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Reconstruction of sedimentation rates based on the chronological framework of Lake Pykara, Tamil Nadu, India

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Abstract This work presents a piece of initial information about the estimation of the sedimentation rate for Lake Pykara. In this investigation, a chronological sequence of sediment core was set up dependent on ^{137}Cs and $^{210}Pb_{ex}$ analysis to study sediment accumulation rates in Lake Pykara. Caesium-137 (Cs) is an artificial radionuclide and is regularly utilized in building up the chronology of lake sediments in the Anthropocene period. The unsupported ^{210}Pb profile shows a non-exponential decline of ^{210}Pb activity with sediment depth. Sedimentation rates dependent on global atmospheric nuclear weapon maximum fallout of ^{137}Cs (1963) bolster the utilization of the consistent rate of ^{210}Pb supply (CRS) model in core sediments. The geochronology studies of the core were performed using the ^{137}Cs method, to evaluate the model of time changes in the sediment. The ^{137}Cs radioactivity was resolved directly by gamma spectrometry and fluctuated from 13.11 ± 1.3 Bq kg^{-1} for top layers to 1.21 ± 0.1 Bq kg^{-1} for the bottom of the core. Two trademark peaks of ^{137}Cs radioactivity identified with the global fallouts after atomic weapons testing and the Chernobyl mishap were observed and used to affirm the ^{210}Pb dating method. Radioactivity of $^{210}Pb_{ex}$ ranged from 8.00 ± 1.0 to 1.40 ± 0.1 Bq kg^{-1}. The mean sedimentation rate evaluated from both models was 0.71 ± 0.06 cm year^{-1}, while the estimated age of Lake Pykara was 514.08 years (^{137}Cs) and 521.43 years ($^{210}Pb_{ex}$), respectively.

Keywords Radiometric dating · Sedimentation rate · Lake Sediments · ^{210}Pb and ^{137}Cs isotopes · Computation of lake life

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Introduction

Lake ecosystems respond reasonably to the processes happening in the catchment regions. In this way, the data put away in the sediments are regularly valuable for analyzing the natural and man-made variations in their current environment. Reliable chronologies of lake sediments are primitive for rebuilding paleoclimatic variations and stipulating the Anthropocene epoch (Wang et al., 2019; Waters et al., 2016). This is particularly significant for sediments kept loaded over the last century, as this stage is continually observed for limnological and climatic varieties, delivering calibration for sedimentary proxies (Klaminder et al., 2012; Ojala et al., 2017). Subsequently, the investigation of sediments has incredible significance to the comprehension of the collaboration among man-made activities and aquatic frameworks. Moreover, the inception of comprehensive and precise chronologies for sediments, in other words, the assessment of the rate of sedimentation, is of primary significance to build up a range of insight into environmental progressions.

The most encouraging technique for the determination of sediment rate is employing the ^{210}Pb method, which is a natural radionuclide with a half-life of 22.3 years, resulted from the ^{238}U decay chain. It is sensible for the dating of various materials, for example, soils, sediments, ice, corals, mosses, and peat bogs up to 100–150 years (Appleby et al., 1997; Baskaran et al., 2014; Simon et al., 2017), oceanic and marine investigations (Sanders et al., 2011), and estimations of atmospheric fallouts, deposition, and contamination (Baskaran, 2011; Bikit et al., 2004; Krmar et al., 2013), following sedimentary processes for example transport, erosion, and mixing (Jeter, 2000; Sanders et al., 2006). Disequilibrium among ^{210}Pb and its parent isotope in the sequence, ^{226}Ra, emerges through the diffusion of the intermediary gaseous isotope radon-222. A small amount of the radon atoms, conveyed by the decay of ^{226}Ra in soil releases into the environment where they decay through a sequence of short-lived isotopes to ^{210}Pb. Because of its short residence time in the atmosphere, it is immediately sequestered in sediments and, over only a couple of months, it turns out to be perpetually fixed onto sediment particles (Guo et al., 2020; Tee et al., 2003; Xueshi et al., 2020). This radionuclide has been broadly used to build up persistent chronologies of the rate of sedimentation and pollutant loadings for a dating horizon of around seven half-lives, i.e., somewhere in the range of 120 and 150 years (Kirchner, 2011; Corcoran et al., 2018; Guo et al., 2020).

Widespread global dispersal of artificial radionuclide ^{137}Cs to the atmosphere resulted because of thermonuclear weapon tests ever since 1952 (Perkins & Thomas, 1980), which forms as another possibility of dating the lake sediments. During these events, the ^{137}Cs were released into the stratosphere and are distributed worldwide (Longmore, 1982). According to Longmore (1982), the fallout of ^{137}Cs is sturdily associated with local precipitation and the rate of loading. The most extreme measure of atmospheric ^{137}Cs was found during 1963 or 1964 (Robbins & Edgington, 1975), though records of significant incidental fallout of ^{137}Cs for instance the Chernobyl Accident (CA) and Fukushima Daiichi (FD) thermal energy station mishap have additionally been accounted for. CA happened at the Chernobyl reactor, USSR, on April 26, 1986 (Appleby, 2001; Sarı et al., 2018; Shah et al., 2020). FD accident caused by the tsunami because of the Tohoku earthquake on March 11, 2011, comprises huge emanation of radioisotopes into the environment (Butler, 2011; Chino et al., 2011). In the Northern Hemisphere, the deposition arrived at a significant level up to 1954 and shot up rapidly later. This method of ^{137}Cs dating has gotten progressively significant as a complementary tool to ^{210}Pb dating when setting up the age-depth models in recent sedimentary loadings (Appleby, 2001; Sanders et al., 2006; Kumar et al., 2007; Smol, 2008; Sari et al., 2018; Guo et al., 2020). The current research is mainly focused on assessing the sedimentation rate and computation of the life of the lake, which can help in lake management, determining existing conditions, and anticipating potential developments. The predicted sedimentation rates would pave the way for future palaeoenvironmental and palaeoclimatic studies on the high-altitude lakes and also valuable in understanding its productivity and life under normal environmental conditions.

