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Rate of Sedimentation in Veeranam Lake, South India, Using ^{137}Cs and ^{210}Pb

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Abstract In recent years there has been an increased interest in the dating of recent lake sediments, since its importance for the reconstruction of pollution history and other activities of man has been well demonstrated. This is imperative as there has not been any record on this aspect of research in Lake Veeranam. Hence, in the present study it is proposed to establish the rate of sedimentation and determination of sediment age. The present study gives special emphasize on understanding the rate of sedimentation in Veeranam Lake. The core sediment of 46cm has been collected from the lake using gravity corer were sliced to 2cm and subjected to the analysis of ^{137}Cs and ^{210}Pb trends. The radio isotopic (^{137}Cs and ^{210}Pb) study reveals that the rate of sedimentation is 0.32 cm/year (^{210}Pb) and 0.35 cm/year (^{137}Cs) and the useful life of the lake may be of 965.71 years (^{137}Cs) or 1056.25 years (^{210}Pb) under normal environmental conditions.
Keywords *Dating; Environmental Conditions; Lake Life; Sediment Age*

1. Introduction

The usefulness of a particular isotope will depend on its half-life, and the accuracy of the associated model. For example, radiocarbon dating based on the decay of ^{14}C (half-life 5730 years) may provide accurate dates over a period spanning thousands of years, but will be inaccurate when used conventionally for dating sediments younger than approximately 1800AD as a result of anthropogenic inputs of ^{14}C into the environment (Seuss, 1965). Radionuclides, such as lead-210 (^{210}Pb, $t_{1/2}$ = 22.3Y) and cesium-137 (^{137}Cs, $t_{1/2}$ = 30.2Y), are the most common and reliable method employed to calculate short term (year to decades) sediment deposition and accumulation rates in the estuarine, fluvial and lacustrine environment (Kim, 2003).

Estimation of sedimentation rates in lakes and reservoir are vital in many schemes involving the formulation and impoundments of water storage, and pragmatic measurements can contribute both directly through their role in developing and testing models. The computation of Lake sedimentation is in the present study considered as a tool of scientific prediction in the planning, management, and operational phases of conservation of Veeranam Lake. The present study is the first of its kind on the detailed investigation about the rate of sedimentation in Veeranam Lake, a typical major lacustrine system of the tropics enjoying moderate rain fall and climate, located essentially in the Northern Tamil Nadu. As the Veeranam lake is the major wetland system supplies water to the agriculture activity in the Cuddalore district and is known for its New Veeranam water scheme, through which water has been transported to Chennai to meet out the metro water demand.

2. Study Area

The area chosen for this study is Veeranam Lake, which was created during Chola period in the tenth century, built from 1011 to 1037AD and is 16-kilometre (9.9 mi) long dam in northern Tamil Nadu. Veeranam Lake is located 14 km (8.7 mi) SSW of Chidambaram in Cuddalore district, Tamil Nadu, India. The lake falls between north latitudes $11^0 15'$ to $11^0 25'$ N and east longitudes $79^0 30'$ to $79^0 35'$ E (Figure 1). It falls in the geological survey of India toposheet no. 58 M/11. The lake is bounded by Vellar River in the north and Coleroon River in the south. It has good network of roads and railways.

