STUDIA UBB AMBIENTUM, LX, 1-2, 2015, pp. 129-136
(RECOMMENDED CITATION)

HIGHLIGHTING THE MAJOR HYDROLOGICAL EVENTS USING ^{210}PB RADIOMETRIC METHOD IN VALEA VINŢULUI RIVER FLOODPLAIN

Daniela VASILACHE[1]*, Nicoleta BRISAN[1], Robert Csaba BEGY[1]

[1]Faculty of Environmental Science and Engineering, Babeş-Bolyai University, Cluj-Napoca, Cluj, 400294, Romania
**Corresponding author: Tel.: +40 749 420316; E-mail address: vasilachedaniela.fsim@yahoo.com*

ABSTRACT. The growing interest in the dynamics of floodplains and the important role of alluvial sedimentation in river meadows, which acts as an archive of sediment, have focused on the need to document contemporary and recent sedimentation rates. This paper presents the results obtained of highlighting the major hydrological phenomena for Valea Vinţului and Pian river meadows, located in the Mureş river basin, characterized as high-risk flood areas. For the first time in Romania, ^{210}Pb radiometric method was used to obtain first estimates of sedimentation rate in a floodplain (Valea Vinţului river). After chemical preparation (acid leaching) of alpha spectrometric sources, ^{210}Pb concentrations in the samples were determined by measuring its daughter istope ^{210}Po using the alpha spectrometer ORTEC Soloist, equipped with a PIPS detector with 900 mm^2 active surface for recording of alpha particles 5,3 MeV ^{210}Po. Activities from 23±5 to 94±6 Bq/kg ^{210}Pb were found for Valea Vinţului river floodplain. After applying the CRS model (Constant Rate of ^{210}Pb Supply), the results of this method were compared with reports from literature and from Water Management System Alba and there were observed periods of massive depositions due to floodings between years 1936 and 2012 (± 2 years) with a alluvial sedimentation rate of 1.863 ± 0.167 up to 6.185 ± 1 g/cm^2*y.

Key words: *sedimentation rate, ^{210}Pb dating method, alpha spectrometry, CRS model.*

INTRODUCTION

Historical changes accentuation in major hydrological processes and soil erosion caused by overexploitation of surface vegetation, reforestation and changing agricultural techniques, can be achieved by studying natural sediment deposits, these layers containing also information about possible air pollution by organic pollutants, heavy metals and even radioactive emissions from nuclear facilities (Appleby, 2001).

One of the most important dating methods to determine the exact chronology of sedimentation is the ^{210}Pb method which uses the natural radioisotope of Pb resulting from decay of ^{238}U series. This method is more effective in environments with constant sediment accumulation rate, where the calculation of age is well established (Tylmann, 2004), but it works also in environments where sedimentation rate is not constant (Appleby & Oldfield, 1978).

Obvious contrast include that an area of meadow will receive a continuous input of ^{210}Pb due to direct deposition and intermittent inputs associated with the accumulation of alluvial sediment during floods. Thus ^{210}Pb will accumulate near the surface of the meadow, due to deposition and will then be buried by sediment that will produce a new surface which will afterwards receive other deposits (Humphries et al., 2010).

In the case of ^{210}Pb dating method, attention is directed to the reducing activity of ^{210}Pb at the core base which, in turn, reflects the rate of sedimentation. ^{210}Pb has a half-life of 22.3 years, and if the sedimentation rate is relatively fast, ^{210}Pb activity will decline relatively slowly with depth. However, where the sedimentation rate is relatively low, ^{210}Pb activity will decrease more rapidly with depth.

Nevertheless, there may be uncertainty about the reliability of the results obtained, due to the possibility that the use of different interpreting models for ^{210}Pb measurements may produce different results and the need to introduce evidence elements to restrict the assumptions made and to validate the estimates (Robbins, 1978).

