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DETERMINATION OF SEDIMENTATION RATES OF A NORTHERN DANUBE DELTA LAKE BY ^{210}Pb METHOD

Robert-Csaba BEGY[1]*, Hedvig SIMON[1], Szabolcs KELEMEN[1], Edina REIZER[1] & Luminița PREOTEASA[2]

[1]*Babes-Bolyai University, Faculty of Environmental Sciences and Engineering, Cluj-Napoca, Romania,*
**robert.begy@ubbcluj.ro*
[2]*University of Bucharest, Faculty of Geography, Bucharest, Romania*

Abstract: The ^{210}Pb radiometric dating method was applied in order to determine the sedimentation rates of a northern Danube Delta lake (Merhei Lake) using α and γ spectrometry for assessing the radionuclides of interest. Another objective is to measure the geochronology of each sediment layer and to determine the dynamics of the characteristic sedimentation processes. The Danube Delta is the second largest river delta in Europe, having an approximate surface of 4152 km^2. The Danube branches into three main distributaries into the delta: Chilia, Sulina and Sfântul Gheorghe. Two sediment cores (one from the close proximity of the estuary and another one from a more secluded area) were taken from a northern lake, namely Merhei Lake, formed between the Chilia and Sulina branches. The sedimentation rate was measured by ^{210}Pb using its α emitting progeny, ^{210}Po, for determining the solid discharge of the delta branches and, respectively, the spacial and temporal variations; while ^{226}Ra (determining the supported and unsupported ^{210}Pb content of the sediments) was determined using high resolution γ spectrometry. The sediments have been dated up to 1885, having average mass sedimentation rates of 0.30 ± 0.04 g/cm^{2}y and linear sedimentation rates of 0.68 ± 0.18 cm/y. The sediment is transported throughout the lake, so the more secluded part of the lake has at some depths up to twenty times more sediment intake than the one near the estuary.

Keywords: sedimentation rate, ^{210}Pb dating method, Danube Delta

1. INTRODUCTION

The Danube Delta is the second largest river delta in Europe, having a extent of 4152km^2. At the mouth of each of the three channels: Chilia, Sulina and Sfântul Gheorghe gradual formation of new land takes place, which leads to the expansion of the delta (Jweda & Baskaran, 2011, Humphries et al., 2010).

Because the fluvial sediment supply varies in space and time as a result of the reworking done by waves and currents, the processes causing the rates of sedimentation are continuously changing as well. These variations are caused by both natural and anthropogenic factors (Nittrouer et al., 1979, Michels et al., 1998), so understanding the evolution of the Danube Delta's sedimentary system in the near future and in assessing its vulnerability to extreme events such as sea level rises, storms, floods, droughts etc. is in directly proportional with the natural processes (changes in climate, weather etc.) and human interventions (dams, river regulations, hydro energetic power plants, meanders cut offs, artificial channels cuttings, protection walls etc.) events (Kuehl et al., 1982, 1986; DeMaster et al., 1985; Alexander et al., 1991; Harris et al., 1993), which have been performed within the Danube basin within the last century.

2. MATERIALS AND METHODS

Two sediment cores (ME15 being 54 cm, taken from near the estuary, and ME16 being 67 cm and was taken from a more secluded part of the lake) were taken with a gravity corer from the Merhei Lake, situated between the Chilia and Sulina branches, in the northern part of the Danube Delta. Each sediment core was sub sampled in 1-2 cm sections, which were weighted and dried at the temperature of 105°C in a drying oven. Samples were then homogenized, and stored for 28 days, until the secular equilibrium between ^{226}Ra and ^{222}Rn was established. After storing, the samples were measured by high resolution gamma spectrometry. Measurements for ^{226}Ra ($^{210}Pb_{sup}$) and ^{137}Cs concentrations have been performed using an ORTEC DigiDart spectrometer with a HpGe detector, Gamma-X (GMX) type using the 295 keV and 351 keV gamma lines for ^{226}Ra.

