OBSERVED INFERENCES FROM SUDDEN CHANGES IN THE SEDIMENTALOGICAL PROCESSES DURING THE DECEMBER 26, 2004 TSUNAMI ALONG THE EAST COAST OF INDIA

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ABSTRACT

In connection with observations made on the impact of beach placer mining, a study area extending from Poompuhar to Nagoor, in Tamil Nadu, had been chosen for regular profiling and sediment sampling since April 2003. The on-set of the tsunami of 26th December 2004 encouraged continuation of the study in order to understand the sudden changes in the sedimentological processes caused by this tsunami. As a profiling survey of the area had been completed on 16th December 2004, an exact quantum of erosion level caused by the tsunami was determined for several stations. Except for Nagoor, all other stations showed erosion of the beaches, with a maximum of 2.5 m, particularly in the Karaikkal area. The study identified two major geomorphologic parts, the first extending from northern Poompuhar to Karaikkal and the second from southern Karaikkal to Nagoor. Changes in the geomorphologic characters observed at these two areas were attributed to the nature of the inner shelf bathymetry. The different beach profiles for the pre- and post-tsunami periods that were prepared through trend analysis, clearly show huge deposition of sediments on the Nagoor beaches. The influence of inlets in Karaikkal, Poompuhar and Nagoor are strongly indicated by the nature of sediments that were deposited on beaches at these locations. When the sediment texture of pre-tsunami deposits is compared with that of post-tsunami deposits, a characteristic shift in kurtosis is observed on all the beaches, while skewness and mean establish a shift on beaches that eroded. Examination of heavy mineral composition in sediments indicates a dramatic shift in concentration, ranging from 19 to 76 % in the Nagoor area. Further study of sedimentological process may shed additional light on tsunami impacts on any beach in the study area, particularly because of the ongoing monitoring and the availability of past baseline records.

Keywords: Tsunami, Coastal areas, Sediments, Mineral compositions

1. Introduction

Worldwide tsunami impacts of the last century have been documented by many researchers (Heck, 1947; Iida et al., 1967; Nakata et al, 1993; Lander and Whiteside, 1997; NGDC, 2001 and Shi et al 1995, Maramai et.al., 2005; McMurtry et. al., 2004; Scheffers and Kelletat, 2003; Tappin et.al., 2001; Nanayama et. al., 2000; Clague et.al., 2000; Dominey-Howes et. al., 2000; Papadopoulos and Chalkis 1984; Monge and Mendoza, 1993; Mörner, 1999). In most cases, post tsunami collected data was used for evaluation and assessment. The present study discusses the erosional and depositional processes in a coastal area of India, before and after the tsunami of 26th December 2004. The tsunami brought sudden changes in sedimentological processes and resulted in transformations of coastal landforms, which also affected the quality of life. The huge amount of erosion that occurred in the foreshore and backshore areas, created drastic changes of the coastal geomorphology, thus necessitating also a new approach to coastal management for this area.

Since April 2003, there was an ongoing project in the study area relating to the impact of placer mining so, profiles were monitored regularly and samples were collected fortnightly. A complete set of geological observations, such as beach profiling, wave numbers, wave failures, littoral drift, sediment texture, heavy mineral distribution, etc., in the tsunami worst affected area, i.e., were collected fortnightly for more than a year, up to December 2004. Such detailed baseline data enabled the assessment of post tsunami changes on sediments and sedimentation processes in this coastal zone. In the recent years, in spite of frequent cyclones, there had been no drastic changes or massive transportation of beach sediments either inland or offshore, except for those caused by the 1999 super-cyclone Orissa in the northern part of the east coast of India. However, the 2004 tsunami caused large and abnormal changes along the Nagapattinam coast. The present paper discusses the nature of changes in sediment composition and transport and in coastal landforms that were caused by the tsunami.