After consulting the Preliminary Assessment Report for flood risk by the Mures Water Basin Administration, due to its classification as an area with significant flooding risk potential as a case study for this work was chosen the area of Valea Vintului river floodplain located in the Mures river basin, between the towns of Alba-Iulia and Sebes, near the village Vurpăr, downstream of Valea Vintului village, and for reference measurements was chosen the river meadow from proximity of Pian hydrometric stations. Historical flood damages made over the years because of the Mures river rapidly flow increase joined by flash floods showed an important study potential for floodplain of the river Valea Vintului.

The area for sampling from the valley was selected to provide places where deposition was expected to appear and the area of reference was characterized by permanent pasture and limited slope, so any redistribution of sediment due to erosion and deposition was not likely to have occurred in recent years.

MATERIALS AND METHODS

Study site

Valea Vintului river is located in the central-west part of Romania, springing from Metaliferi Mountains at a mean altitude of about 460 m and draining into Mures river in the proximity of Vurpar village (Alba county) at 210 m altitude above the sea level, reaching a length of approximately 7 km. The catchment area of Mures is 28.310 km^2, Valea Vintului being only a small narrow tributary river which has no affluents collecting the majority of surface drainage on the slopes along its course. The Mures river regime is dominated by spring and early summer floods, with considerable sediment draining. The average concentration of suspended sediment is 500 g/m^3, but during the flood may increase by an order of magnitude (Kiss et al., 2011).

Two cores were collected from the closeness of Valea Vintului and Mures junction (46°00'14.96''N; 23°28'26.17''E) and from the opposite shore of the Pian hydrometric station (45°59'14.91''N; 23°28'45.47"E).

Sampling and analysis

For ^{210}Pb dating were collected two core samples using a corer, one of the Valea Vintului river floodplain and the second core was taken for reference from Pian river meadow, where a hydrometric station is located. The core`s lenght was 55 cm for Valea Vintului and 35 cm for Pian. Columns from Valea Vintului and Pian meadows were divided into 13, respectively 8 layers with an average thickness of about 3 cm up to 5 cm each and were stored in plastic bags sealed and labeled for safe transport and avoiding waste and contamination.

Total ^{210}Pb concentrations were determined through ^{210}Po measurements, its daughter isotope which is in secular equilibrium with ^{210}Pb after 2 years (Sert et al., 2012). After drying at 70° C (Begy et al., 2008), the aliquots were milled and weighed accurately. As a yield tracer, ^{209}Po (30 mBq/l) (Begy et al., 2011) was used in alpha spectrometric measurements to determine losses during the analysis because it does not interfere with analyzed peaks and has the same physico-chemical behavior as ^{210}Po has throughout the chemical processes. For acid digestion it is used a solution of hydrofluoric acid, hydrochloric acid and nitric acid (Edgington & Robbins, 1975) and after 3 hours of spontaneous deposition ^{210}Po is deposited on a surface of stainless steel disc with high nickel content. Measurements were carried out with an Ortec Soloist spectrometer, equipped with a PIPS detector (an active surface of 900 mm^2 to 5.3 MeV alpha particles recording ^{210}Po). For the determination of ^{210}Pb in situ was measured ^{226}Ra (Du & Walling, 2012), which is in secular equilibrium with the ^{222}Rn descendants after one month storage (Masque, et al., 2002). The samples, were enclosed in regular cylindrical cans (Ø 4.9 cm; 1 cm height) with analyzed material, milled and then closed tightly, sealed and weighed. The measurements of ^{226}Ra were performed using a ORTEC Digidart gamma spectrometer with HPGe detector, with a resolution of 1.92 keV at 1.33 MeV line of ^{60}Co and the relative efficiency of 34.2%, the acquisition of the spectrum requiring at least 24 hours, ^{222}Rn being measured from the ^{214}Pb and ^{214}Bi peaks (Sanchez-Cabeza & Ruiz-Fernandez, 2012). ^{210}Pb activity was determined using the 46.5 keV gamma emissions with the relative intensity of 4%, the limit of detection for ^{210}Pb being 8 ± 2 (2d) Bq/kg.

