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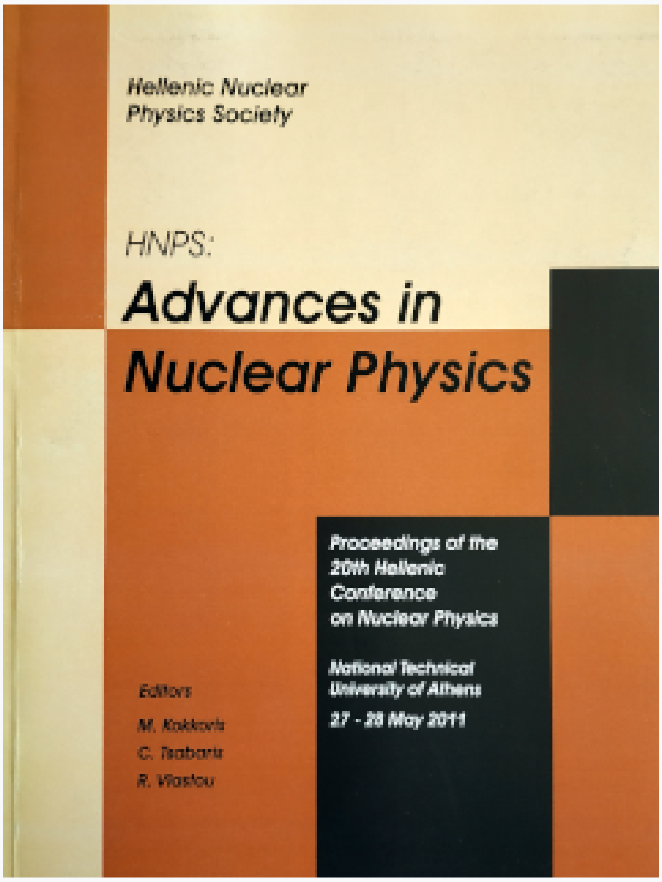

Recent sedimentation rates using 210Pb and 137Cs vertical profiles of core sediments at the Gulf of Corinth, Litochoro Coast and Marmara Sea

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Recent sedimentation rates using ^{210}Pb and ^{137}Cs vertical profiles of core sediments at the Gulf of Corinth, Litochoro Coast and Marmara Sea

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Abstract

In this work, core sediment samples up to 50 cm have been collected from three different marine environments; Gulf of Corinth, Gulf of Thermaikos, specifically from Litochoro Coast and Lake Uluabat from the wider region of Black Sea. Natural (^{210}Pb) and anthropogenic (^{137}Cs) radionuclides in the samples were measured using an HPGe detector, calibrated for sediments geometry. The vertical distribution of ^{137}Cs and ^{210}Pb was used to determine the sedimentation rate. The results were 0.56 cm/year for the Gulf of Corinth and 0.54 cm/year for the coast of Litochoro. In the case of the lake Uluabat the sedimentation rate was 0.41 cm/year.

Keyword: Sedimentation Rate; ^{137}Cs; ^{210}Pb; Black Sea; Aegean Sea

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1. Introduction

The artificial radionuclide ^{137}Cs (with half life of 30.05 ± 0.08 years) is observed in the marine environment due to atmospheric nuclear tests, accidents in nuclear plants and discharges of radioactive wastes. Commonly, in the vertical activity concentration profiles of marine sediment cores ^{137}Cs fallout causes an old peak, which is attributed to the incidence of nuclear weapons tests, carried out during the 1950's and 1960's and resulting in a maximum fallout in 1963 [1]; and a new peak, which corresponds to the Chernobyl accident, in 1986. In many cases, ^{137}Cs is hardly observed from sediments due to its low concentration, the variation of residence time in the seawater and the mobility within sediments caused by diffusion processes [2].