2. The Study area

A survey of the coastal sector between Poompuhar and Nagoor of Nagapattinam district, Tamil Nadu (Figure 1) had been carried since December 2003 for the purpose of understanding the potential environmental impact of proposed beach placer mining. Within this 35 km coastal distance, 8 profiling stations were maintained at intervals of 5 km. A permanent benchmark was fixed at each profiling station and beach profiling was conducted fortnightly since December 2003. The last profiling was completed on 16th December 2004 before the tsunami struck. Similarly, sand sampling was also done at each station at intervals of 5 m along each profiling track. Briefly after the tsunami, on 7th January 2005, another profiling was done after re-checking and re-fixing the benchmark. There were drastic shifts in erosional levels at all stations except for Nagoor. Out of the five stations where measurements were made, at Karaikkal there was 2.5 m change in erosion level, whereas at Poompuhar and Kottucherimedu the erosion levels were 0.5 m to 1.5 m respectively at high tide, and at Chinnankudi and Chandirapadi there was only a marginal change.

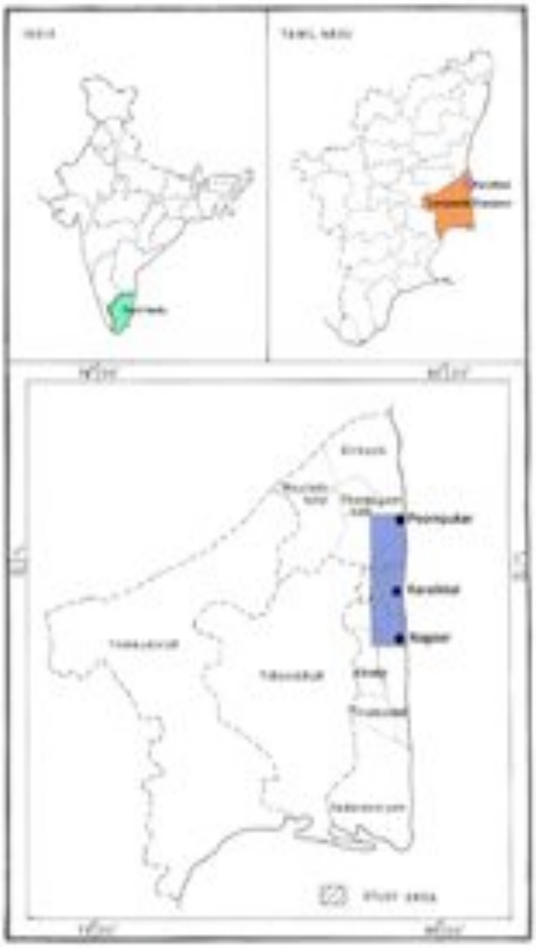


Figure 1. Study Area

3. Coastal Geomorphology and Shelf Characteristics

The study area has a straight coastline trending in N-S direction. After the tsunami, the geomorphologic characters the area was divided into two significant geomorphologic parts viz., Poompuhar to Karaikkal (PK) and Karaikkal to Nagoor (KN). The PK area has wider coastal extent with four massive beach ridges, whereas the KN area represents a narrower coastal spread with one or two low elevated, small beach ridges. The inner shelf off the PK area is narrower, whereas the shelf of KN is comparatively wider. Based on the shelf configurations, it is expected that more sediments must have been flushed into the KN coastal area as compared to PK area, where erosion would be greater.

4. Changes in the Landforms

Notable changes occurred along the study area. The entire coastal geomorphology changed and resulted in new landforms which were subjected to dynamic changes during readjustments with ongoing beach building activities. In many places, it was noted that the steep beaches were converted into gentle ones and vice versa. The behavior of beaches was significantly changed and the response to the post disaster scenario was reversed to that of the earlier time but with quick transformations. Some of the examples are presented below with field illustrations (Figures 2 & 3).

Figure 2 a & b. Pre and Post Tsunami effects at Chandirapadi

Figure 3 a & b. Pre and post tsunami changes at Poompuhar

5. Profiling During Pre- and Post- Tsunami Period

More than 24 beach profiles each for 8 stations along the study area are available for the period during the tsunami. All profiles are mapped. But for the present analysis, pre and post tsunami profiles are discussed here for only three locations viz., Poompuhar (North), Karaikkal (Centre) and Nagoor (South) beaches, where drastic change in profiling are characteristically noticed (Figure 4 a & b).