CRS model

Disequilibrium between ^{210}Pb and the series parent isotope, ^{226}Ra, occurs through the ^{222}Rn intermediary gaseous isotope diffusion. A fraction of the ^{222}Rn atoms, produced by decay of ^{226}Ra in sediment, escapes into the atmosphere where it is disintegrated by a short-lived series of radionuclide ^{210}Pb which is removed from the atmosphere by precipitation or dry deposition, falling onto ground or in lakes (Begy et al., 2009). Thus deposited ^{210}Pb remains accumulated for several months due to a fixing between sediment particles.

Initially, the methodology was developed for lacustrine sediments (Appleby P.O., 1978; Robbins, 1978) dating based on three main assumptions according to which:

- unsupported ^{210}Pb deposition rate from the atmosphere is constant;
- ^{210}Pb in freshwater is rapidly removed from solution onto particles of material, so its activity in sediment is due to precipitation in the atmosphere;
- ^{210}Pb activity in sediment is not redistributed thru post-depositional processes and decays exponentially with time, according to the law of radioactive decay.

Thus, the model CRS involves a steady flux of ^{210}Pb in the atmosphere and a uniform deposition rate on the surface of interest (Birch et al., 2012). Applying these assumptions to places where sedimentation rate is not uniform led to the development of the CRS model (Constant Rate of ^{210}Pb Supply). Using the model to certain places was tested and validated by Oldfield and Appleby and their collaborators.

If the CRS model is valid, sedimentation rate changes will lead in time to changes of initial concentrations of unsupported ^{210}Pb (Oldfield & Appleby, 1984). Accordingly, older sediment deposition dates are calculated from the distribution of Pb in the recorded sediments and not from their current concentrations (Appleby, 2001).

To determine the age of the sediments at a certain depth in the vertical profile of ^{210}Pb this model is used following equation:

$$t = \frac{1}{\lambda}\ln\left(\frac{Io}{Im}\right), \text{ where:}$$

t – age (years);
I_0 – total inventory of excess ^{210}Pb (Bq cm^{-2});
I_m – inventory of excess ^{210}Pb below the cumulative mass depth m (Bq cm^{-2}) (Szmytkiewicz & Zalewska, 2014)

Table 1. *CRS model dating - Pian river*

Conc. ^{210}Pb (Bq/kg)	**±**	**Conc. ^{226}Ra (Bq/kg)**	**±**	**Uns. ^{210}Pb (Bq/kg)**	**±**	**Age from now**	**±**	**Sed. rate g/cm^{2}*y**	**±**
85	4	19	1	66	5	2006	1	0.351	0.07
75	6	18	1	57	6	1998	1	0.325	0.1
33	7	19	1	14	1	1991	1	1.067	0.07
59	5	17	1	42	1	1985	1	0.292	0.02
52	6	19	1	33	4	1973	1	0.251	0.13
43	4	19	1	24	1	1959	1	0.228	0.04
60	5	21	1	39	1	1930	1	0.056	0.03

Table 2. *CRS model dating - Valea Vinţului river*

Conc. ^{210}Pb (Bq/kg)	±	Conc. ^{226}Ra (Bq/kg)	±	Uns. ^{210}Pb (Bq/kg)	±	Age from now	±	Sed. rate g/cm^{2}*y	±
25	4	19	1	**6**	1	2012	2	3.724	0.168
94	6	18	1	**76**	6	2008	2	0.257	0.085
60	7	19	1	**41**	1	1993	2	0.303	0.024
23	5	17	1	**6**	1	1990	2	1.863	0.167
31	6	19	1	**12**	2	1988	2	0.873	0.201
33	4	19	1	**14**	1	1984	2	0.661	0.071
50	5	21	1	**29**	1	1973	2	0.228	0.034
23	6	22	1	**1**	1	1971	2	6.185	1
35	7	22	1	**13**	1	1967	2	0.417	0.077
33	3	21	1	**12**	1	1952	2	0.280	0.083
23	8	20	1	**3**	1	1940	2	0.784	0.333
23	5	22	1	**1**	1	1936	2	2.057	1
38	4	21	1	**17**	1	1918	2	0.069	0.059

RESULTS AND DISCUSSION

After applying the CRS model, the results for Valea Vintului river can be seen in Table 1 obtained results show six years when sedimentation rate was more evident. To test the reliability of results obtained, this model was applied also for the reference sample from Pian river meadow (Table 1) where since 1986 hydrometric measurements were recorded.