The natural radionuclide ^{210}Pb is a daughter of the primordial radionuclide ^{238}U decay series. ^{222}Rn is produced in rocks and soils as a result of the decay of ^{226}Ra, a member also of the ^{238}U series. A portion of the ^{222}Rn diffuses into the atmosphere where it decays to ^{210}Pb. The ^{210}Pb produced under these conditions is not supported by ^{226}Ra and decays with a half life of 22.23 ± 0.12 years [3]. The variation through time of this unsupported ^{210}Pb fraction can be used as dating method for the calculation of the sedimentation rates in soils. The ^{210}Pb dating method was firstly applied to the marine sediments by Koide et al. (1972) [4].

In this work, three core sediments were analyzed for ^{210}Pb and ^{137}Cs activities in order to determine experimentally the sedimentation rates in the regions of closed aquatic compartments (like Marmara Sea and Corinth Gulf) as well as of a coastal zone that interacts with river estuary (Litochoro region at the Central Aegean Sea).

2. Experimental

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Study Areas

The Gulf of Corinth is a 115 km long and maximum 30 km wide, semi-enclosed, marine basin located in Central Greece. It is separated from the open marine environment to the west by the Rion-Antirion strait and since 1893 to the east by the Isthmus of Corinth. This basin separates the Peloponnesus (to the south) from continental Greece (to the north) and is developed perpendicular to the Alpine Hellenides mountain chains. The sampling at the Gulf of Corinth took place on February 2007 at a depth of 780 m and the length of the collected core was 48.5 cm.

The Thermaicos Gulf is a gulf of the Aegean Sea located immediately south of Thessaloniki, east of Pieria and Imathia, and west of Chalkidiki. Near Thessaloniki, the length (north-south) of the gulf is about 100 km, while its width (east-west) is about 5 km. The length of the gulf in its northern part (from its northern extent down to "megalo emvolo" cape) is estimated to stretch 15 km, while after "megalo emvolo" cape towards the south, its length extents a further 50 km. Cape Kassandra lies to the southeast end of the gulf.

The coast of Litochoro is one among the gulf's sea sides. The rivers emptying into the gulf are the Pineios, Aliákmon, Loudias, Gallikos and Axios; several streams, including one near Pydna, also empty into the gulf. The core sample from Litochoro was taken from a depth of 40 m and had a length of 50 cm

Lake Uluabat is a freshwater lake in the vicinity of Bursa, Turkey. It is a large lake, covering an area of between 135 and 160 km² depending on the water level, but very shallow, being only 3 m deep at its deepest point. The lake contains eight islands and one more that, depending the water level, appears to be an island or a peninsula. The largest island is called Halilbey Island. In the southwest side of the lake is the Mustafa Kemal Paşa River estuary, which has formed a silty delta. Water exits from the lake through the Ulubat stream, flowing to the west, and reaches the Sea of Marmara via the Susurluk River. The sampling at the Lake Uluabat took place on June 2007 and the length of the collected core was 16 cm.

Fig. 1. Locations map showing the sampling sites in Gulf of Corinth (Cor82b), Thermaikos Gulf (LT-10) and Lake Uluabat (ΠΝΚΤ-ΚΙ-07).

Materials and Methods

Three sediment cores from the sampling stations were taken to the laboratory and kept in a temperature of -5°C, to ensure that the interstitial water remain at the corresponding level. Then the column sediments were sectioned into slices of 0.5 up to 2 cm thickness and all samples were dried out at 60°C for two days. The water content was determined from the wet and dry weights of each sample.