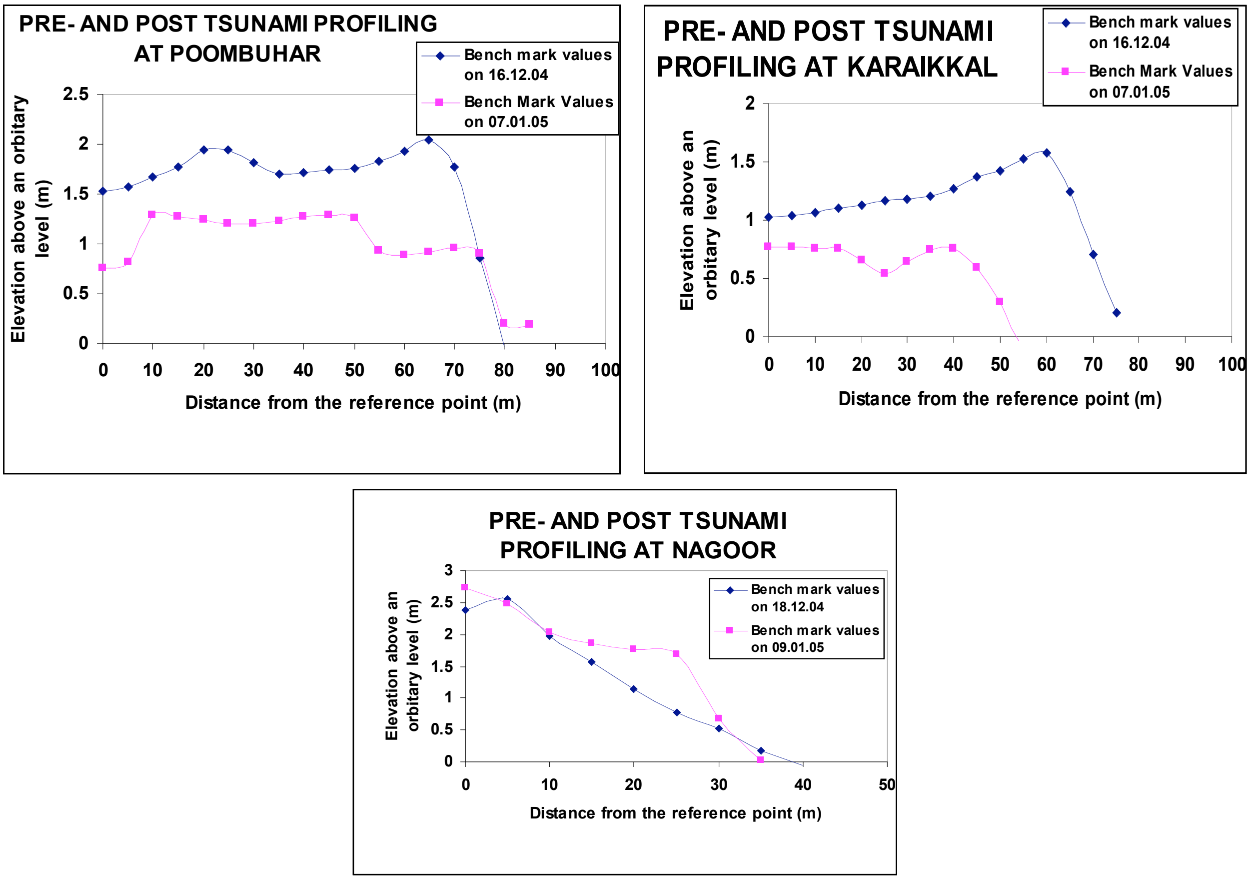
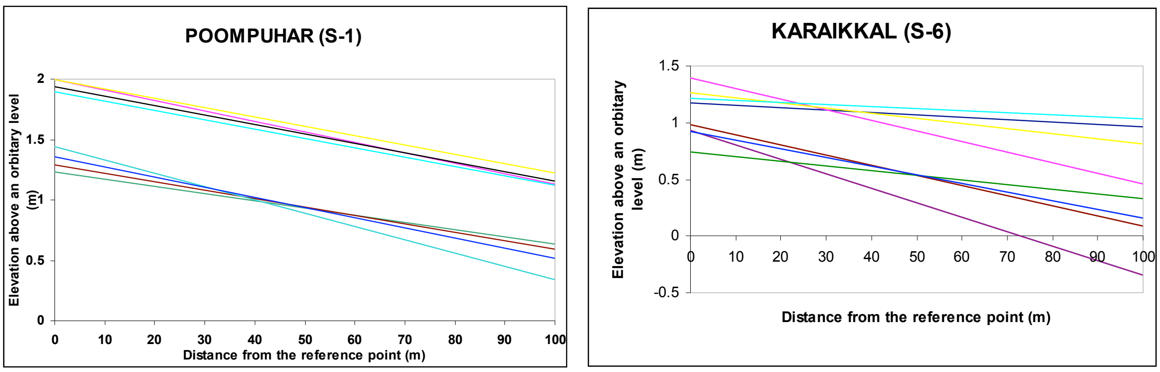