The nonlinearity of unsupported ^{210}Pb profile is due to interruption of the normal process of sedimentation, variation of the sediment concentration or sediments mixing through physico-chemical and biological processes.

Applying the model CRS, the age of each sediment layer and sedimentation rate variation over the years was determined in the two taken cores. Values variations obtained for radionuclide concentrations in sediment layers can be seen illustrated below (Fig. 1) for Valea Vintului and Pian rivers.

^{210}Pb concentration profile shows a decrease exponentially with the depth at the bottom of the column, which is typical for areas with a constant sedimentation rate. On the top of the sediment, ^{210}Pb concentration is decreasing due to dilution of atmospheric deposition after floods and sedimentation rate increase.

For each layer of sediment from the column of around five centimeters thick, for each sampling point was calculated the average sedimentation rate which is defined as the average for the period, determined by ^{210}Pb and ^{210}Po radionuclide concentrations.

In the following charts (Fig. 2) it can be seen the sedimentation rate determined by ^{210}Po measurement using alpha spectrometry in meadows Pian, respectively Valea Vintului.

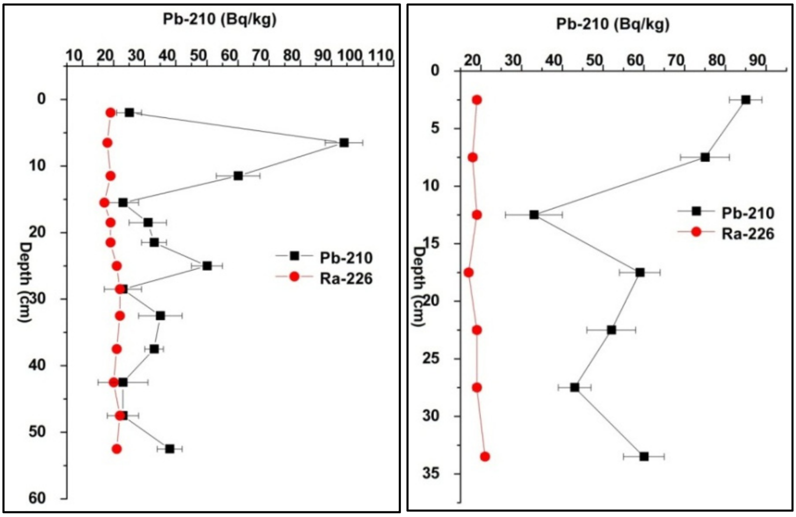

Fig. 1. *Rarionuclides concentrations in sediments - Valea Vinţului and Pian rivers*