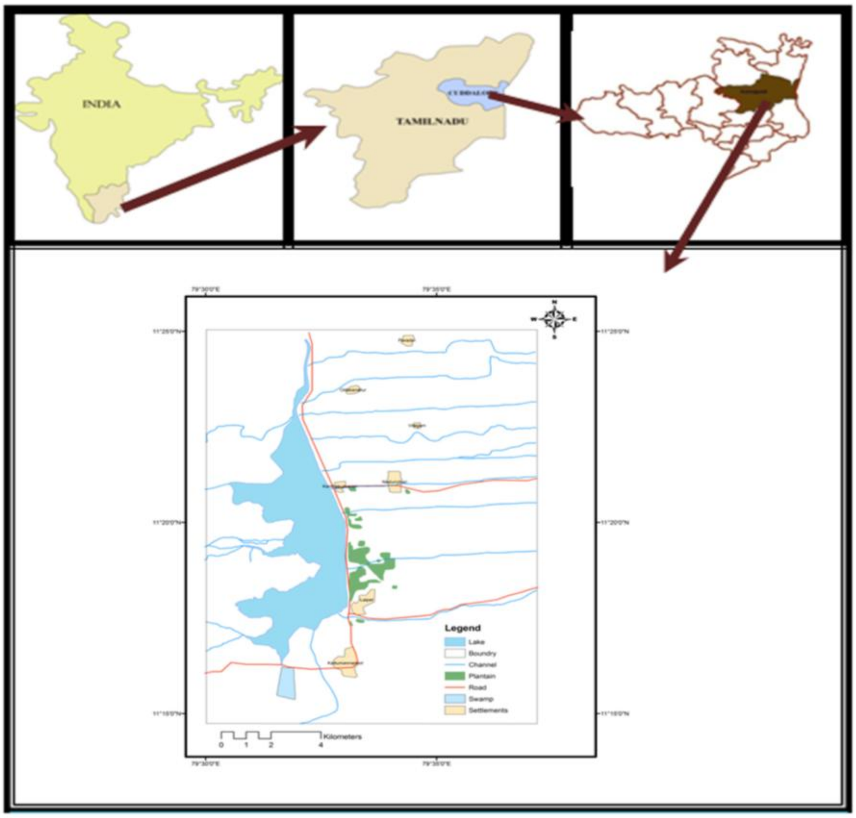

Figure 1: *Geographic Location of Veeranam Lake*

3. Methodology

^{137}Cs is produced in the atmosphere due to cosmic ray interactions. However, its concentration increased many folds in the atmosphere due to the test of nuclear weapons and since 1954, it has been globally detectable. ^{137}Cs is strongly absorbed on tiny particles like clay materials, silts and humic materials. Surface soils with an adsorptive capacity will have a ^{137}Cs content and therefore be able to act as a self-tracer.

The sediment core was recovered from deepest part of the Veeranam Lake and the location is shown in Figure 2. Samples were ground and placed in a polyethylene tube (4.5 OD x 3 cm heights) and inserted into the well of an intrinsic high pure Germanium (HPGE) gamma detector. For measurement of ^{137}Cs activity the multichannel gamma ray spectrometer (MCA) was used. The Priston Gamma Tech., USA (PGT) converts the radioactivity incident on the Germanium crystal into analogue signal that is received by the MCA system. The core sample from Veeranam Lake was counted for four hours to determine the activity of ^{137}Cs at 662 keV. The analysis was performed at National Institute of Hydrology (NIH), Roorkee, India, in Canberra – Gamma ray spectroscopy GC –3520.

The applications of ^{210}Pb dating are many and varied; this method is very popular and has been applied in several lake studies, the world over. A sediment core records a detailed history of the environment in its vicinity and the ^{210}Pb dating technique provides a chronology covering a time scale of 100 to 150 years, uniquely suited to the period of man's greatest impact.

The ^{210}Pb activity is measured through the α- counting of its grand-daughter, namely ^{210}Po, which is assumed to be in secular equilibrium with its parent. The α-counting of the grand-daughter product (^{210}Po) is more widely used. In this case, the basic radiochemical procedure involves adding of ^{208}Pb as a yield tracer, leaching the sediment samples with aquaregia, filtering off the residual solids and converting to chloride with concentrated HCl. The final solution is taken in 0.5 M HCL. Polonium nuclides are then spontaneously deposited on silver planchette by adding ascorbic acid in the HCl solution. The alpha counting was performed using silicon surface barrier detector connected to a multi-channel analyzer. The entire operation is controlled through the Genie -2000 Software v 3.2. The counts were carried out for six hours to determine the activity of Veeranam Lake core sediment sample. The analysis was carried out in Canberra – Alpha Analyst – Alpha spectrometer – 7200-04.

