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Determination of sedimentation rates in Izmir Bay using ^{210}Pb radionuclide

Mutlu İçhedef[1] · Güngör Yener[1] · Hasan Baha Büyükışık[2] · Ebru Yeşim Özkan[2]

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Abstract In this study, using the constant rate of supply model, sedimentation rates of Izmir Bay were calculated and discussed. For this purpose, eight sediment cores were collected from inner part of the bay and sedimentation rates were calculated from vertical distribution of ^{210}Pb. ^{210}Pb activities were determined indirectly from ^{210}Po activities. Sedimentation rates ranged from 0.10 to 0.52 cm/year. The highest sedimentation rates were determined in stations close to the Poligon stream. It was concluded that main transporting mechanism for sediments is river and streams in the area. In addition, sediment cores taken from the harbor were mixed due to bioturbation, water circulation and/or other factors.

Keywords Sedimentation rates · İzmir Bay · ^{210}Pb · ^{210}Po

1 Introduction

Marine sediments and sedimentation rates have been investigated for decades [1–7], for establishment of chronologies, development of history of erosion and pollution, investigations of ecological and coastal management. Madsen et al. [8] reported that sedimentation rates give information about present trends on the sea level changes. Thus, estimates of mass accumulation rate (MAR) and sedimentation rate (SR) are useful to understanding sediment routes. The main sources of sedimentation are the movement of particles. This movement is mainly related with terrestrial input. In addition to these sources, another way for transport of lithogenic particles is associated with deep-sea sediments [9].

As a member of uranium decay series ^{210}Pb ($t_{1/2}$ = 22.3 year) is an ideal radioisotope to determine sedimentation rates and for dating sediment layers within a period of 150 years. This time period includes both the pre-industrial and industrial eras in the world; hence, the importance of the method for studying the environmental changes caused by human activity [10]. ^{210}Pb is produced in the atmosphere as a daughter of ^{222}Rn [1, 11]. Main sources of ^{210}Pb in sediments are supported and unsupported components of ^{210}Pb. The supported ^{210}Pb is a product of the ^{226}Ra in sea and lake sediments. The unsupported ^{210}Pb is called as excess ^{210}Pb which is formed in atmosphere. Therefore, surface sediments have higher ^{210}Pb concentration, and ^{210}Pb levels decrease with depth. This means sedimentation rates and date of sediment layers can be calculated from vertical profiles of ^{210}Pb in cores [11].

The main goal of this study is to determine sedimentation rates in the inner part of Izmir Bay using the vertical profile of ^{210}Pb. The bay is adjacent to the third crowd city in Turkey, and Izmir harbor is sited on the inner part of the bay. To our knowledge this study is the first attempt to determine sedimentation rates in the inner bay.

✉ Mutlu İçhedef
ichedef@yahoo.com

[1] Institute of Nuclear Sciences, Ege University, 35100 Izmir, Turkey

[2] Faculty of Fisheries, Ege University, 35100 Izmir, Turkey

2 Materials and methods

2.1 Study area

İzmir Bay is one of the largest bays of the Mediterranean Sea. It is surrounded by the İzmir Metropolitan Municipality. Total surface area of the bay is over 500 km^2 and water capacity of the bay is approximately 11.5 billion m^3. Izmir Bay consists of three parts: the inner, middle and outer bays. The outer bay is located between Karaburun and Foça and is around 20 km wide. The inner bay is the smallest (57 km^2) and shallowest part of the bay. The water depth decreases from outer bay to inner bay [12, 13].

2.2 Sediment sampling

Sediment samples were collected with core sampler at eight locations (Table 1) in the inner bay in 2004 [14]. All samples were transferred to the laboratory, and sediment cores were cut into 4 cm thick using plastic tools. Each sediment layer was dried until a constant dry weight was obtained. Dried samples were disaggregated and passed through a 250-μm sieve.

Water content of samples was calculated by:

$$\text{Water content(wt.\%)} = (\text{water weight}/\text{wet sediment weight}) \times 100.$$