Materials and methods

Study site

The study area forms a part of Toposheet 58 A/11 situated in the Nilgiri district of Tamil Nadu. It falls between latitude 11° 27′ 37.96″ N to 11° 24′ 17.45″ N and longitude 76° 36′ 21.20″ E to 76° 34′ 16.79″ E, located about 19 km from Ooty, Tamil Nadu (Fig. 1). The Pykara River is viewed as extremely consecrated by the Todas. It ascends at the Mukurthi crest, streams northward, and afterward swing toward the west after achieving the edge of the level. The waterway moves through Murkurti, Pykara, and Glenmorgan dams and structures some portion of an imperative hydroelectric power venture. Pykara flaunts very much secured, fenced sholas, Toda settlements, vast green knolls, and great natural life living space. The Pykara Dam falls and the repository pulls in numerous visitors. There were no stringent laws and regulations in placed to protect and save India's most pristine lakes in ancient times, and most of India's high-altitude lakes are tourist attracted places. As a result, more anthropogenic activities in these areas influence the enhancement of sediment concentration. Previous studies suggest that the Lake Pykara water is enriched with heavy metals like Cu, Zn, Mn, Ni, Cr, Al, Li, and K (Anusiya Devi et al., 2015). The

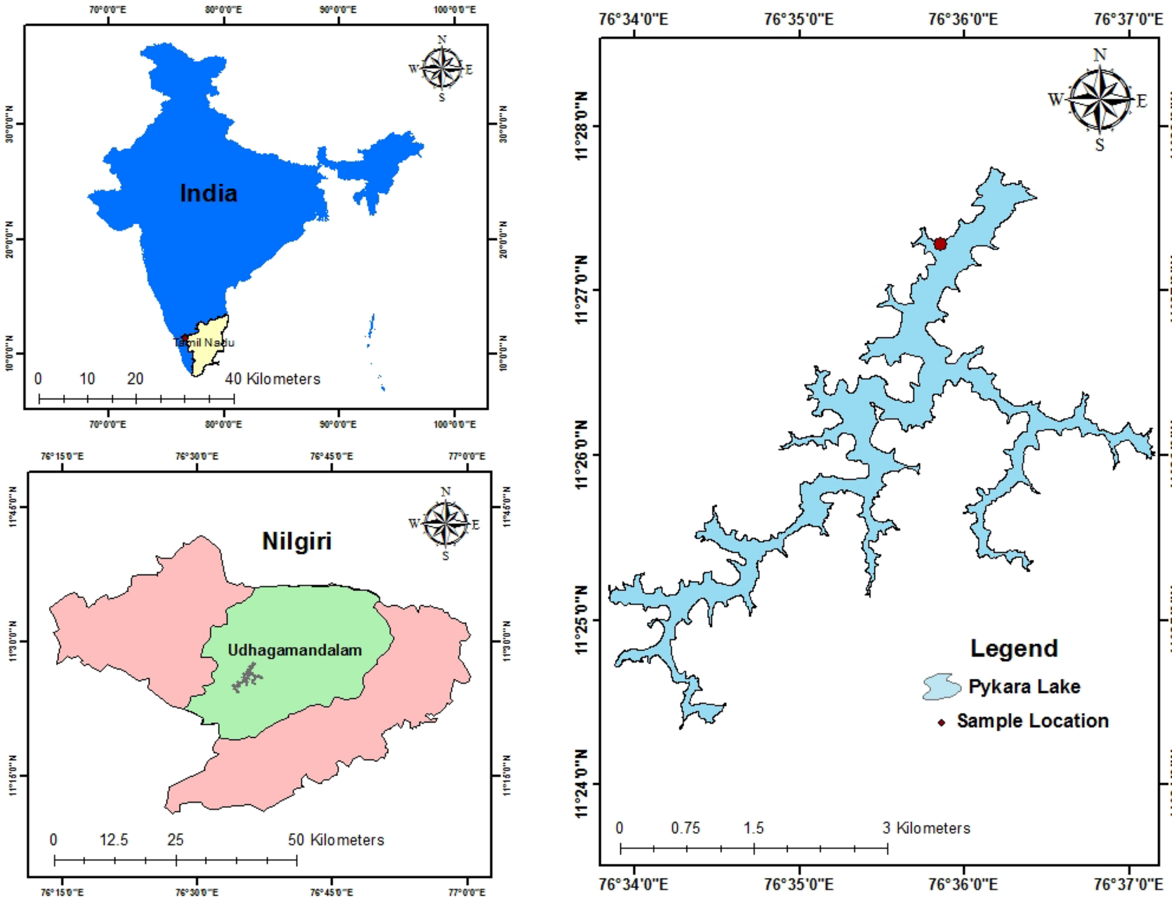


Fig. 1 Location map of the study area

study area experiences a subtropical monsoon climate, and the temperature fluctuates from 10 to 25 °C throughout the year. The mean annual precipitation is 1,920.80 mm and gets rainfall from both monsoons. Furthermore, the climatic conditions in the study area are favorable for rock weathering. Both the anthropogenic and climatic factors play a significant role in the input of the sedimentation into the Lake Pykara.