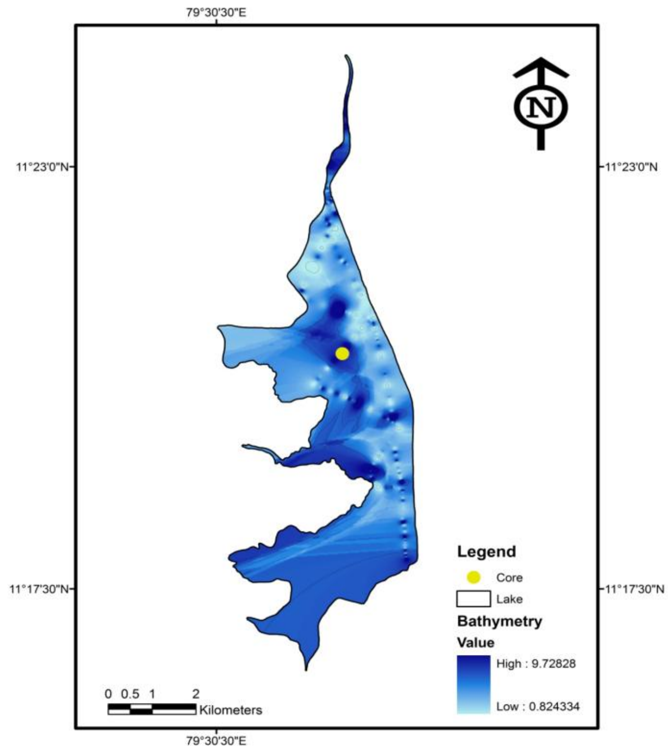

Figure 2: *Core Location in the Bathymetry Map of the Veeranam Lake*

4. Results and Discussion

4.1. Sedimentation Rate

A) Cesium – 137 (^{137}CS) Dating

Over the last 25 years there have been many convincing demonstrations of the chronological value of ^{137}Cs measurements especially in relatively rapidly accumulating sediments (Livingstone and Cambray, 1978; Heit et al., 1984). Counting the gamma emissions of ^{137}Cs at 662 KeV is relatively simple, non-destructive procedure. The 30.17 years of half-life ensures the continuing use of the method for chronological purposes some way into the next 50 to 75 years. Moreover, in areas affected by deposition from the 1986 Chernobyl accident an additional "Spike" is now emerging as a possible future aid to sediment dating.

The technique is based on the following characteristics of ^{137}Cs; Relatively short residence time in the atmosphere, Absolutely of anthropogenic origin with no natural production, Significant variation in production levels during different time periods, Half Life is 30.17 years, Reliable records of global distribution, Characteristic to adhere with organic, silt and clayey material accompany by negligible mobility in the environment.

The first occurrence of ^{137}Cs in core sediment of Veeranam Lake is observed at 38 cm (Figure 3). However, samples below 38cm were not available for present study and we cannot therefore assign a date to the first appearance of ^{137}Cs in core sediments of Veeranam Lake. The 16cm peak in ^{137}Cs, however, is interpreted to represent 1963 the peak year of nuclear testing (Chillrud et al., 1999). Based on this, it is assigned that the date of 1963 to the 16cm depth in core of Veeranam Lake (Figure 3). At the sampling location, the ^{137}Cs profile closely paralleled its weapon fallout record pattern reported by earlier investigators (Eakins and Cambay, 1985; Engstrom et al., 1985; Farmer, 1978) i.e., an initial appearance in 1952-53; a subsidiary peak in 1957-58; and major peak in 1963-64. With the depth corresponding to 1963-64 as time marker, the average sedimentation rate (both linear and mass unit) of Veeranam Lake was computed. The close similarity in the deposition and fallout pattern of ^{137}Cs probably indicates that the residence time of ^{137}Cs in the lake water is small and post-depositional mobility of the radionuclide in the sediment core, if any, is insignificant. However, the ^{137}Cs profile of Veeranam Lake may be viewed as an ideal case.

B) Lead – 210 (^{210}Pb) Dating

Lead-210 geochronology is an isotopic method of age estimation based on the radioactive decay of ^{222}Rn and ^{210}Pb. Since its inception, the ^{210}Pb method has been practiced using the basic techniques, models and assumptions of its originator (Goldberg, 1963). The strong community confidence in this method is demonstrated by numerous successful results and the increased number of studies using it. Because of the relatively short half-life of ^{210}Pb (22.26 years), this method is chiefly applied in palynological, limnological, marine, and glaciological studies to estimate sedimentation rates for the past century or more. The ^{210}Pb method is widely used in the determination of sedimentation rates in lacustrine and marine depositional records.