2.3 Radioisotope analysis and sedimentation rate calculation

^{210}Pb activity of each sediment layer was determined by alpha spectroscopy of its daughter ^{210}Po. Before alpha counting, radiochemical separation and electrochemical deposition process was applied to all samples. In this stage, each sediment sample (1 g of dry sediment) was digested in Teflon beaker with a mixture of concentrated HCl, HF and HNO_3 together with ^{209}Po yield tracer (0.1 Bq/mL, $E_{\alpha} = 4.88$ MeV, $t_{1/2} = 102 \pm 5$ year) on a hot plate. And then, ^{210}Po was spontaneously deposited onto copper discs in 0.5 M HCl in the presence of ascorbic acid to reduce of Fe^{3+} to Fe^{2+} [15]. The samples were transferred to 0.5 M HCl medium in the presence of ascorbic acid to reduce of Fe^{3+} to Fe^{2+}, and ^{210}Po in the solution was deposited on a copper disc using magnetic stirrer at 60 °C for 4 h [16]. The discs were washed with distilled water, and measurements of ^{210}Po were performed through its 5.30 MeV alpha particles by using passivated implanted planar silicon (PIPS) detectors. Collected samples were analyzed 2 years later [17, 18]. The activities of ^{210}Pb in the lowest layers of the cores were assumed to be in equilibrium with parent ^{226}Ra ($^{210}Pb_{sup}$). The activities of the layers were therefore subtracted from the total ^{210}Pb activities in order to compute the excess ^{210}Pb. ^{210}Pb geochronology is originated from the radioactive decay of ^{210}Pb with depth (m) in a sediment core. The decay of ^{210}Pb, $A(t)$, is ruled by the radioactive decay law:

$$A_{\text{Pb-210ex}} = A_0 e^{-\lambda t},$$

where A_0 is the ^{210}Pb activity (surface) at $t = 0$, and $\lambda = 0.03114$ year^{-1} is the decay constant for ^{210}Pb. For accepted constant sedimentation rates (CRS), time (t) is linked to depth m through $m = wt$, where w is the sedimentation rate. Consequently,

$$A_{\text{Pb-210ex}} = A_0 e^{-\lambda m/w}.$$

Sedimentation rate is estimated from an exponential decrease of ^{210}Pb, using $A(m)$ at depth m [19]. Using this CRS model, the slope of ln($^{210}Pb_{ex}$) profile distribution gave the sedimentation rates in cm per year (Fig. 1).

Table 1 Core locations and water depth of study area

Sites	Coordinates	Date	W.D.
C1	38°27′42″N, 27°08′54″E	24.02.2004	6
C2	38°27′15″N, 27°07′51″E	25.03.2004	11
C3	38°26′33″N, 27°07′52″E	20.01.2004	13
C4	38°26′36″N, 27°06′26″E	17.05.2004	15
C5	38°25′54″N, 27°06′24″E	20.01.2004	19
C6	38°25′18″N, 27°06′15″E	24.02.2004	17
C7	38°24′38″N, 27°05′29″E	17.05.2004	16
C8	38°25′15″N, 27°05′30″E	17.05.2004	17

W.D. water depth in meter

3 Results and discussion

The ^{210}Po activity concentration measured by alpha spectrometry corresponded to the total ^{210}Pb activity. $^{210}Pb_{tot}$ (total ^{210}Pb) activities of all cores were plotted against the depths (Fig. 2).