Core sampling and analysis

The sediment core was retrieved from Lake Pykara in January 2019. The core was collected using a gravity corer, and the core was recovered for 48 cm. The samples were carried to the research facility lab and stored in a freezer at 4 °C before being sliced at 1-cm intervals. Water content (%) and dry bulk density (DBD, g cm^{-3}) of the samples were determined by weighing the 1 cm slices of the sediment core before and after drying at 60 °C overnight.

Estimation of dry bulk density (ρ_d) and porosity (Φ)

The dry bulk density and porosity were measured from the natural moisture and grain specific gravity esteems utilizing the conditions of soil mechanics;

$$\rho_d = \frac{W_d}{V} \tag{1}$$

$$\varphi = 1 - \left(\frac{\rho_d}{\rho_p}\right) * 100 \tag{2}$$

where $\rho_{d,}$ W_d, V, ρ_p, and Φ are bulk density, dry weight (g), volume (cc), particle density, and porosity of the sediment, respectively. Inorganic sediment particle density (ρ_p) is within the range of 2.6–2.7 and is routinely taken as 2.65 g cm^{-3} (Avnimelech et al., 2001; Blake & Hartge, 1986; Boyd, 1995).

Radioactivity measurements

Following Sanchez-Cabeza (1998), 2 gm of dried ground sediment samples were taken to determine the ^{210}Pb concentration utilizing ^{210}Po alpha emitter assuming secular equilibrium with ^{210}Pb. Then, the ground samples were treated with HNO_3, HF, and HCl. The radionuclides were deposited on silver coins after the conversion of Fe^{3+} to Fe^{2+} with the addition of $C_6H_8O_6$ (ascorbic acid). After that, the silver coins were positioned amid ZnS (Ag) phosphor discs, and each side of the discs was measured at alpha energy of 5.30 MeV utilizing ^{209}Po (4.88 MeV alpha emission) as the internal tracer by alpha spectrometry (ORTEC, OCTAT) with 13% efficiency. Chemical yields utilizing a ^{209}Po tracer varied from 87 to 92%. The activity was calculated by the ratio of counts per second (alpha emission of ^{210}Po) with the sample mass. Intercalibration practices were additionally performed utilizing standards samples. The supported ^{210}Pb-specific activity was subtracted from the total ^{210}Pb-specific activity to determine the excess (unsupported) ^{210}Pb (Kumar et al., 2015).

The ^{137}Cs concentration was estimated by gamma spectrometry utilizing a cylindrical NaI (Tl) detector. The size of the NaI (Tl) crystal is 4″×4″ with a well of 1″ diameter×2″ height. The ^{137}Cs esteem was calculated by measuring the gamma peak at 661.62 keV with an 85% branching ratio. The energy calibration of the instrument was done with a mixture of ^{137}Cs and ^{60}Co source, while the efficiency calibration was done with reference standard soil (IAEA-326) (Singhal et al., 2012).

Sedimentation models

Assessment of sedimentation rates from the $^{210}Pb_{ex}$ depth conveyances reported for the study requires the utilization of a model to build up the chronology or age-depth relationship for the core. The distribution pattern does not follow an exponential decline, which demonstrates a variable sedimentation rate. The (CIC) model could not be applied since it assumes a consistent sedimentation rate with a monotonously decreasing excess of ^{210}Pb (Alhajji et al., 2014). Consequently, the (CRS) model was utilized for evaluating the rate of sedimentation and the chronology of the sediment layers. The CRS model presumes a consistent ^{210}Pb flux however allocated the sediment supply to fluctuate. Accordingly, this method is applied to many sedimentary basins where the sediment furnish might fluctuate in response to climatic or anthropogenic alterations. The CRS dating method is communicated as follows:

$$A_t = A_0 e^{-\Lambda t} \quad (3)$$

where A_t = cumulative $^{210}Pb_{ex}$ below the level representing time t, λ = decay constant of ^{210}Pb (0.03114 $year^{-1}$), A_0 = total cumulative $^{210}Pb_{ex}$ inventory (Bq m^{-2}) at the point where the $^{210}Pb_{tot}$ activity reaches radioactive equilibrium with the supporting ^{226}Ra (Gharibreza et al., 2013).

$$A_0 = \Sigma(\rho_i h_i A_i) \quad (4)$$

where ρ_i = dry sediment bulk density (kg m^{-3}) of the *i*th depth interval, hi = thickness of the *i*th depth interval (m), and A_i = $^{210}Pb_{ex}$ (Bq kg^{-1}) (Gharibreza et al., 2013). Besides, ^{210}Pb flux (Bq m^{-2} $year^{-1}$) can be measured by the accompanying equation:

$$^{120}PB_{flux} = A_0{}^* \lambda \quad (5)$$

The age of the sediment at any depth can be calculated by the following equation:

$$t = \frac{1}{\Lambda} * \ln\frac{A_0}{A} \quad (6)$$

The rate of sedimentation was estimated as per the accompanying condition:

$$S = \frac{h}{t} \quad (7)$$

where S = rate of sedimentation (cm $year^{-1}$); h = depth of sediment deposition (cm), and t = estimated time (year).