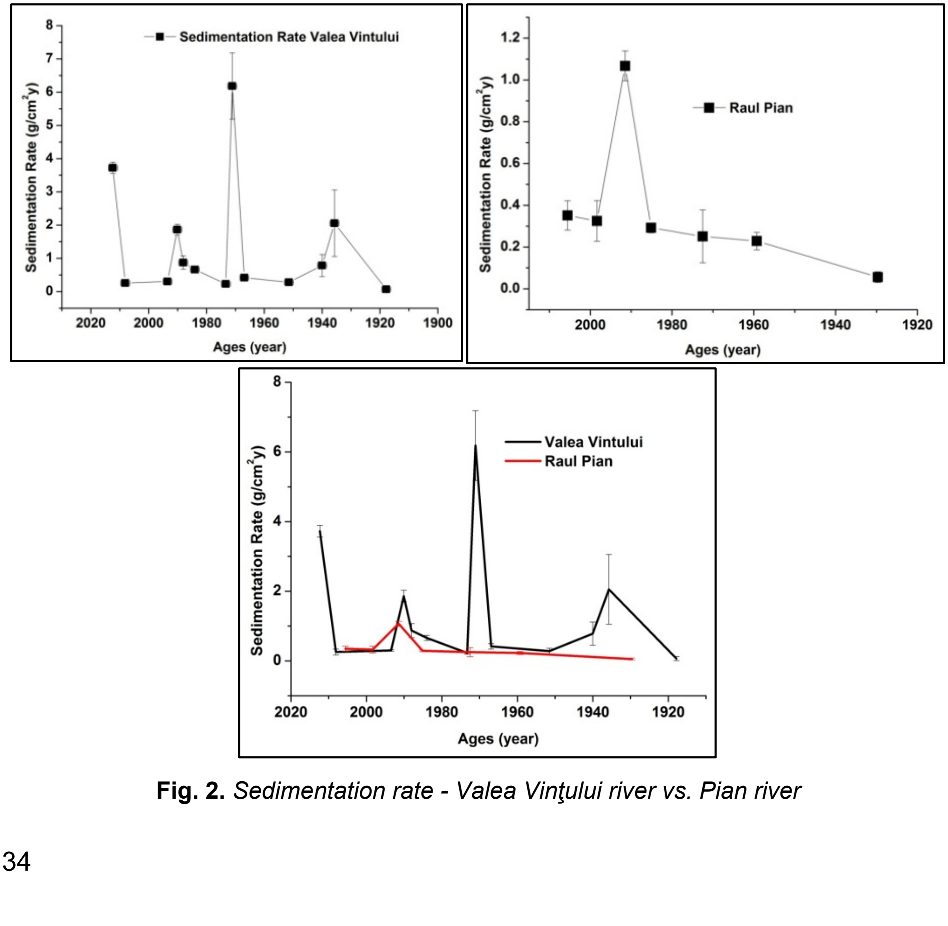

Fig. 2. *Sedimentation rate - Valea Vinţului river vs. Pian river*

For sedimentation rate values from 1.863 ± 0.167 up to 6.185 ± 1 were obtained emphasizing the years with major events (1936, 1971, 1990, 2012; ± 2 y error) that confirm periods of floods from the literature (Mustăţea, 2005). These relatively high values of alluvial sedimentation rate indicate the magnitude of erosional processes from Valea Vintului river basin. In figure 2 is shown sedimentation rate in both floodplains rivers and it can be seen that within the period 1980-2000, using the CRS calculation model is highlighted the flood from 1990. Because of possible disturbances in the river Pian the rest of the values obtained for sedimentation rate in this sampling point cannot be considered representative for the entire meadow. However, taking into account historical mentions (Mustăţea, 2005) of major hydrological events in this area, it can be considered that the method is effective for dating sedimentation rate in meadows.

CONCLUSIONS

Major hydrological phenomena on Valea Vintului and Pian river floodplains were emphasized by high values obtained for sedimentation rates (1.863 ± 0.167 up to 6.185 ± 1) indicating important erosional processes in the studied area.

This study demonstrates that radioisotopic methods represent important tools that can be applied for fully understanding the formation of wetlands, development and operation in the region, highlighting the major hydrological episodes. Large floods are quasi-permanent, causing both large rivers and small streams having a variable distribution in time and space. Hydrological forecasts and operation of reservoirs on major rivers in particular may be ways of defense against floods by taking measures to avoid or eliminate the damage and casualties.

The entire work is intended as a clear example of the complexity of natural phenomena showing that the application of radio-chronological methods can provide valuable information on the process of sedimentation, which can be used to gain a better understanding of environmental changes in the drainage basin, despite the reduced number of reference cores that provide higher statistical confidence.

AKNOWLEDGEMENTS

The authors gratefully acknowledge the support of Water Management System Alba for the reports provided and Kelemen Szabolcs, Reizer Edina and Simon Hedvig that showed valuable assistance in the field and laboratory.

REFERENCES

Appleby, P., Oldfield, F., 1978, The calculation of lead-210 dates assuming a constant rate of supply of unsupported 210Pb to the sediments. *Catena* ***5***, pp. 1-8.