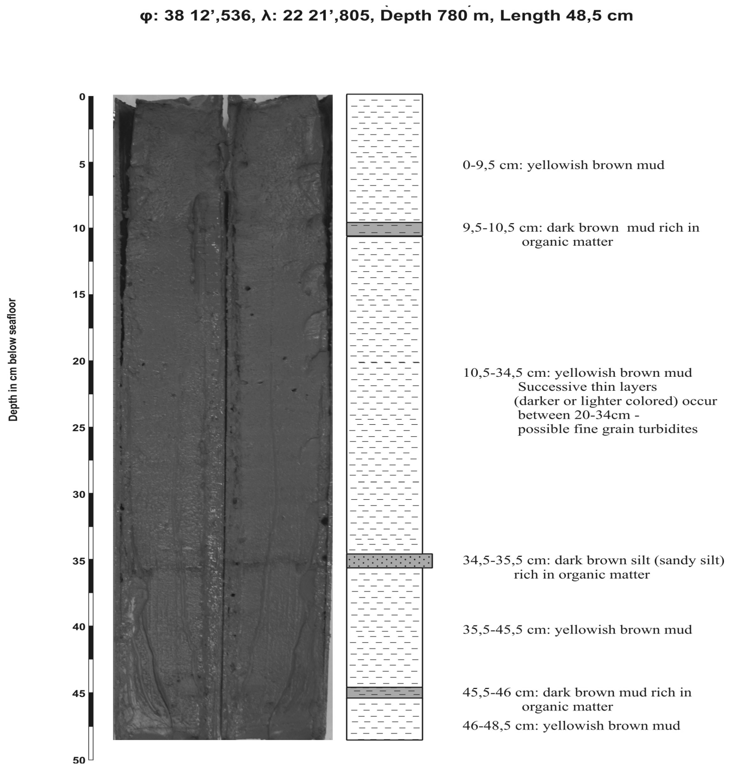

Fig. 2. Photograph of the core from Corinth Gulf.

To ensure the homogeneity of the samples for the gamma ray spectrometry measurements, an electric sieve was used to a grain size less than 0.5 mm. Thereafter, the sediments were placed in cylindrical plastic containers, with a diameter of 5 cm, for further measurements. The same geometry was used for all samples. The activity was measured with a 50% relative efficiency HPGe detector (GEM-FX8530P4, ORTEC®). The measuring time was 24 h. Every 5 days a 24 h background spectrum was recorded. In order to minimize any systematic errors, a phantom sample containing only inert material was used for the background spectra, thus simulating the absorption of the ambient background radiations taking place in its passage through the samples. The energy and efficiency calibration were performed using certified sources of ^{152}Eu (93%)/ ^{154}Eu (7%) prepared at NCSR ''Demokritos''.

The measured data were analyzed using the SPECTRW software [5]. A typical spectrum of a sample from the studied region is depicted in Fig.3. The result of the analysis with SPECTRW is the number of counts detected from the HPGe in each photo-peak. Using these counts, we can calculate the activity in Bq/kg from the equation:

$$Activity = \frac{cps}{m \cdot eff \cdot I_{\gamma}} \qquad (1)$$

where *cps* is the number of counts to the time of measurement (24 h), *m* is the mass of each sample in kg, *eff* the efficiency of the detector and I_{γ} (%) is the intensity of each gamma ray.

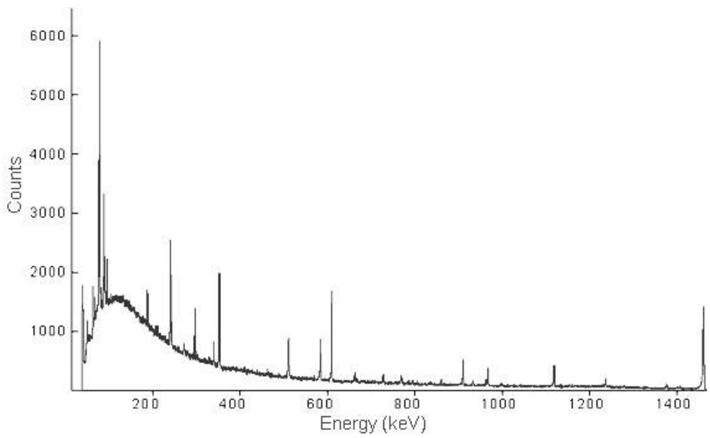

Fig. 3. Typical gamma ray spectra.

The sediment depth distribution for ^{137}Cs exhibits two typical photo-peaks that correspond to Chernobyl accident (1986) and the atmospheric nuclear weapon tests (maximum fallout 1965). Sedimentation rate using ^{137}Cs is calculated from the ratio between the peak's depth to the time of the deposition. In addition, their depth distance offers the sedimentation rate at the specific period.