For ^{137}Cs estimation, the rate of sedimentation was determined as per the ^{137}Cs maximum layer, which communicates to the 1963-time indicator. The period of different layers was acquired depend on the rate of sedimentation of the recognized marker. Even though there may be an upward or downward diffusion of the ^{137}Cs peaks, it would not affect the position of the ^{137}Cs peaks in the sedimentary profiles or the utilization of the ^{137}Cs peak as time markers (Cheng et al., 2019). The ^{137}Cs inferred mean rate of sedimentation for a sample was determined utilizing the following conditions:

$$SR_1 = \frac{H_1}{(n-1963)} \; \& \; SR_2 = \frac{H_2}{(n-1986)} \tag{8}$$

where SR_1 and SR_2 are the sedimentation rates (cm year^{-1}) for this sample, H_1 and H_2 are the depths (cm) of ^{137}Cs peaks for the 1963- and 1986-time markers, and *n* is the year of sampling. The mean rate of sedimentation of the core sample is given as the average esteem of SR_1 and SR_2. In this manner, the age for the layers deposited over the 1963-time indicator depth can be communicated as:

$$T_n = A + \frac{(H - h_n)}{r} \tag{9}$$

where is the sedimentation rate, T_n = age (year),and h_n = depth (cm) for this layer, A = the time markers (1963 or 1986). For the layers deposited underneath the 1963-time indicator depth, the age was determined as follows:

$$T_0 = A - \frac{(h_0 - H)}{r} \tag{10}$$

where T_0 = age (year) and $h_0$depth (cm) for this layer. The accuracy of ^{210}Pb dates, via the CRS model, is substantiated by reference to the well-determined peaks of ^{137}Cs at individual horizons. ^{137}Cs horizons incorporate the first appearance in sediment columns (1952–1954), the fallout maximum (1963–1964) from atmospheric testing of nuclear bombs, and the Chernobyl accident (1986).

Computation of lake life

The calculation of lake life gives a thought regarding the timeframe after which the lake would not be valuable for water-related activities. The limit of the lakes is diminished due to sedimentation up to a degree that it is outrageous to anticipate to fulfill out the water necessitates. This activity ought to be done periodically to comprehend the lake condition and to design appropriate estimates convenient for lake reclamation if the reduction of lake capacity is found at higher rates. The anticipated useful life of the lake is calculated by the ratio of the mean depth of the lake by a weighted average sedimentation rate. The useful life of the Lake Pykara is determined as:

$$L_u = D_m \times \frac{100}{R_s} \tag{11}$$

where L_U = useful life of the lake (year), D_m = mean depth of the lake (m), R_s = sedimentation rate (cm year^{-1}).

Results and discussion

Porosity and bulk density

The average dry bulk density and porosity of the core sediment fluctuated as 1.11–1.38 g cm^{-3} (average 1.26 g cm^{-3}) and62.53–79.46% (average 76.06%), respectively (Table 1). Generally, bulk density and porosity were varied under the statistical fluctuations all through the core depth. As a whole, the sediment bulk density increments, and porosity lessened as core depth increases and expresses a negative relationship. The noticed increment in bulk density may be because of sediment consolidation or compaction of lower layers by the load (overburden pressure) of upper sediment layers.

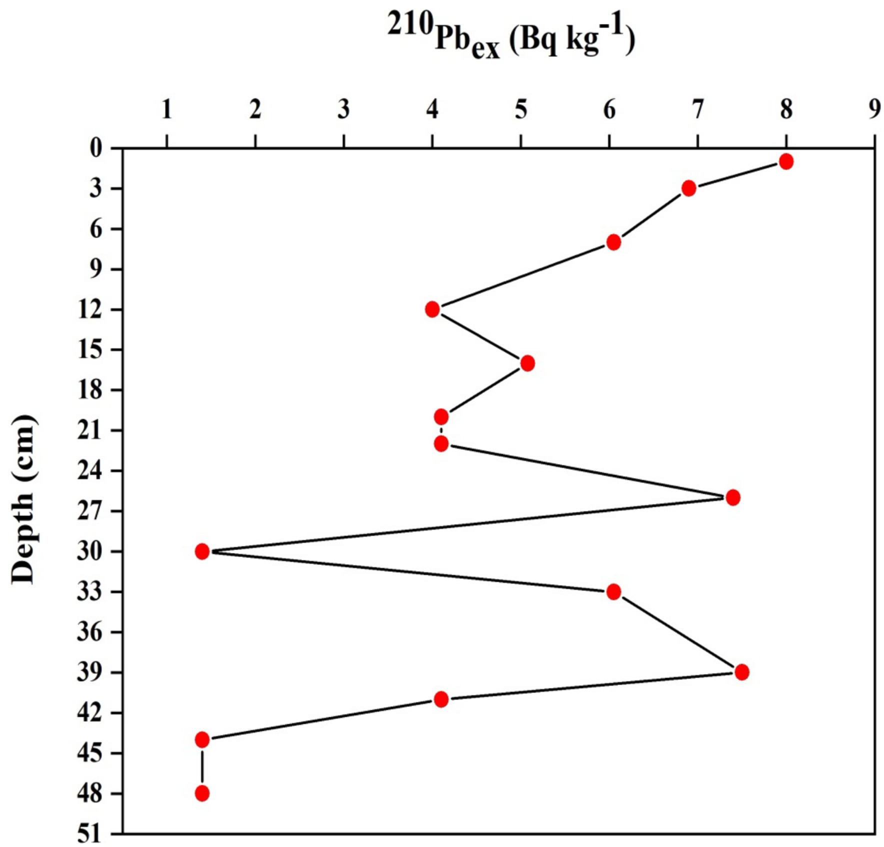
Vertical concentration profile of $^{210}Pb_{ex}$