The total ^{210}Pb was determined via ^{210}Po, these two elements reaching secular equilibrium after 2 years. To 0.5g of each sample was added 0.3 ml ^{209}Po (4.88 MeV) as tracer, then the samples were put to acidic digestion in 50ml Erlenmeyer flasks. The samples were treated with 20ml 65% HNO_3, after which they were heated to almost dryness. Subsequently, the samples were added 10 ml of 37% HCl, which was evaporated to almost dryness and then three times 10 ml 6N HCl was added for further digestion. 2 ml $HClO_4$ was added to the samples and a few drops of H_2O_2 (until the reaction between the sample and the H_2O_2 didn't take place any more). The resulted solution was brought to 100 ml, its pH being regulated to be in the 0.1 – 0.3 range using 2M HCl, respectively NaOH. The ^{210}Po source was prepared by spontaneous deposition on high nickel content stainless steel discs. These were heated in an oven for 3 hours at 82°C. Before deposition, ascorbic acid was added to the samples to eliminate the interferrents (Begy et al., 2011).

The ^{210}Po sources were then measured using an ORTEC Soloist alpha-spectrometric system with Ultra ENS-U900 detectors, having an active surface of 900 mm^2 and a resolution better than 29 keV.

3. RESULTS AND DISCUSSION

The values for the ^{210}Pb were measured with the help of its α particle emitting progeny, ^{210}Po, which reaches secular equilibrium with its mother element after a period of two years. In case ME16 (Fig. 1), a decreasing tendency can be observed in the polonium/lead activity according to the disintegration law (from 52 ± 3 Bq/kg to 22 ± 2 Bq/kg), while the activity concentration of the ME15 core decreases from 73 ± 5 Bq/kg to 21 ± 3 Bq/kg and has two local maximums, one being at the depth of 23 cm, the other 47 cm (Fig. 2). This can be explained by the fact that this core was taken at the estuary of the lake, where the mixing of sediments and the sediment intake is more pronounced.

The primary radiogenic component of ^{210}Pb results from the natural disintegration of ^{226}Ra in the soil. These two elements reach secular equilibrium, so that the radium activity equals the lead's activity from terrestrial origin. It can be observed, that in both cases the ^{226}Ra activity is relatively constant, the average activity being 16 ± 5 Bq/kg.

The quantity of the excess lead can be calculated by subtracting the in situ ^{210}Pb concentration (measured by the ^{226}Ra isotope) from the total lead activity. This lead quantity is used for the sediment dating. The core dating was made according to the CRS model, which is used at lakes with variable sedimentation, but which receive a constant amount of atmospheric ^{210}Pb.

