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RATE OF SEDIMENTATION IN THE YAMUNA RIVER AROUND DELHI USING THE $^{226}Ra-^{210}Pb$ METHOD

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For six sediment cores collected from Yamuna river (tributary of Ganges) around Delhi, rate of sedimentation was determined by the $^{226}Ra-^{210}Pb$ method. While an average rate of 42 mm/y is obtained, there are variations core to core. A clear-cut downstream increase in the rate, from 5 mm/y when the river enters Delhi, to 80 mm/y when it leaves Delhi, indicates solid waste contribution from the urban areas. The sediment flux of 4000 mg/cm^2/y is not balanced by the calculated rate of erosion (40 tonnes/km^2/y) in the river. Thus, much of the sediment flux is of local origin.

Introduction

In recent years, several investigations have evaluated the use of ^{210}Pb (T = 22.26 y) measurements for determining sedimentation rates in modern aquatic environments and compared them to other methods.[1–4] Actual measurements have been carried out in diverse environments, from inland lakes to marine conditions.[5–10] In this paper, the use of ^{210}Pb method has been extended to determination of sedimentation rates in an alluvial terrain.

Experimental

From Yamuna river (tributary of Ganges) around Delhi, sediment core samples were collected during a dry season (summer, 1981) at six locations. The sampling sites (Fig. 1) were chosen so as to cover the nearly 50 km stretch of the river through the urban areas of Delhi. Within this region, seventeen drains discharge their solid and dissolved wastes into the river. Since Delhi has been inhabited at least for the last five hundred years, the recent sediment history is likely to contain signatures of human impact.

Coring was done by inserting a one meter long PVC pipe enclosed in cast-iron tube and pushed manually as far down as possible. Samples were kept refrigerated

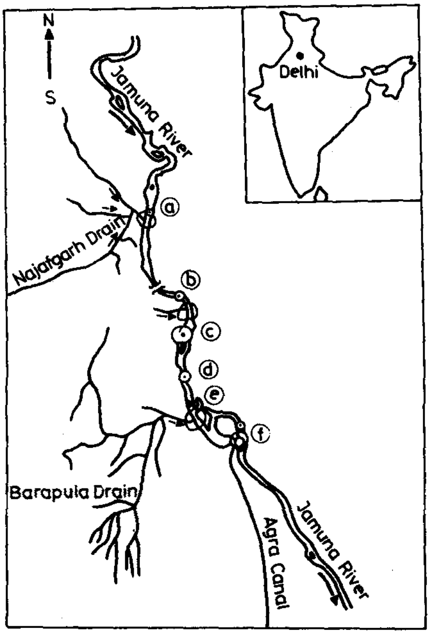

Fig. 1. Location of sediment cores in Yamuna river around Delhi. Rate of sedimentation: (a) 5.6 mm/y; (b) 15.8 mm/y; (c) 31.5 mm/y; (d) 47.7 mm/y; (e) 70.3 mm/y; (f) 82.1 mm/y

at 3 °C until processed in the laboratory. Because of the sandy nature of the core minimum penetration of only 38 cm was possible and large depth intervals have to be chosen for extraction in the laboratory. The sections of the cores were cut at 6 cm internal and processed for ^{210}Pb and ^{226}Ra extraction in the laboratory.

The radioisotope ^{210}Pb is an intermediate member of the ^{238}U decay chain. The excess ^{210}Pb activity (total ^{210}Pb minus activity of ^{210}Pb due to in situ decay of ^{226}Ra), is present due to the uptake of decay products of ^{222}Rn from atmospheric precipitation. The total ^{210}Pb in a soil/sediment column is given by

$$^{210}Pb \text{ total} = {}^{210}Pb_{Atm} + {}^{210}Pb_i + {}^{210}Pb_d + {}^{210}Pb_p$$

where the subscripts refer to atmospheric input, in situ production, dissolved load and particulate load.[1] ^{210}Pb is measured by conventional extraction procedures.[8] Briefly, a Pb carrier (usually $Pb(NO_1)_2$ is added to the sediment, aqua regia added, evaporated, dried and dissolved in 1.5N HCl. This solution is passed through an anion exchange column and the absorbed Pb is eluted with de-ionized water and finally $PbSO_4$ is precipitated from this eluent, purified and transferred to a perspex disc. The disc is kept for one month so that ^{210}Bi equilibrate with ^{210}Pb and then counted in a beta-counter. The background of the counter used was 0.09 cpm at 43% counting efficiency. Similarly, the activity of ^{226}Ra was obtained by the measurement of ^{222}Rn through the emanation method.[11]

Results and discussion

Table 1 summarizes the various measurements made in this work. Figure 2 shows the distribution of excess ^{210}Pb, with depth for the six stations studied. Once the ^{210}Pb deposits in the sediments, its depth distribution should be

Table 1
Results of measurements

Core, No.	Depth, cm	^{210}Pb, dpm/g	^{226}Ra, dpm/g	$^{210}Pb_{excess}$, dpm/g
1	0–6	42.82	0.77	42.05
	6–12	32.86	0.62	31.47
	12–18	23.03	2.32	20.71
2	0–6	37.87	0.82	37.05
	6–12	32.53	0.77	31.76
	12–18	29.31	1.18	28.13
	18–24	26.60	1.01	25.59
3	0–6	33.33	0.83	32.50
	6–12	30.70	0.88	29.82
	12–18	29.31	0.58	28.73
	18–24	28.58	1.29	27.29
4	0–6	27.92	1.53	26.39
	6–12	25.68	1.20	24.48
	12–18	25.22	1.46	23.76
	18–24	24.93	1.30	23.63
5	0–6	26.54	1.76	24.78
	6–12	24.63	0.92	23.71
	12–18	23.90	1.19	22.71
	24–30	22.82	0.51	22.30
6	0–6	29.09	0.74	28.35
	6–12	28.95	1.04	27.90
	12–18	28.87	1.65	27.22
	18–24	27.58	1.27	26.31