The depth distribution of $^{210}Pb_{ex}$ activity in the core is designed alongside depth from the sediment surface is appeared in Fig. 2. The activity levels of $^{210}Pb_{ex}$ in the core sediments varied from 1.40 ± 0.1 to 8.00 ± 1.0 Bq kg^{-1}, with an average of 4.82 ± 0.5 Bq kg^{-1} (Table 2). The lowest activity within the Lake Pykara core sediment was observed at depths around 44 and 48 cm (1.40 ± 0.1 Bq kg^{-1} each). $^{210}Pb_{ex}$ specific activity illustrates an approximately monotonic decay with depth in the initial 12 cm. This decrease in the $^{210}Pb_{ex}$ activities

Table 1 Dry bulk density and porosity outcomes in Lake Pykara core sediment

	Dry bulk density (g cm^{-3})	Porosity (%)
Min	1.11	62.53
Max	1.38	79.46
Avg	1.26	76.06

Fig. 2 Depth profile distribution of $^{210}Pb_{ex}$ in Lake Pykara



demonstrates a somewhat undisturbed condition for each section where bioturbation or physical mixing could be viewed as insignificant and points to various sedimentation rates for each part. While below 12 cm up to the bottom of the core, $^{210}Pb_{ex}$ displayed a clear vertical fluctuation in its profile. This outcome demonstrated that the $^{210}Pb_{ex}$ dispersion with depth in the lake does not fit well with the linear/exponential decay model, most likely since sediments in this lake had been extraordinarily disturbed. It might likewise be owing to disturbances in the normal cycle of sediment amassing or blending of the surficial sediments by physical or biological cycles. The accumulation of radioisotopes in the study area may also be affected by the variations in the silt/sediment deposit. The probability of $^{210}Pb_{ex}$ mobility in the upper core is insignificant, and its profile can be useful to sediment dating. Additionally, $^{210}Pb_{ex}$, when integrated into the sediment, doesn't diffuse through pore water (Garcia-Tenorio, 1988). Movement can happen just in incredibly acidic situations (Urban & Schurr, 1990), which might be the situation in Lake Pykara, where the sediments are marginally acidic (Alvarez-Iglesias et al., 2006).

Figure 3 uncovers the least and highest sedimentation rate of Lake Pykara during 2019 AD and 2002 AD, respectively. From the information, it has been seen that there was a tediousness increment in the sediment rate from 1910 AD up to 1986AD, with a mean of 0.61 ± 0.05 cm year^{-1}. On the other hand, there was a consistent dropoff of sedimentation rate from 2002 AD to later, with a mean of 0.72 ± 0.07 cm year^{-1}. In the middle of 1986 AD to 2002 AD, a vacillation of the sediment rate was observed. Altogether, the rate of sedimentation in Lake Pykara changes from 0.33 ± 0.04 to 1.01 ± 0.15 cm year^{-1} with a mean of 0.70 ± 0.07 cm year^{-1} by applying the CRS model and the age of the core obtained was 109 years (Table 2).

The estimated accumulation rate of Lake Pykara varies from 0.04 ± 0.01 to 1.25 ± 0.81 with a mean of 0.28 ± 0.06 kg m^{-2} year^{-1}. It shows monotonic increasing values from bottom sediments to the top of the core (Fig. 4). The average accumulation rate for the oldest layers (before 1974 AD) was

Table 2 Analysis data using CRS model to calculate the age dating and mean sedimentation rates of sediments