The sedimentation rate can also be calculated from the excess (unsupported) activity (C) of ^{210}Pb along with depth (x) according to the Constant Flux-Constant Sedimentation (CF:CS) model :

$$C(x) = C_0 e^{\frac{-kx}{r}} \qquad (2)$$

where C_0 is the surficial unsupported specific activity (Bq/kg), k is the ^{210}Pb radioactive decay constant (0.03114 y^{-1}), x is the depth of sediment (cm) and r is the sedimentation rate of the core (cm/y).

The dependence of the logarithm of the unsupported ^{210}Pb specific activity with depth shows a linear correlation and the mean sedimentation rate is then calculated from the slope (k/r) of the fitted line.

3. Results and discussion

This radiogeological study was carried out to provide data for the radioactivity levels as well as for sedimentation rates in two Hellenic regions (Gulf of Corinth and Litochoro Coast) and one aquatic compartment in Turkey (Lake Uluabat). This work intends to apply radiometric vertical profiles of ^{210}Pb and ^{137}Cs in order to provide a basis for an assessment of the sedimentation rates of the specific regions. The results are divided according to the type of the radionuclide and the study areas. .

^{137}Cs is present due to the radioactive fallouts in the 50's, the 60's and the Chernobyl accident (1986). The measured values of mass activities of ^{137}Cs in the sediments of the Hellenic regions exhibit typical activities of coastal sediments [6]. However, in the lake of Uluabat the values are exhibit also typical values compared to east Mediterranean Sea measurements [6]. The measured core activity of ^{137}Cs along with the depth of each profile is plotted in Fig. 4, 5 and 6 (Gulf of Corinth, Litochoro Coast and Uluabat Lake, respectively). The mass activity of ^{137}Cs exhibits two peaks in most cases corresponding to the Chernobyl accident (1986) as well as to the year of nuclear weapons tests (1963). The trend of the activity variation increases from surface until the period of Chernobyl accident and then decreases till the nuclear tests period. The mean sedimentation rates for Gulf of Corinth are 0.31 cm/y (from 2007 to 1986) and 0.56 cm/y (from 1986 till 1963). The mean sedimentation rates in the regions of Litochoro and Uluabat Lake are 0.54 cm/y and 0.41 cm/y, respectively.