Figure 4 a & b. Pre- and Post-Tsunami Profiling

6. Trend Analysis on Beach Profiling

Beach profiles generated during the pre- and post- tsunami periods were analyzed using linear trend analysis. Pre-tsunami fortnightly profiles (4 Nos.) and Post-tsunami fortnightly profiles (4 Nos.) were studied and details are given in Figure 5a & b. For the purpose of the present discussion, the correlation for Poompuhar, Karaikkal and Nagoor stations are considered.



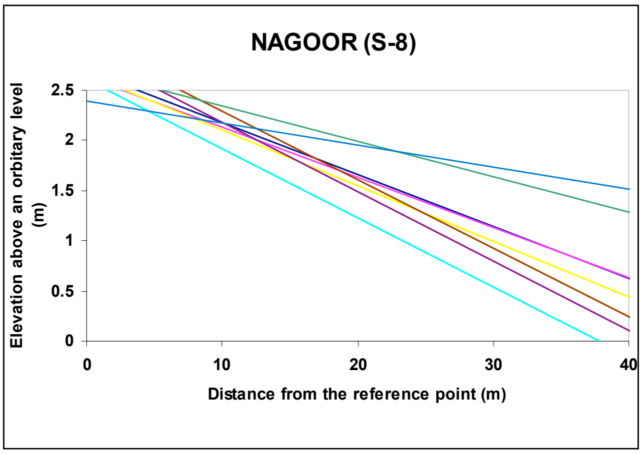


Figure 5 a & b. Trend Analysis

Pre- and post- tsunami trends are smooth at Poompuhar and beach building activity is continuing, whereas sedimentation process at Karaikkal is complex especially after the tsunami. The building capacity is more and severe.

In Nagoor, the trend shows very complex and huge deposition in quick span of time in the post tsunami scenario.

In Nagoor, a meter of deposit occurred in the low tide zone and no erosion in the high tide level. Probably, the drastic change in the deposition at Nagoor may be due to the presence of inlets on either side of the beach. At Karaikkal and Poompuhar strong beach erosion occurred as well as the single inlet and the southern end. Since there was good baseline data for these beaches, the impact of the tsunami was determined accurately. The profile made on the 16th December 2004, as compared to that of 7th January 2005, is indicates the value of good baseline data.

The analysis of high tide samples show that the mean values of these sands in the beaches are showing good relation to the strength of erosion. Wherever strong erosion is observed like at the Poompuhar and Karaikkal beaches, a change from fine to medium size sand was observed, whereas at beach like Chinnankudi the sands became finer. The surficial washing must have removed somewhat the coarser sands. The Nagoor beach shows more or less no change in grain size. The high tide region of the beach at Chandirapadi shows a new variety of sand as a result of erosion. Similarly, at Karaikkal beach the complete change in the present surface sands that was observed was caused by the erosion. In all beaches, there was a characteristic shift in the character of the texture of sand between the pre-tsunami and post-tsunami periods (Table 1).

Table 1. Sand textural values of Pre- and Post Tsunami Sediments

Station	Mean	Std.Dev	Skew.	Kurtosis
Poompuhar	2.08(1.64)	0.58(0.44)	0.14(0.10)	1.44(2.85)
Chinnankudi	2.59(3.04)	0.60(0.48)	-0.04(-0.04)	0.94(1.43)
Chandirapadi	2.63(1.99)	0.58(0.65)	-0.02(0.52)	0.95(1.30)
Kottucheri	2.48(2.67)	0.56(0.57)	0.18(-0.10)	1.20(0.91)
Karaikkal	2.59(1.83)	0.58(0.69)	-0.02(0.26)	0.99(1.25)
Nagoor	2.50(2.83)	0.72(0.60)	-0.21(0.06)	0.66(1.01)

Note: Post Tsunami values are given in brackets.