Disintegration of the intermediate isotope ^{226}Ra (half-life 1622 years) yields the inert gas ^{226}Rn, this in turn decays (half-life 3.83 days) through a series of short-lived isotopes to ^{210}Pb. Radium-226 is supplied to the lake sediments as part of the particulate erosive input. The ^{210}Pb formed by the in situ decay of this radium is termed as the "supported ^{210}Pb" and is normally assumed to be in radioactive equilibrium with the radium. In general, however, this equilibrium will be disturbed by a supply of ^{210}Pb from other sources. Lead-210 activity in excess of the supported activity is called the "excess" or "unsupported" ^{210}Pb.

The principal source of unsupported ^{210}Pb is generally taken to be direct atmospheric fallout, although the importance of the other sources has not been extensively evaluated. In this context three components have been identified (Oldfield and Appleby, 1984):

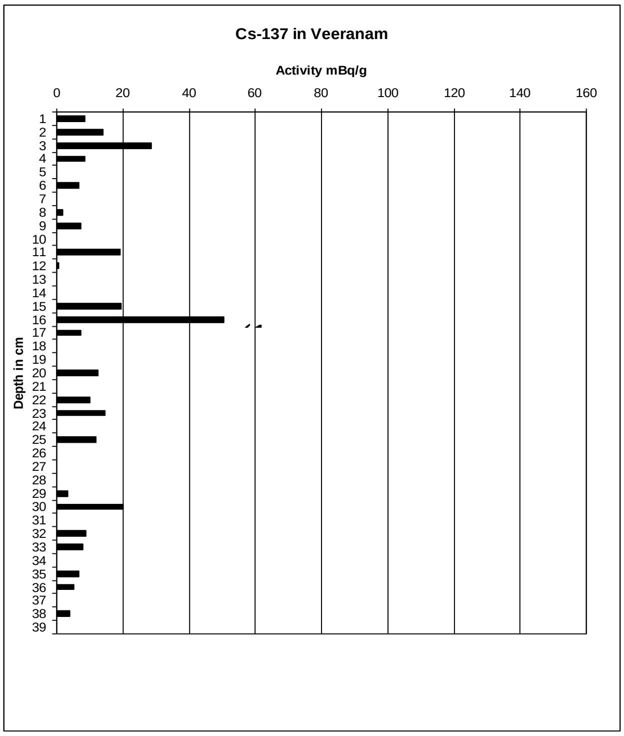

Figure 3: *Sediment dating of ^{137}Cs deposition Profile in Veeranam Lake.*

The ^{210}Pb dating techniques have been used to cross check and authenticate the results obtained using ^{137}Cs dating technique in the present study. The estimation of sedimentation rate using ^{137}Cs dating technique is easier in comparison with ^{210}Pb dating technique as later requires complicated chemical process for the separation of ^{210}Pb from sediments. The sedimentation rates estimated by ^{210}Pb dating technique are found close to the sedimentation rates determined by ^{137}Cs dating technique. The ^{210}Pb activities determined in the sediment cores are shown in Figure 4. The total ^{210}Pb activities are depicted by an almost linear decline in relation to depth. The $^{210}Pb_{excess}$ is assumed to come from the atmosphere (or) fluxes not explained by the ^{238}U series equilibrium. The $^{210}Pb_{excess}$ was fitted to the least square procedure (r^2 = 0.202) and slope (r^2 = 0.202; n = 4.40; P< 0.05) and slope of the long linear curve (Y = -12.3x + 54.59) allowed the calculation of the sedimentation rate (6.2 mm/year) (Apple by and Oldfield, 1992). Thus, the bottom of the sediment core (46cm) was estimated to be near 1935 year old. As the atmospheric deposition flux of ^{210}Pb at the lake site is unknown, the available mean atmospheric flux of ^{210}Pb at Mumbai station, India, (0.025 Bq/cm^2/yr; Edington et al., 1976) has been considered. As seen in Figure 4, at core location, the (total) ^{210}Pb profile shows a more or less exponential decrease in concentration with depth to a constant value maintained by in-situ decay of ^{226}Ra. In lakes, the inflow velocity and other forces such as gravitational force and the secondary forces of flow turbulence control the spatial distribution of incoming sediments.