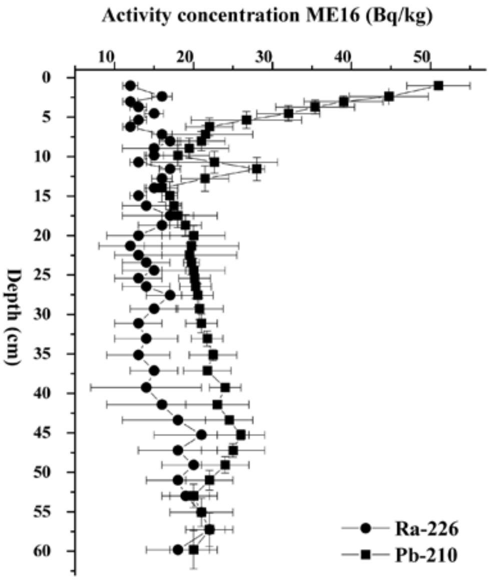

Figure 1. The activity concentration of ^{226}Ra and ^{210}Pb in the ME16 core

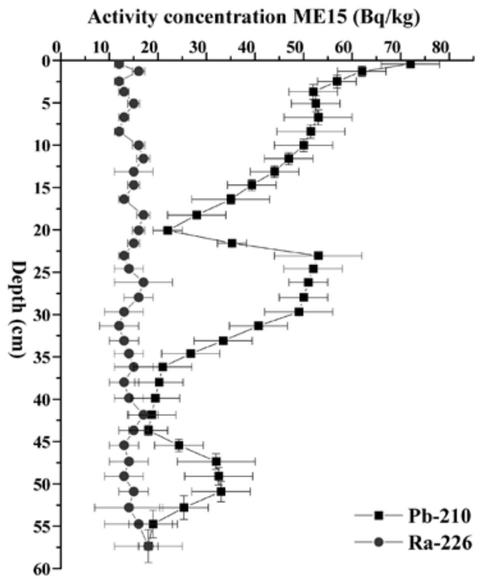

Figure 2. The activity concentration of ^{226}Ra and ^{210}Pb in the ME15 core

In case of ME15 (Fig. 3), the ages of the sediments show a constant, but slow decreasing, where most of the sediment has been deposited in the last 30 years, while ME16 (Fig. 4) shows a rapid decreasing. This leads to the conclusion that the part of the lake, where ME16 was taken receives a lower, but more constant sediment income. This leads to the fact that samples below 15 cm have a lower activity concentration than the limit of detectability of the used detector.

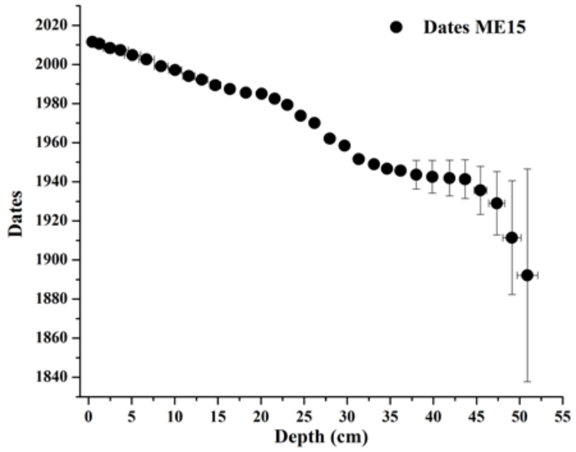

Figure 3. Ages of the ME15 sediment layers according to their depth

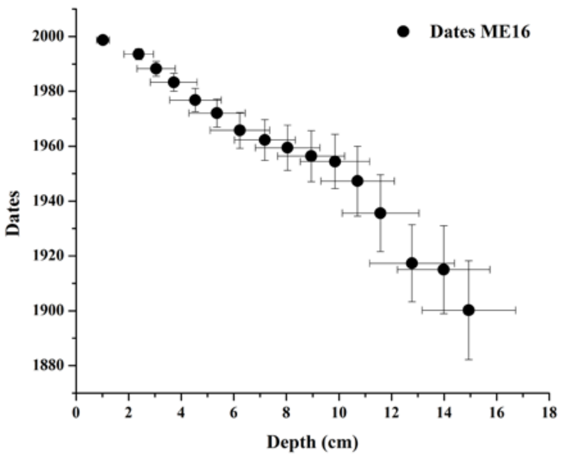

Figure 4. Ages of the ME16 sediment layers according to their depth

After determining the ages of each sediment sample, both linear and mass sedimentation rates were determined for both sediment cores. The obtained sedimentation rates confirm the presence of major floods in the territory of the Danube Delta. In the case of ME15, the linear sedimentation rate has values ranging from 0.11 cm/y to 1.82 cm/y, with an average of 0.71 ± 0.12 cm/y, while the mass sedimentation rate has an average value of 0.23 ± 0.02 g/cm^{2}y, its values being in the 0.13 – 0.92 g/cm^{2}y range. Also, there are three periods with relative constant sedimentation rates: 1890 – 1933 (0.11 ± 0.02 cm/y and 0.06 ± 0.01 g/cm^{2}y), 1950 – 1980 (0.37 ± 0.05 cm/y and 0.14 ± 0.03 g/cm^{2}y) and 1990 – 2013 (0.42 ± 0.05 cm/y and 0.23 ± 0.03 g/cm^{2}y). There were two bigger sediment depositions shown by both mass and linear sedimentation rates, one between 1980 and 1990, and the second approximately in 1940 (Fig. 5). The one produced in 1940 had a water flow of 15100 m^3/s, being the second greatest flood registered in the last century (Diaconu, 2007); the measured inflow and outflow in suspended sediment transport between 1980 and 1990 in the Iron Gates region reaches values between 15 - 24 Mt/year on the inflow and 3 – 6 Mt/year on the outflow. Maximum values can be observed in 1980 and 1987, those values appear also in deposited sediment (Babic Miladenovic, 2013).

