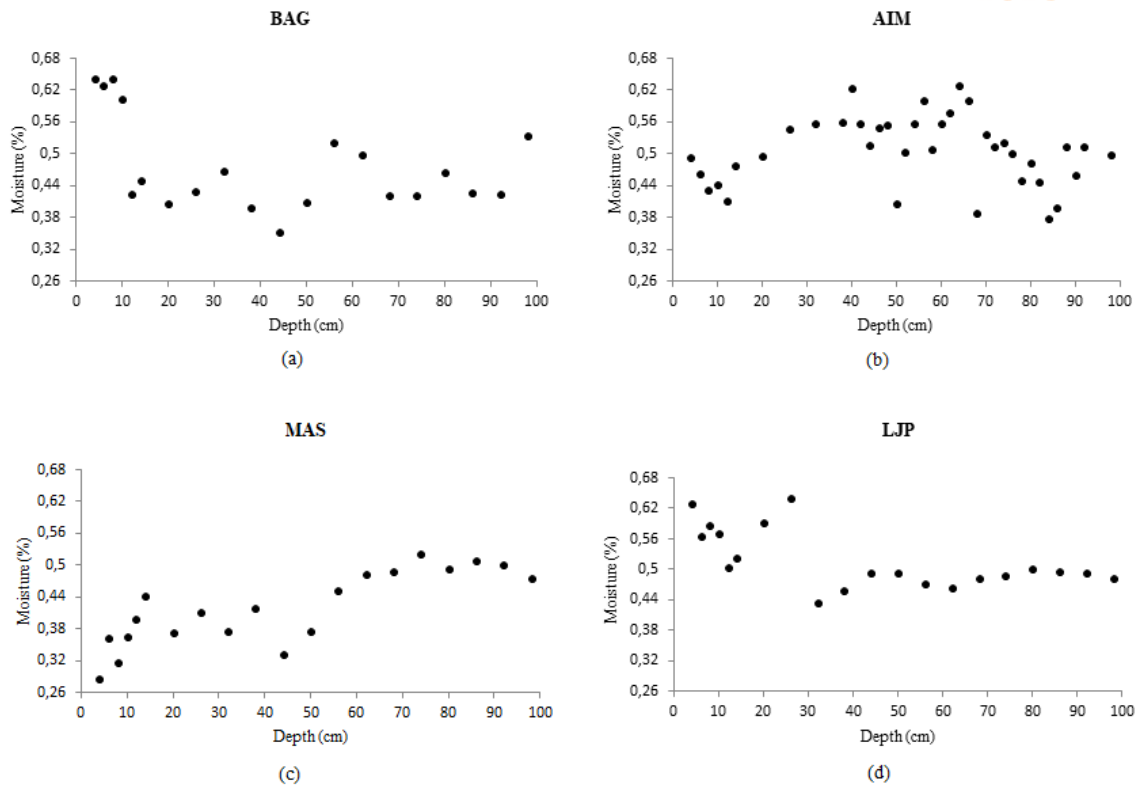


Figure 3. Graphs of moisture along the depth of the sampled sediment profiles: BAG (a), AIM (b), MAS (c) and LJP (d).

After analysis carried out on the LJP profile, it was observed that the tailings slurry did not reach the Juparanã lagoon. Therefore, there was a need for a new collection.

The same moisture profile analysis was performed on these new samples. Based on what has been previously commented, the cores labeled as LNV, LAL and LAO were qualified as promising to be submitted to the Pb-210 dating technique. The graphs in figure 4 show the moisture profiles that resulted from the analyzes carried out on the samples collected in April 2023.