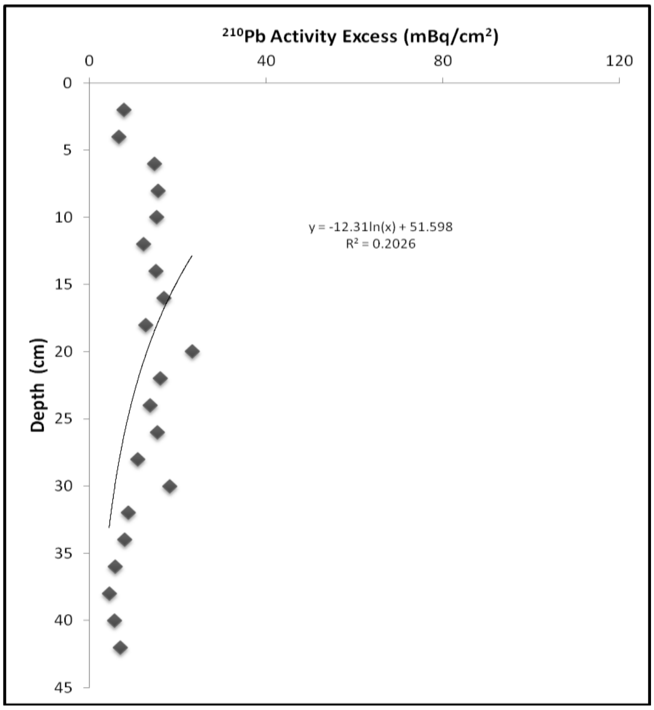

Figure 4: *Sediment dating of ^{210}Pb Concentration Profile in Veeranam Lake Core*

5. Computation of Lake Life

The lake may be in filled with deposited sediment and gradually become a wetland such as a swamp or marsh. Large water plants accelerate this closing process significantly because they partially decompose to form peat soils that fill the shallows. Conversely, peat soils in a marsh can naturally burn and reverse this process to recreate a shallow lake. Turbid lakes and lakes with many plant-eating fish tend to disappear more slowly. A "disappearing" lake (barely noticeable on a human timescale) typically has extensive plant mats at the water's edge. These become a new habitat for other plants, like peat moss when conditions are right, and animals, many of which are very rare.

The lake life has been estimated taking into account the estimated sediment accumulation rates in the single zone and the present volume of the lake. The useful life of the Veeranam Lake is calculated as;

Useful Life of the Lake (L_U) = D_m x 100 / R_S

i) ^{137}Cs = 3.38 x 100 / 0.35
= 965.71 Years

ii) ^{210}Pb = 3.38 x 100 / 0.32
= 1056.25 Years

The total sedimentation in Veeranam Lake, taking into account mean accumulation rate is 0.32cm/yr (^{210}Pb) and 0.35 cm/yr (^{137}Cs). If the sediment deposition continues at the same rate, the lake may completely be filled up in 965.71 years (^{137}Cs) or 1056.25 years (^{210}Pb) under normal environmental conditions.

6. Conclusion

The first occurrence of ^{137}Cs in Veeranam core is at 38cm. The maximum peak value of ^{137}Cs at 16cm was interpreted to represent 1963 the peak year of nuclear testing (Chillrud et al., 1999). With the depth corresponding to 1963-64 as time marker, the average sedimentation rate in Veeranam Lake computed as 6.1mm/year. The total ^{210}Pb activities determined in the sediment cores depicted by an almost linear decline in relation to depth. The ^{210}Pb excess is assumed to come from the atmosphere (or) fluxes not explained by the ^{238}U series equilibrium. The $^{210}Pb_{excess}$ allowed the calculation of sedimentation rate as 3.2mm/ year. Veeranam Lake, taking into account means accumulation rate ranges between 0.32 cm/year (^{210}Pb) and 0.35 cm/year (^{137}Cs). The rate of sedimentation calculated based on ^{137}Cs and ^{210}Pb reveals that the life span of the Veeranam Lake is around 965.71 years and 1056.25 years respectively. The computations of the lake life were estimated with the condition, which prevails during sampling.

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