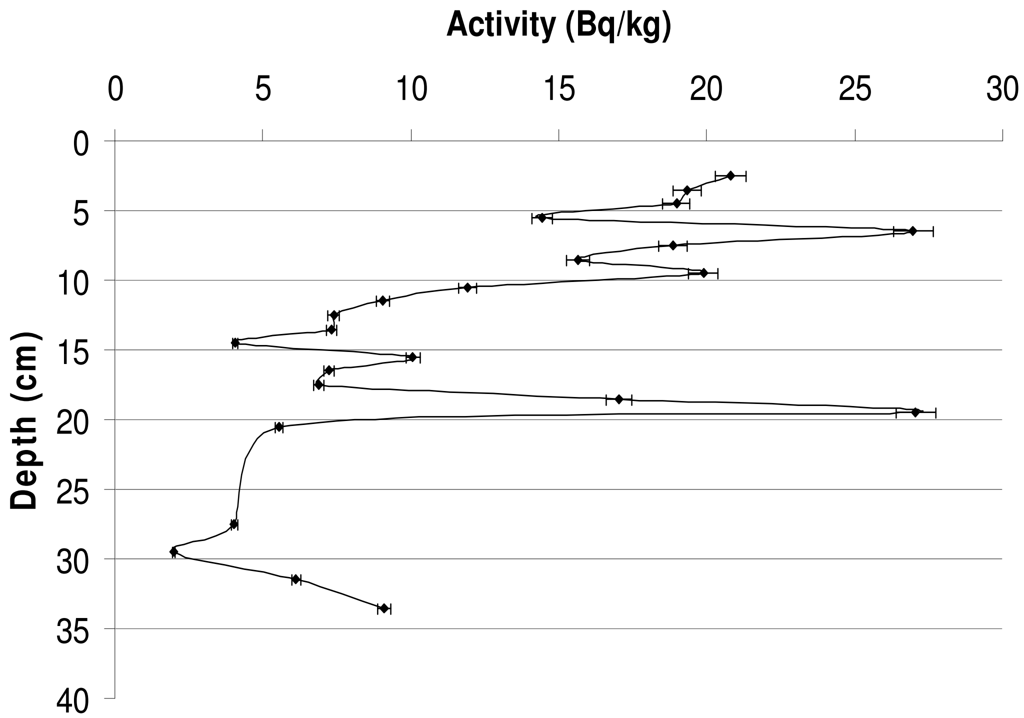

Fig. 4. Vertical distribution of activity of ^{137}Cs along depth in core from Gulf of Corinth.

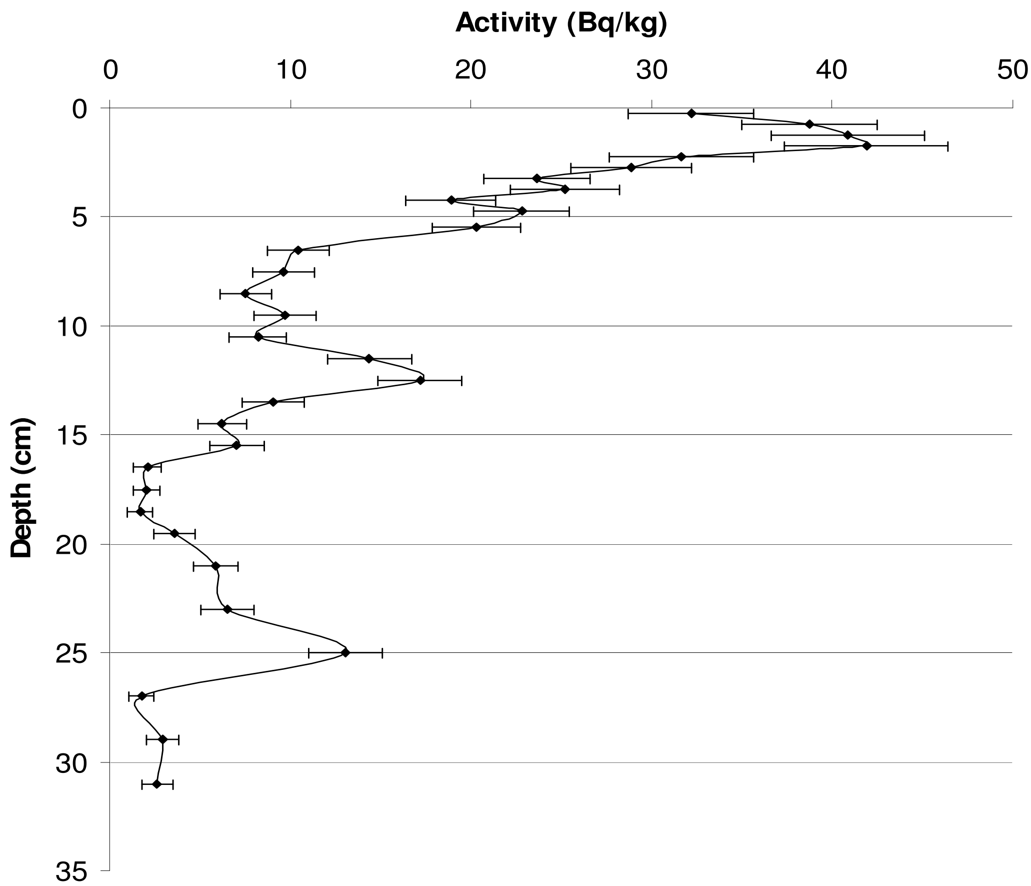

Fig. 5. Vertical distribution of activity of ^{137}Cs along depth in core from Litochoro Coast.