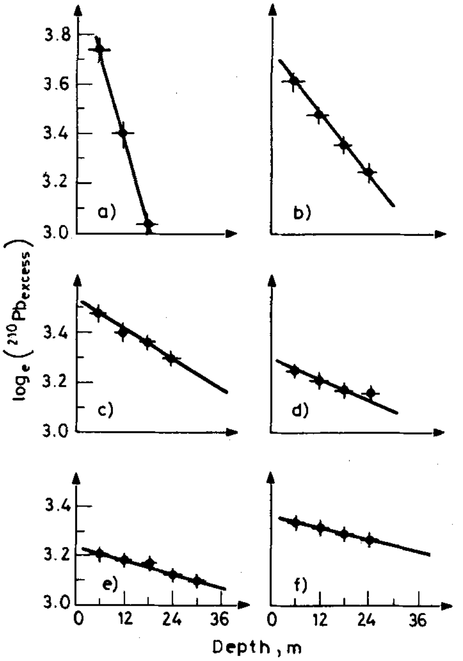

Fig. 2. Depth variation in the ^{210}Pb excess values for various sediment cores (see Fig. 1)

governed by the relationship

$$\ln C = \frac{\lambda}{S} D + \ln Co$$

where Co, C – activities of excess ^{210}Pb at the surface and depth D, respectively,

λ – is the decay constant for ^{210}Pb ($3.15 \cdot 10^{-2}$ y^{-1}),

S – sedimentation rate.

From the plots in Fig. 2, S values were calculated and are indicated in the respective plots.

The decrease in the activity (dpm/g) of excess ^{210}Pb shows three well-defined regions, the sharp decrease with depth for the two northern zones, moderate decrease in the southern zones. There is a progressive increase in the sedimentation rate from the point where the river enters the city (Wazirabad) to the point where the river exits from the city (Okhla). The Wazirabad core (Fig. 2a) shows a constant rate of sedimentation, whereas the other cores show a zone of constant rate of sedimentation overlain by a surface zone of sediment mixing.

Table 2
Comparative rates of sedimentation by ^{210}Pb method

Area	Rate, mm/y	Remark	Reference
Yamuna river sediments, Delhi	42.15	Range for six cores 5.6 to 82	This work
Gulf of Cambay	15	Single core	13
Bay of Bengal	20	Coastal region	10
Green Bay and Lake Michigan	0.12	Range for 5 cores 0.001 to 0.430	7
Lock Lomond fresh-water sediment	0.36	One core	6
Saskatchewan Lakes, Canada	5.3	4.7 to 6.6 for six cores	5
Lake Mendota, USA	6	–	2
Nearshore of California	0.7	Single core	8
Lake Tanse, India	40	–	9
Lake Tulsi, India	2.6	–	9

The rates of sedimentation observed for the Yamuna river around Delhi is within the broad range of values reported for a number of fresh water and marine environments. Table 2 compares various ^{210}Pb rates reported from around the world. The average rate of about 42 mm/y for Yamuna is somewhat high because of the fact that Yamuna river contributes annually about 65 million tonnes of sediments (average total suspended sediment = 1255 ppm)[12] to the Ganges river system and has a sediment erosion rate (total sediment load divided by basyn area) of about 400 tonnes/km^2/y. With a sediment thickness of 1000 m the bottom of the alluvial bed reaches an age of Plio-Pleistocene (about 2–3 million years) and within this period, the river is known to have progressively shifted eastward. The present sediment thickness of 1000 m would require, at the measured sedimentation rate of 42 mm/y, only about 25 000 years to accumulate.

Figure 3 shows the fluxes of sediments (flux = SX porosity) for various stations. Since the bulk of the sediments eroded upstream is transported to the Ganges river,

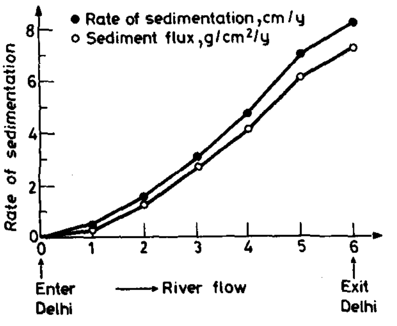

Fig. 3. Downstream trend in the rate of sedimentation and flux of sediments ($mg/cm^2/y$) in Yamuna river around Delhi

the flux of sediments accumulating around Delhi will be very much smaller. The erosion rate of $40 \cdot 10^3$ $kg/km^2/y$ (in other words 4 $mg/cm^2/y$) is very small relative to the sediment flux rate at Delhi (4000 $mg/cm^2/y$). The increased sediment flux around Delhi is thus not due to the natural rate of supply but perhaps to local supply to the river system. Within Delhi, the systematic increase in sediment flux downstream may in fact reflect addition of city waste to the sediment weight. In the southern zone the sediment contains up to 50% organic matter at various stages of decomposition. Thus, while the rate of erosion appears to be small relative to the rate of sedimentation, the unnatural increase in sediment accumulation rate downstream around Delhi may reflect solid waste contribution from the urban areas to the sediment budget.

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