Depth (cm)	Pb_{ex} (Bq kg^{-1})	Mass flux (kg m^{-2})	Inventory (Bq m^{-2})	Cumulative inventory (Bq m^{-2})	Estimated year (year)	Date (AD)	Sedimentation rate (cm $year^{-1}$)	Accumulation rate (kg m^{-2} $year^{-1}$)
1	8.00 ± 1.0	3.81	26.30	289.72	3.05	2019	0.33 ± 0.04	1.25 ± 0.18
3	6.90 ± 0.8	3.89	31.11	263.42	7.10	2016	0.42 ± 0.05	0.55 ± 0.11
7	6.05 ± 0.5	3.97	24.04	232.31	10.60	2012	0.66 ± 0.06	0.37 ± 0.8
12	4.00 ± 0.2	3.93	15.71	208.27	13.12	2008	0.91 ± 0.1	0.30 ± 0.6
16	5.08 ± 0.6	3.81	19.38	192.57	16.52	2006	0.97 ± 0.11	0.23 ± 0.03
20	4.10 ± 0.3	4.20	17.20	173.19	19.80	2002	1.01 ± 0.15	0.21 ± 0.03
22	4.10 ± 0.3	4.16	17.06	155.99	23.60	1999	0.93 ± 0.11	0.18 ± 0.03
26	7.40 ± 1.1	4.69	34.68	138.93	32.80	1995	0.79 ± 0.08	0.14 ± 0.02
30	1.40 ± 0.1	4.20	5.88	104.25	34.70	1986	0.86 ± 0.09	0.12 ± 0.02
33	6.05 ± 0.9	4.51	27.27	98.36	45.12	1984	0.73 ± 0.07	0.10 ± 0.01
39	7.50 ± 1.4	4.63	34.74	71.09	66.66	1974	0.59 ± 0.05	0.07 ± 0.01
41	4.10 ± 0.3	4.97	20.37	36.35	93.04	1952	0.44 ± 0.06	0.05 ± 0.01
44	1.40 ± 0.1	4.48	6.27	15.98	109.05	1926	0.40 ± 0.06	0.04 ± 0.01
48	1.40 ± 0.1	6.94	9.71	9.71	-	1910	0.40 ± 0.06	-
Min	1.40 ± 0.1	3.81	5.88	9.71			0.33 ± 0.04	0.04 ± 0.01
Max	8.00 ± 1.0	6.94	34.74	289.72			1.01 ± 0.15	1.25 ± 0.18
Mean	4.82 ± 0.5	4.44	20.69	142.15			0.70 ± 0.07	0.28 ± 0.6

0.7 ± 0.15 kg m^{-2} $year^{-1}$, but it increased to about 0.16 ± 0.03 kg m^{-2} $year^{-1}$ between 1974 and 2002 AD. Recent layers have seen a dramatic rise in the accumulation rate, up to 0.54 ± 0.11 kg m^{-2} $year^{-1}$ on average (Table 2). This shift may be linked to the growing population, human, and industrial activities. The sedimentation rate, on the other hand, infers that the highest value is observed in a few layers underneath the surface sediment (20 cm), indicating that the top layers are influenced by the waves and current and favors for the slower rate of sediment settling.

Vertical concentration profile of ^{137}Cs

The utilization of ^{137}Cs as a chronological indicator depends on the recognition of its earliest appearance which is narrated to ^{137}Cs transportation alongside the sedimentary record and its greatest contributions to the activity profile (Andersen et al., 2000; Nielsen, 1995). The ^{137}Cs profile in the core sediment as appraised with NaI (Tl) detector gathered from Lake Pykara appears in Fig. 5. The variety in ^{137}Cs concentrations could be simply because of changing rate of sedimentation as different factors like physicochemical variety of sediment composition or organic matter content have a trifling effect. In Fig. 5, two characteristic peaks of ^{137}Cs activity are recognized at the depth of 23 and 40 cm with subsequent activities of 15.35 ± 1.4and 17.57 ± 1.7 Bq kg^{-1} (Table 3). The deeper ^{137}Cs peak is allocated to the highest atmospheric universal fallout that matched 1963 while the shallower peak is attributed to the Chernobyl mishap in 1986. Average sedimentation rates were calculated utilizing the ^{137}Cs peaks of 1963 and 1986 by dividing the sediment depth where the peak is located by the elapsed time and the ages are assigned from the extrapolated mean sedimentation rate (Singhal et al., 2012). Hence, the rate of sedimentation of Lake Pykara employing the 1963 and 1986 time markers was estimated to be 0.71 ± 0.06 and 0.70 ± 0.06 cm $year^{-1}$with a mean of 0.705 ± 0.06 cm $year^{-1}$ and the respective age of the core was 67 years (Table 3). The outcome revealed that the mean rate of sedimentation obtained from ^{137}Cs in the profile was corroborating with that from $^{210}Pb_{ex}$.

However, there was an evident inconsistency between the chronology derived from ^{137}Cs and the time mark of $^{210}Pb_{ex}$, which may exhibit that ^{137}Cs were moved from the soil. The ^{137}Cs time

Table 3 Analysis data using ^{137}Cs to calculate the age dating and mean sedimentation rates of sediments

Depth (cm)	^{137}Cs (Bq kg^{-1})	Marker years	Mean sedimentation rate (cm year^{-1})		Date (AD)	Estimated years (years)
			From 1963	From 1986		
1	13.11 ± 1.3	1963 and 1986	0.71 ± 0.06	0.70 ± 0.06	2018	1
2	10.32 ± 1.1				2016	3
3	3.29 ± 0.3				2015	4
7	7.57 ± 0.6				2009	10
10	5.00 ± 0.4				2005	14
13	5.79 ± 0.6				2001	18
16	7.00 ± 0.6				1997	22
18	5.26 ± 0.5				1994	25
20	8.95 ± 0.9				1991	28
23	15.09 ± 1.4				1987	32
26	10.30 ± 1.1				1983	36
29	2.35 ± 0.3				1978	41
33	1.78 ± 0.1				1973	46
36	12.49 ± 1.2				1969	50
39	16.28 ± 1.5				1964	55
40	17.15 ± 1.7				1963	56
42	1.56 ± 0.1				1960	59
45	2.26 ± 0.2				1956	63
47	1.41 ± 0.1				1953	66
48	1.21 ± 0.1				1952	67
Mean sedimentation rate			0.705 ± 0.06			

markers of 1963 and 1986 in the lake were obvious, and there was a significant correlation among ^{137}Cs and sediment depth in the profile, showing a particular time of sediments. The $^{210}Pb_{ex}$ concentration profile exhibited fluctuation in the profile with a sporadic variation in depth. Therefore, the rate of sedimentation has been deciphered precisely by utilizing the combination of ^{137}Cs and $^{210}Pb_{ex}$ dating, as 0.71 ± 0.06 cm year^{-1} and 0.70 ± 0.06 cm year^{-1}, respectively.