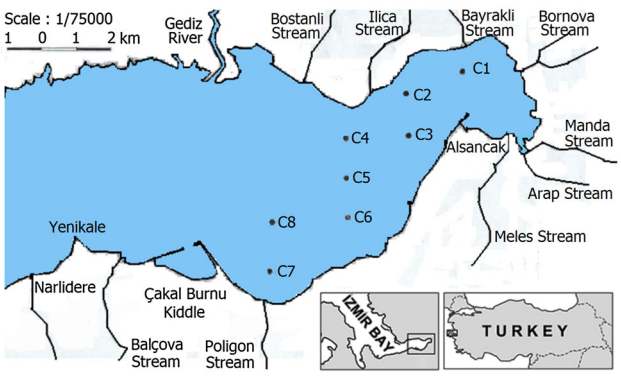

Fig. 1 Map of the study area

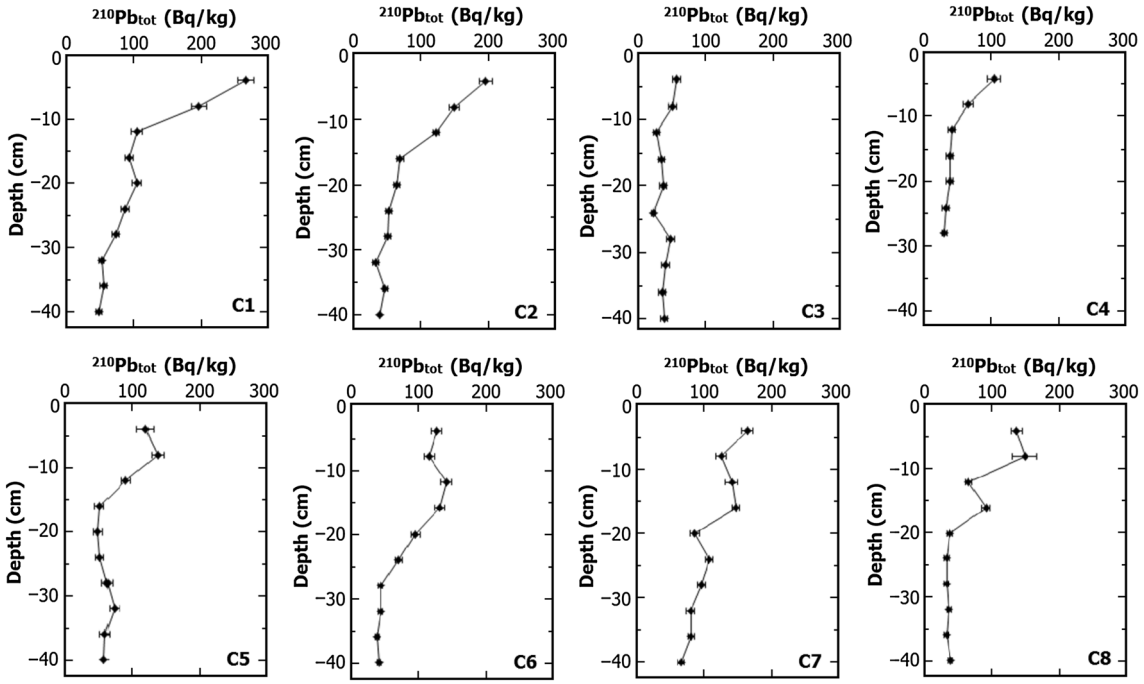

Fig. 2 ^{210}Pb (total ^{210}Pb) activities of all cores against the depths

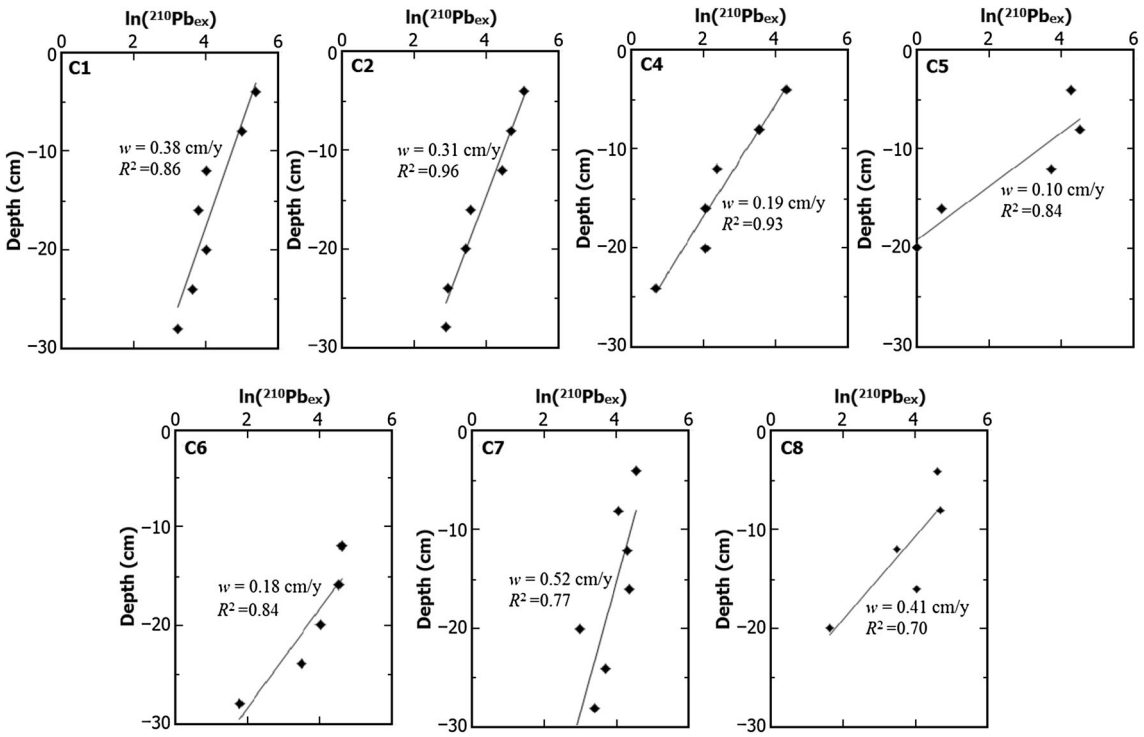

Fig. 3 Depth profiles ln(^{210}Pb$_{ex}$) in sediment profiles

The ^{210}Pb activity that remained constant below a certain depth is considered as supported ^{210}Pb (existence of ^{226}Ra in the sediment), and the unsupported ^{210}Pb(^{210}Pb$_{ex}$) profile distribution was obtained from the differences between the total ^{210}Pb and supported ^{210}Pb values. The ^{210}Pb$_{sup}$ activities determined for each core varied between

32 and 50 Bq/kg. The depth profiles ln($^{210}Pb_{ex}$) in sediments for eight cores are shown in Fig. 3.