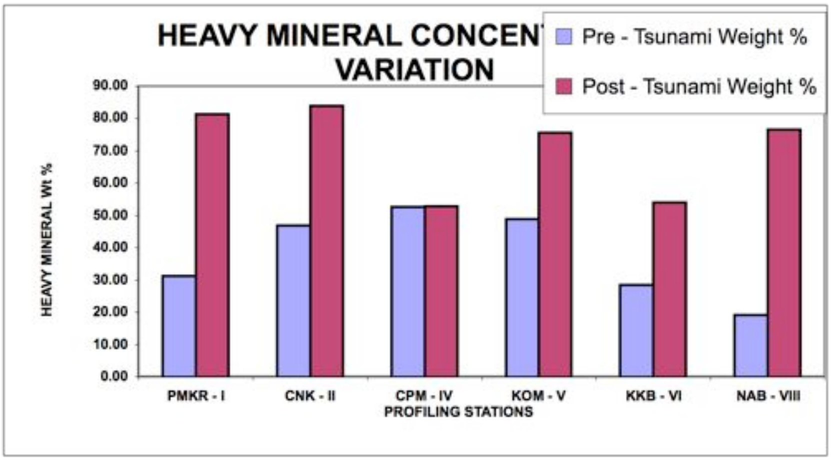


Figure 6. Heavy Mineral deposition scenario

Unlike sediment texture, the heavy mineral analysis showed appreciable changes not only in the concentration but also in the mineral composition. At the Nagoor beach, a dramatic change took place in heavy mineral enrichment. Generally for many years, this beach used to have a 20 % content of heavy minerals. Immediately after the tsunami the heavy mineral compositions was enriched by four times the pre-tsunami level. Moreover, the composition has shown the presence of only garnet, zircon and epidote in the place of fourteen different non-opaque minerals in the assemblage, mainly of flaky constituents (Table 2).

Table 2. Heavy Mineral changes in Weight %

Station Name	Pre – Tsunami Wt %	Post – Tsunami Wt %
Poompuhar	31.10	81.32
Chinnankudi	46.83	83.79
Chandirapadi	52.48	52.79
Kottucherimedu	48.76	75.5.0
Karaikkal	28.25	54.00
Nagoor	19.00	76.45

Whether a beach was erosive or depositive, the heavy mineral concentration has gone to the minimum of twice the strength (Figure 6). The Chandirapadi beach was found to remain an anomaly in maintaining the percentage in tact even after tsunami. However, the composition was found to be without flaky constituents. At Chandirapadi the the impact of the tsunami occurred only at the high tide level segment of the beach.

Detailed studies of the impact of tsunamis on beach sediments may help identify paleo-tsunami material if boreholes are made. In certain places, the concentration of heavier sediments was found to be 2 cm thick. If such thickness with low value of flaky minerals can be found, then such composition may be attributed to deposition by earlier tsunamis.

7. Selective tsunami impacts

Significant Observations

- With all the pre-tsunami beach profiles, it was observed that at least 15 days earlier, there was significant sediment deposition, irrespective of coastline character and behaviour.

- In many locations, the depositional beaches became erosional and vice versa.

- Some of the selected erosional sites became more severely erosional, while at other depositional areas, sediment accretion increased drastically.

The data obtained during pre- and post-tsunami helped assess the selective impacts of the tsunami within a short distance along the shore. Within a coastal distance of 35 km alternate erosion and deposition of sediments were observed. The strong changes in geomorphologic landforms at Poompuhar, associated with the complete removal of the upper sandy layer and its replacement by the lower clay layer suggest the possible influence of inlets in concentrating the tsunami's energy. At the same time, the presence of two inlets on either side neutralizes the tsunami's path and results in the accretion of sediments on the bounded beach. The various changes observed in sediment landforms and mineralogy indicates the possibility of greater impact through the inner-shelf bathymetry. The concentration of heavy minerals indicates that the outer shelf is the source of origin.

Acknowledgements

The authors wish to thank the Honorable Vice-Chancellor of SASTRA University, Thanjavur for encouraging this study. Also, the authors acknowledge with appreciation the Council of Scientific and Industrial Research (CSIR) & the National Resource Data Management System (NRDMS) Division and Earth System Science Division of the Department of Science and Technology (DST) for providing the financial assistance and the necessary equipments to accomplish this study.

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