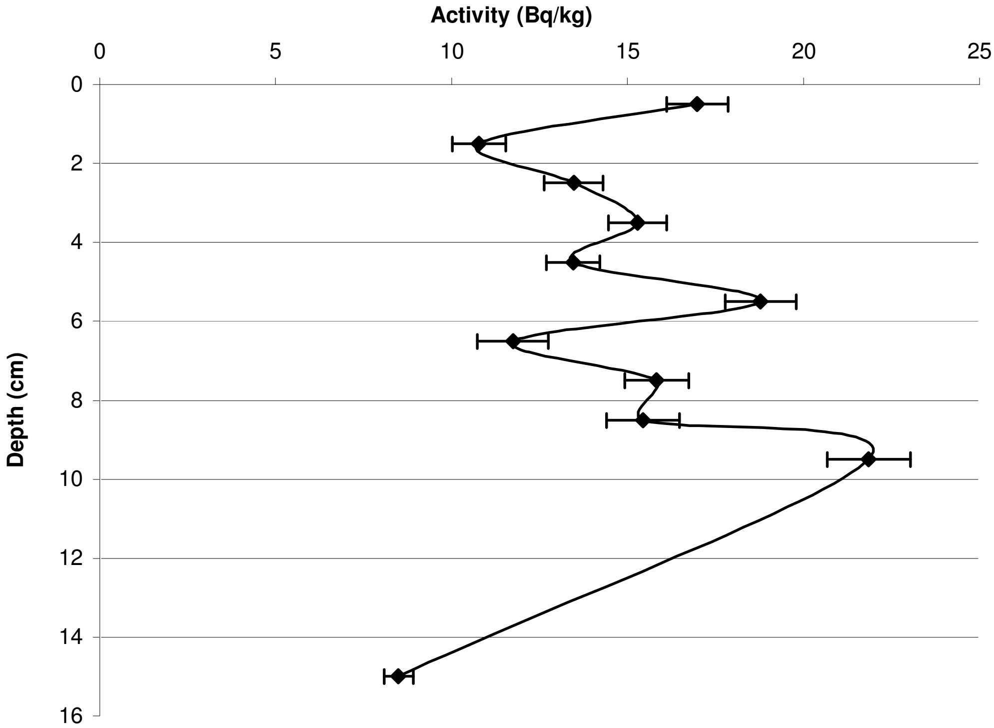

Fig. 6. Vertical distribution of activity of ^{137}Cs along depth in core from Uluabat Lake.

Sedimentation rates were also determined for sediment cores using the ^{210}Pb radiometric method. The logarithmic unsupported ^{210}Pb activity is plotted along with the depth of the core (see Fig. 7) and then the sedimentation rate is calculated using the decay constant of the ^{210}Pb. The Fig.7 depicts values from the Litochoro region. The slope of the line provides a sedimentation rate of 0.58 cm/y. In the region of Uluabat Lake, the ^{210}Pb values are depicted in Fig. 8. The slope of the line provides a sedimentation rate of 0.44 cm/y. However, the results at the Gulf of Corinth are not given due to the fact that the sediments were taken from 700 m depth, reducing due the big depth the materials fast transport for applying the method.

The relative uncertainty of ^{137}Cs is varying form 4% and is mainly due to compaction effects. The relative uncertainty of ^{210}Pb is 6% and is mainly due to (i) the subtraction of the unsupported form the supported activity in order to determine the excess activity (^{210}Pb minus ^{226}Ra) and due to (ii) the compaction effects of the cores.