In this study sedimentation rates varied from 0.10 to 0.52 cm/year. Our results and literature data are given in Tables 2 and 3, respectively. The sedimentation rates obtained for Izmir Bay are in the ranges of the reported values and agree well with the two locations in the Mediterranean Sea shown in Table 3. The highest sedimentation rates were found at C7 (0.52 cm/year) and C8 (0.41 cm/year). The two sites are in the southern portion of the bay and are affected by the Poligon stream which undergoes flooding every year. The lowest sedimentation rate was at C5 (0.10 cm/year) where the water is the deepest of all the sites, and it is located in the middle of the study area, being the farthest from river and/or streams.

Figure 4 shows the spatial distribution of $^{210}Pb_{tot}$ in surface sediments of the bay. $^{210}Pb_{tot}$ activities on sediment surfaces ranged from 56 to 268 Bq/kg. The distributions show that $^{210}Pb_{tot}$ was concentrated near at C1. This part of the bay has an enclosed environment and two streams drain into the area. Duman et al. [13] reported that sediment contamination level is extremely high in the inner part of the bay.

Table 2 Sedimentation rates of İzmir Bay

Station	Sedimentation rates (cm/year)
C1	0.38
C2	0.31
C3	–
C4	0.19
C5	0.10
C6	0.18
C7	0.52
C8	0.41

Table 3 A review of sedimentation rates (w) deducted from excess ^{210}Pb geochronology

Location	w (cm/year)
Marmara Sea [20]	0.09–0.19
Northwest Mediterranean [7]	0.01–0.60
Santa Monica Bay [21]	0.19–2.28
Thane Bay [22]	0.32–0.92
Tokyo Bay [23]	0.78–1.02
İse Bay [23]	0.32–0.56
Red Lake, Romania [24]	0.32–2.83
Atibaia River basin, Brasil [25]	0.16–1.32
SãPaulo, Brazil [26]	0.60–3.20
Baltic Sea [27]	0.14–0.31

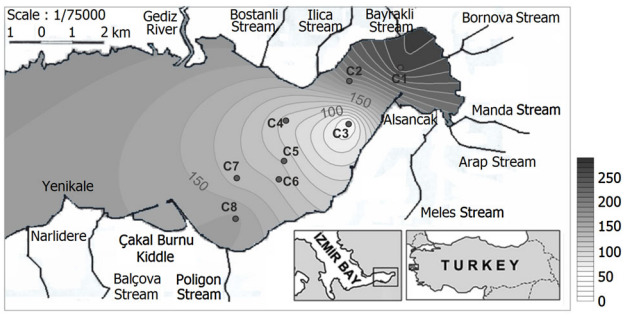

Fig. 4 Spatial $^{210}Pb_{tot}$ distribution of surface sediments

Our results show the highest $^{210}Pb_{tot}$ concentrations in surface sediments. But, in some sediment cores, the highest levels were detected in subsurface layers. It may be linked to effects of natural process like turbidity, surface water circulation and intense harbor activities. Nevertheless, ^{210}Pb concentrations decreased exponentially with depth in all cores except at C3, where the $^{210}Pb_{tot}$ distribution was nearly linear; $^{210}Pb_{tot}$ concentrations in every layer of this core being almost the same. Bioturbation can cause mixing that result in the linear ^{210}Pb distribution noted. In addition, water depths of the inner part of the bay are quite low. This is a problem that blocked large container ships from entering the bay; thus, the harbor area was dredged two times between 1976 and 1990. Collected sediments were dumped on the sea-bed at Goztepe Bay Dump Site and Hekim Island Dump Site, respectively [28]. These dredging activities may be another reason for the non-exponential distribution of ^{210}Pb in the core.

4 Conclusion

This study is planned to present preliminary data on sedimentation rates of Izmir Bay (inner part) and levels of ^{210}Pb of surface sediments. The study area (Izmir Bay) is surrounded by heavily populated landscape and intense industrial activity. Also, harbor activities make that bay an important location. Our results showed that highest sedimentation rates were obtained at C7 and C8, in the southern portion of the bay. They are affected by the Poligon stream which undergoes flooding every year. Low sedimentation rates were found at C4 (0.19 cm/year), C5 (0.10 cm/year) and C6 (0.18 cm/year), which are far away from the streams.

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