Appleby, P. 2001, Chronostratigraphic techniques in recent sediments. In W. Last, J. Smol (Eds), *Tracking Environmental Change Using Lake Sediments. Volume* **I***: Basin Analysis, Coring, and Chronological Techniques*, 171-203. Dordrecht: Kluwer Academic Publishers.

Begy, R.C., Cosma, C., Horvath, Z. 2008, Sediment accumulation rate in the Red Lake (Romania) determined by Pb-210 and Cs-137 radioisotopes. *Earth and Environmental Physics*, pp. 943-949.

Begy, R.C., Cosma, C., Timar, A. 2009, Recent changes in Red Lake (Romania) sedimentation rate determined from depth profiles of ^{210}Pb and ^{137}Cs radioisotopes. *Journal of Environmental Radioactivity* **100** (8), pp. 644-648.

Begy, R.C., Timar-Gabor, A., Somlai, J., Cosma, C. 2011, A sedimentation study of St. Ana Lake (Romania) applying the ^{210}Pb and ^{137}Cs dating methods. *Geochronometria*, pp. 93-100.

Birch, G., Olmos, M., Lu, X. 2012, Assessment of future anthropogenic change and associated benthic risk in coastal environments using sedimentary metal indicators. *Journal of Environmental Management* ***107***, pp. 64-75.

Du, P., Walling, D. 2012, Using ^{210}Pb measurements to estimate sedimentation rates on river floodplains. *Journal of Environmental Radioactivity* ***103***, pp. 59-75.

Edgington, D.N., Robbins, J.A. 1975, Determination of the activity of Lead-210 in sediments and soils.

Humphries, M.S., Kindness, A., Ellery, W.N., Hughes, J.C., Benitez-Nelson, C.R. 2010, ^{137}Cs and ^{210}Pb derived sediment accumulation rates and their role in the long-term development of the Mkuze River floodplain, South Africa. *Geomorphology* **119**, pp. 88-96.

Kiss, T., Oroszi, V.G., Sipos, G., Fiala, K., Benyhe, B. 2011, Accelerated overbank accumulation after nineteenth century river regulation works: A case study on the Maros River, Hungary. *Geomorphology* **135**, pp. 191–202.

Masque, P., Isla, E., Sanchez-Cabeza, J., Palanques, A., Bruach, J., Puig, P., Guillen, J. 2002, Sediment accumulation rates and carbon fluxes to bottom sediment at the Western Bransfield Strait (Antarctica). *Deep-Sea Research II* **49**, pp. 921-933.

Mustăţea, A. 2005, *Viituri excepţionale pe teritoriul României. Geneză şi efecte.* Bucureşti: Tipografia SC ONESTA.COM PROD 94 SRL.

Oldfield, F., Appleby, P. 1984, Empirical testing of 210Pb-dating models for lake sediments. In: Hayworth EY and Lund JWG (Eds). Lake Sediments and Environmental History. *Leicester University Press*, pp. 93-124.

Robbins, J. 1978, Geochemical and geophysical applications of radioactive lead. *Biogeochemistry of Lead in the Environment*, pp. 285–393. Amsterdam: Elsevier Scientific.

Sanchez-Cabeza, J., Ruiz-Fernandez, A. 2012, ^{210}Pb sediment radiochronology: An integrated formulation and classification of dating models. *Geochimica et Cosmochimica Acta* **82**, pp. 183–200.

Sert, I., Yener, G., Ozel, E., Pekcetinoz, B., Eftelioglu, M., Gorgun, A. U. (2012). Estimation of sediment accumulation rates using naturally occuring ^{210}Pb models in Gülbahçe Bay, Aegean Sea, Turkey. *Journal of Environmental Radioactivity 107*, 1-12.

Szmytkiewicz, A., Zalewska, T. 2014, Sediment deposition and accumulation rates determined by sediment trap and ^{210}Pb isotope methods in the Outer Puck Bay (Baltic Sea). *Oceanologia,* **56**, pp. 85-106.

Tylmann, W. 2004, Estimating recent sedimentation rates using Pb-210 on the example of morphologically complex lake (Upper lake Radunskie, N Poland). *Geochronom* **23**, pp. 21-26.