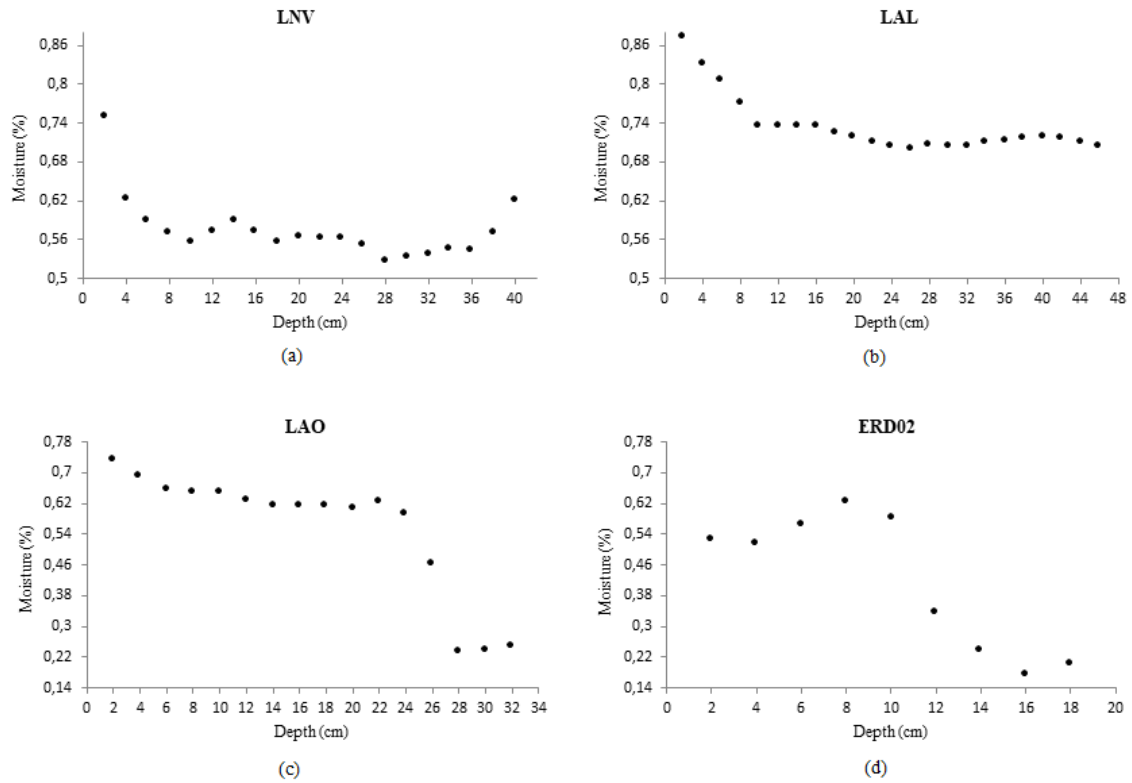


Figure 4. Graphs of moisture along the depth of the sampled sediment profiles: LNV (a), LAL (b), LAO (c) and ERD02 (d).

From the graphs, it is possible to observe that the LNV profile presented a very fast compression and the LAL profile presented a behavior within the expected range. The LAO profile also presents a behavior within the expected range, however there is a discontinuity around 24 cm. The ERD02 profile was discarded due to the presence of shells at different depths, causing bioturbation of the sedimentary layers of this profile, shown in figure 5.



Figure 5. Presence of bivalve (shells) in the ERD02 profile.

From the moisture graphs, the cores qualified for Pb-210 dating were identified. After dating, it will be possible to identify the extent of the contribution of residue in the sediment profiles in these places that were affected by the rupture of the Fundão tailings dam. As there are no bathymetric surveys in these regions, the results of these studies will be important for the Renova Foundation and even for the population, which ends up using the water from these lakes for consumption.

4. Conclusion

Only the ERD profile was discarded before the analysis of the moisture profile, as it only contains sand. Based on the behavior of the moisture profiles, it was possible to identify the sediment cores that had the potential to provide a Pb-210 profile that could be dated. After analysis, three of the nine cores analyzed showed behavior, exponential, within the expected range for dating with Pb-210, namely: LNV, LAL and LAO. The BAG, AIM, MAS, LJP and ERD02 profiles were not considered due to water movement, thus avoiding the homogeneous deposition of sediments and the presence of bivalve.

It is concluded that, based on the moisture content, it is possible to identify which testimonies are datable, with no need to perform an analysis on all the profiles and, in the end, verify that there would be no possibility of dating.

5. References

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