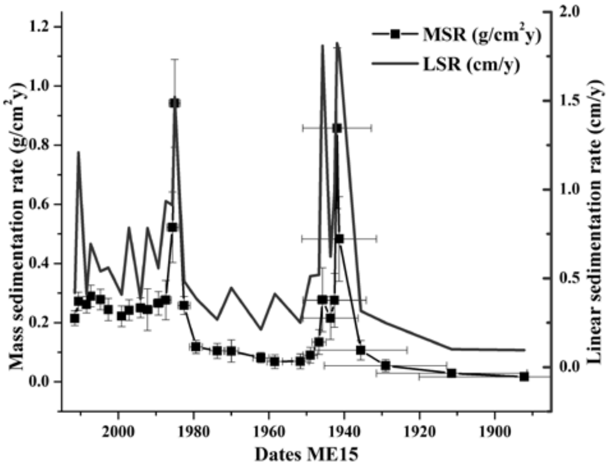

Figure 5. Sedimentation rates of the ME15 sediment core

ME16 shows a relatively constant linear sedimentation with values in the 0.04 – 0.46cm/y range with an average of 0.18 ± 0.02 cm/y, whereas the mass sedimentation ranges from 0.01 to 0.07g/cm^{2}y, having an average of 0.03 g/cm^{2}y. Both sedimentation rates show two local maximums: the first being in 1914 (0.3 cm/y, 0.06 g/cm^{2}y), the second in the 1955 – 1964 period (0.46 cm/y, 0.07g/cm^{2}y), but the recording of the floods in these periods has not been made systematically.

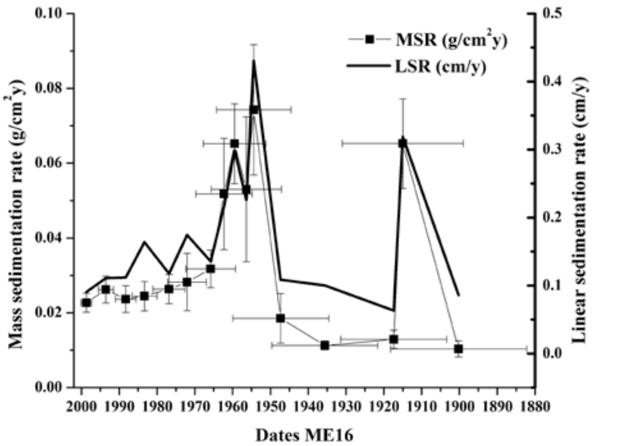

Figure 6. Sedimentation rates of the ME16 sediment core

4. CONCLUSIONS

As a conclusion, it can be stated, that the ^{210}Pb dating method using α and γ spectrometry has been successfully applied on the Merhei Lake, Danube Delta, and both linear and mass sedimentation rates have been calculated.

Results show, that the sediment core further away from the estuary of the lake receives a lower sediment intake, than the one in its close proximity. Also, the sedimentation rates differ much more at the ME15 sampling point, the reason being the same: the sediment inflow is not transported to the more secluded areas of the lake. In case of ME16 the sedimentation is relative constant and slow, so the detection limit is reached at a much higher depth, than in case of ME15. Both sediment cores show that the Merhei Lake has been affected more by the floods, which have taken place more than thirty years ago (such as the major flood in 1940 and the multiple floods in the 1980-1990 period).

The Merhei Lake has bigger sedimentation rates than those of small and shallow lakes (2.9mm/y in case of linear sedimentation and 0.044g/cm^{2}y) (Gasiorowski, 2008) at the estuary (sampling point ME15), but values are slightly similar with the secluded ME16 sampling point; also the isolated sampling point has a similar linear sedimentarion rate as those measured in China (Qian, 2006) Comparing the sedimentation rated those of the Great Lakes shows that even ME16 has more than twice as high a sedimentation rate for both linear and mass sedimentations (1.16 mm/y and 0.023 g/cm^{2}y), than the analysed lake; ME15 having a nine times bigger linear sedimentation rate and a 21 times bigger mass sedimentation rate (Robbins, 1975). Comparing the Merhei Lake to a lake in a highly populated area, we can observe that its average linear sedimentation rate (6.38 mm/y) is half of the measured average sedimentation rate (12.7 mm/y) (Byrne et al., 2004).

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