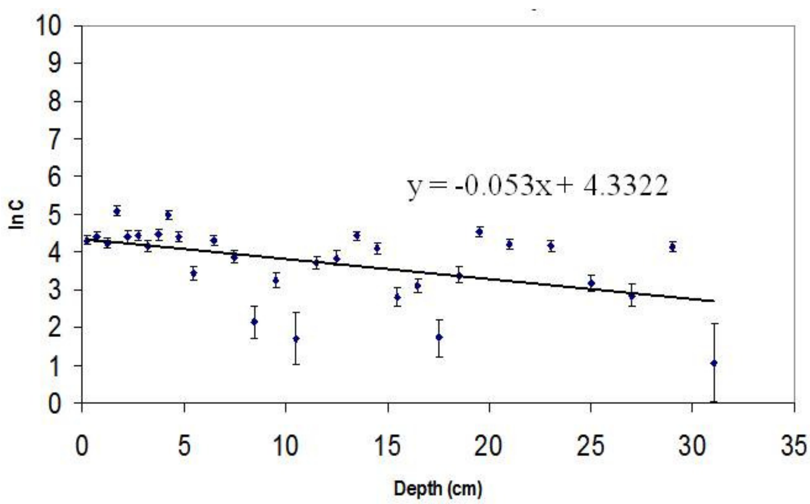

Fig. 7. The logarithmic variation of the unsupported ^{210}Pb specific activity as a function of the depth in the region of Litochoro Coast.

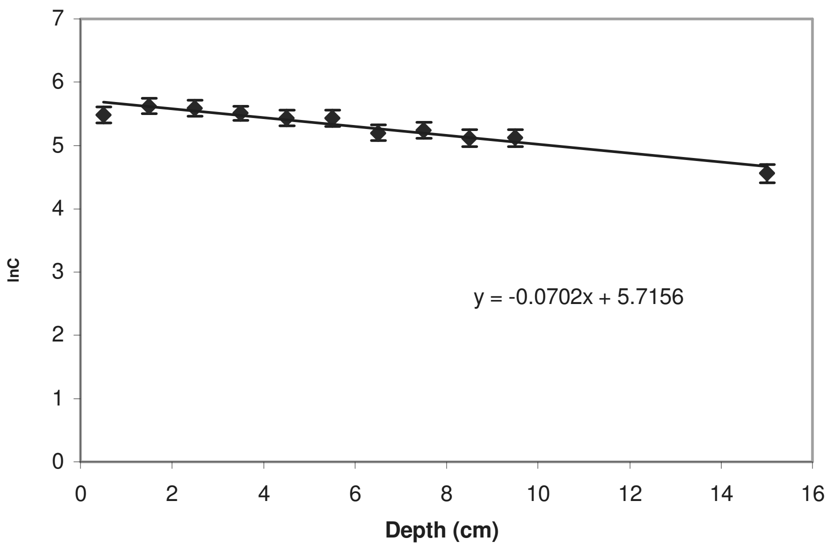

Fig. 8. The logarithmic variation of the unsupported ^{210}Pb specific activity as a function of the depth in the region of Uluabat lake.

The comparative results of the two methods are given analytically according to the area of study.

Gulf of Corinth: the first peak appeared at 6.5 cm and the second at 19.5 cm depth exhibiting sedimentation rates of 0.31 cm/year from 2007 till 1986, 0.56 cm/year from 1986 till 1963.

Litochoro Coast: the first peak appeared at 12.5 cm and the second at 25 cm exhibiting a mean sedimentation rate of 0.54 cm/year. The sedimentation rate using ^{210}Pb is 0.58 cm/year.

Uluabat Lake: in the sample from Black Sea, the first peak appeared at 9.5 cm exhibiting a mean sedimentation rate of 0.41 cm/y. The sedimentation rate using ^{210}Pb is 0.44 cm/year.

4. Conclusions

The measured mass activities of ^{137}Cs were up to 42 Bq/kg for Litochoro Coast, 22 Bq/kg for Uluabat Lake and up to 27 Bq/kg for Gulf of Corinth, respectively. Additionally, dating studies have been performed using ^{137}Cs and ^{210}Pb as tracers for the sedimentation rate calculations. The results using the two tracers are in satisfactory agreement.

Rivers affect Litochoro Coast and thus the sedimentation rate of the studied ecosystem is enhanced compared to north Aegean Sea (0.25-0.35 cm/year). Moreover, in the Gulf of Corinth the high sedimentation values from 1986 till 1963 are attributed to the frequency of earthquake events during that period.

Acknowledgments

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