Computation of lake life

The validity of anticipated lake life depends upon the accuracy of the mean depth of the lake. Even though the impact of the compression of sediments

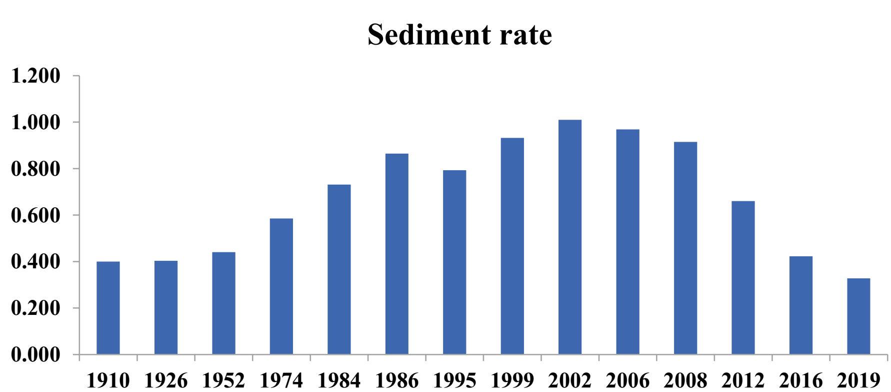


Fig. 3 Rate of sedimentation using CRS model in Lake Pykara

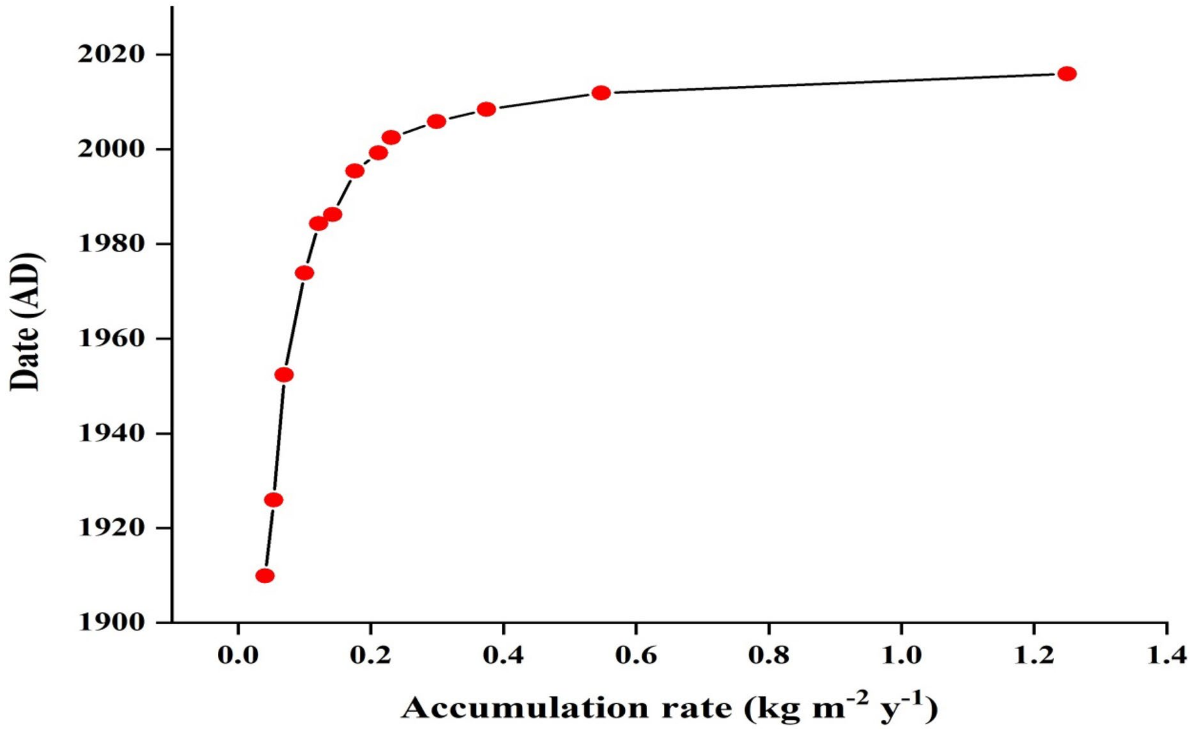


Fig. 4 The variation of accumulation rate with the date of sediment layers in Lake Pykara

