

connectivity and observations to assess the extent and type of damage, response for relief and priority areas for relief. Strengthen the ground (coastal and NE region) and ocean observation networks using automatic weather stations, ocean data buoys, radar etc.

Establishing a Tsunami Warning Centre for the Indian Ocean Littoral States

International efforts under the UN auspices for the establishment of an Indian Ocean Tsunami Warning Centre on similar lines as the Pacific one, are already underway with several agencies, governments and private companies coming forward. India should take a lead in this effort in view of its location as well as its scientific competence. Pending accomplishment of the above, following measures are to be taken by India to strengthen existing facilities.

10. Set up tide gauges to monitor sea level at important places on land, offshore and near islands; and radar-based monitoring stations for measurement of surface currents and waves.
11. Deploy atleast 10 highly sensitive "Deep Ocean Assessment and Reporting of Tsunamis" (DART) systems on a priority basis in the Indian Ocean, in addition to the existing seven gauges already deployed, to accurately record the tsunami waves and relay over satellite to the warning centre. Indigenous fabrication of DART systems substantially reduces the cost.
12. Modelling and simulation of wave propagation data is vital for tracking and issuing early warning on approaching tsunamis.

Education, Research and Development of Manpower

13. Initiate new training programmes at all levels and strengthen existing ocean related programmes in the Universities to build appropriate manpower to face the challenge through interdisciplinary ocean science and technology.
14. Setting up of Rural Science Centres to educate the masses in their regional languages about the need to be prepared to face such hazards. Training programmes should be organized on disaster management including sociological/psychological implications, security aspects and heirarchy of action-plan in case of a disaster and concurrently, strengthen and sensitise the administrative machinery to cope with such crisis situations. Introducing relevant concepts and imparting basic information at the school level is also extremely important in this context.
15. Strictly enforcing coastal zone regulations to avoid construction within the stipulated sensitive coastal zone is of highest priority.
16. A Central Disaster Management Act should be legislated to take care of all the legal aspects of claims and liabilities after any such natural disaster after a thorough public debate.

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TSUNAMI OF 26th DECEMBER 2004: OBSERVATIONS AT CHENNAI AND EAST COAST OF INDIA

The tsunamis generated were observed after about two hours of the earthquake occurring on board the Jason Satellite (NASA) in the Indian Ocean. The surface waves had a wavelength of about 800 km, same as its velocity of 800 km/hr in deep sea. The crest of the waves was higher by 50 cm than normal sea level while the trough was 40 cm than normal. The second wave following had a crest height of 40 cm. But in the northern direction (towards Myanmar it was much less (~40 and 20 cm).

The first tsunami waves hit the East Coast between 7.30 and 9 AM; the second around 11 AM. In Chennai, the tsunami hit the Marina beach around 8 AM. The waves rose

to a height of about 2 m. The area around Marina beach accounted for a large number of deaths due to the fact that the day being a Sunday, several youngsters were playing on the beach and morning walkers were still present. In North Chennai, it was severely felt because of the presence of a large fishermen population, right on the beach, just like at Santhome, a few hundred metres south of Marina beach. In Besantnagar and further south, the loss of life was smaller since not many were living on the beach front. In the Marina area, the wide beach absorbed most of the energy, which prevented it effectively from crossing the road. However, in areas where monuments were constructed on the beach,

the waves rushed in to these structures. In Besantnagar and further south, the sand dunes present along the coast acted as an effective barrier against the advance of the waves, saving the citizens there. In the Marina area, the walls of the lighthouse were damaged, and the ground floor flats in the Santhome foreshore estates were flooded. These apartments are much closer to the seashore than the rest of Marina area. The absence of a beach resulted in the Chennai Beach station, behind Chennai Port being partially flooded.

Further south, in Mahabalipuram, the loss to property was more due to the presence of a large number of luxury resorts, which are constructed very close to the beach. The rising waves were noticed here around 7.30 AM.

In Cuddalore, the waves were reportedly 2-3 m high, while in Kanyakumari the sea waves were reportedly much higher. In Nagapattinam, which suffered the most, the height of the tsunami waves can be gauged from the fact that a goat was found on a overhead water tank, which is about 10 m above ground surface. The tsunamis hit the Velankanni coast around 9.20 AM.

In many places people observed the sea retreating sharply before the waves advanced on to the shore. This is a well known phenomenon, caused due to the mass of water going down whenever there is a vertical (downward on one side) displacement of ocean bottom.

In Veerampattinam, in Nagapattinam, a spring was suddenly noticed flowing into a tank, which attracted a large number of people away from the seashore and this saved many a life there. This phenomenon could be due to the hydrostatic pressure created by the additional water column formed by the rising water mass. This is similar to the groundwater levels rising in coastal confined aquifers during the high tide.

Effects on Groundwater Quality

As per present information the groundwater quality along coastal aquifers has not deteriorated due to seawater flooding the coastal area. This is mainly due to the fact that the seawater withdrew within minutes of moving inland. In some instances, the open wells in the affected zone were filled with seawater, but once they were dewatered, the fresh groundwater inflow in to these wells was seen to be having the same quality as before. Analysis done on groundwater from wells near the beach in Marina and Besantnagar confirm this.

The inundation caused by the tsunami waves have however affected the coastal land by depositing vast quantities of black clay and silt. This has been observed in many areas. In Chennai Marina beach, there was just a veneer of clay, which was washed away with in a few days. But in

Nagapattinam, Cuddalore etc., a very wide swath of land is covered by black clay of up to 3 m thickness. The thickness is directly proportional to the depth of depressions in local topography, with some tanks and low-lying areas having thickest deposits. The salt pans have also suffered immense damage due to deposition of this clay. The material deposited coarsens towards the sea. Many houses have a coating of clay on their walls up to even 2 m height. It is believed that more people died due to ingestion of this mud during the tsunami, rather than by plain drowning. The clay has been obviously scooped by the advancing water body from shallow shelf zones. This is indicated by the rich biota present in this clay material.

As to why some areas suffered more than others on the east coast and why some areas were spared, the answer may lie in a combination of coastal configuration, slope of the coastal shelf zone, presence of vegetation/ mangroves, creation of 'shadow zones' etc. A cursory examination shows that the effects were maximum in the area where the coast juts out in to the sea (from Chennai to Vedaranyam); minimum where the coast is concave inwards (North of Chennai up to Machilipatnam; Rameshwaram area). An appreciable strip of land between Kanyakumari and Vedaranyam had minimal effect due to a combination of factors such as being in the shadow zone behind Sri Lanka (Sri Lanka bore the brunt of tsunami attack) and also the shallow depths of the Gulf of Mannar sea. This rise in sea floor in this zone may also have contributed to the fury of the incoming waves at Nagapattinam in the north and Kanyakumari in the south by diffracting and refracting the incoming waves away from it.

Presence of estuaries also lessened the impact around them since a large volume of water was taken into the estuary and river channels. It was observed that even at 3 PM on that day, Adyar river, which is almost stagnant with effluents and sewage, was flowing in to the sea as if in floods. So did mangroves in many a place.

This unprecedented disaster also teaches us what not to do. It is very clear that wherever man has altered the natural coastal environment, he has paid dearly. Where coastal dunes have been reduced for one reason or the other, human losses have been grave. Probably, the coastal zone regulation act, which prohibits any constructional activity with in 500 m of the high tide line should be strictly enforced.

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