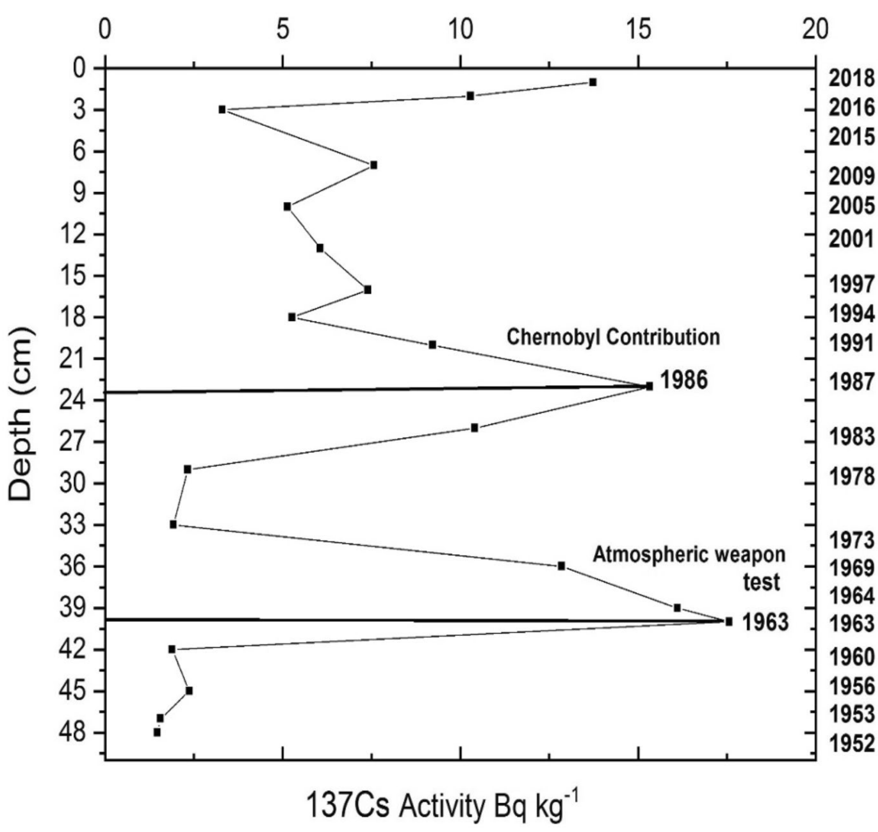


Fig. 5 Depth profile distribution of ^{137}Cs in Lake Pykara

by its weight is subsequently included partially while assessing the sediment rate, for an exact estimate on the useful life of a lake the impact of compression ought to be considered complete. Both ^{210}Pb and ^{137}Cs geo-chronological dating are incredible methods for estimating current sediment accumulation rates in lakes and reservoirs and by implication the valuable life of them. Consequently, the ages obtained by utilizing Eq. 12 as follows:

$$^{137}\mathrm{Cs} = \frac{137}{Cs} = 3.65 \times \frac{100}{0.71} = 514.08 \text{ years} \tag{12}$$

$$^{210}\mathrm{PB} = 3.65 \times \frac{100}{0.70} = 521.43 \text{ years} \tag{13}$$

where the mean depth of Lake Pykara is 3.65 m.

Hence, if the sediment deposition proceeds at a similar rate, the lake may completely be filled up in 514.08 years (^{137}Cs) or 521.43 years (^{210}Pb) under normal environmental conditions.

Conclusion

The chronology of sediments turned out to be very challenging to disentangle with the radiometric dating method because several factors have affected the sedimentary conditions and sediment accumulation rates in Lake Pykara. This investigation focused on the collection of sediment samples, and comparative analysis of isotopes ($^{210}Pb_{ex}$ and ^{137}Cs), in the Lake Pykara core sediment. The vertical distribution of $^{210}Pb_{ex}$ did not show a regular pattern and had a clear disturbance, whereas the accumulation peak of ^{137}Cs was distinct and would thus be able to be utilized as an age reference. The elevated concentrations of these isotopes on the surface sediment in Lake Pykara may be the settling elements delivered from the environment and land or the older sediment approached from the resuspension procedures. The vertical conveyance of ^{137}Cs radioactivity showed two recognized peaks, one at 40 cm which compare to atomic tests (1963), and the other at 23 cm (Chernobyl accident, 1986). By utilizing the CRS model and ^{137}Cs dating strategy, the average rate of sedimentation of Lake Pykara was assessed to be 0.70 ± 0.06 cm year^{-1} and 0.71 ± 0.06 cm year^{-1}. The mean sedimentation rate of different South Indian locale, for example, Kodaikanal Lake (0.52–0.58 cm year^{-1}), Veeranam Lake (0.62–0.65 cm year^{-1}), Perumal Lake (0.61–0.65 cm year^{-1}), and Navegaon Bandh Lake (0.93 cm year^{-1}) while being in the same climatic zone, they showed a great deal of diversity. The obtained relative ages of the Lake Pykara core sample were 109 and 67 years, respectively. The discrepancy in the age is likely because of the recently increased input of catchment-inferred $^{210}Pb_{ex}$ or expulsion of ^{137}Cs from the soil. The computed values based on the $^{210}Pb_{ex}$ and ^{137}Cs demonstrates 521.43 and 514.08 years, respectively, as a life of the lake.

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Code availability The author used ArcGIS 10.1, Origin 2019, SPSS (version 21) to carry out the analysis.

Declarations

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of interest The authors declare no competing interests.

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