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Research Article

The Role of the Public Works Department in Mitigating Tsunami Impact: A Case Study of Kanyakumari District

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ABSTRACT

The 2004 Indian Ocean tsunami had a catastrophic impact on the coastal regions of Kanyakumari District, resulting in widespread devastation to human life, infrastructure, and the local economy. This study examines the tsunami's effects on physical geography, including inundation distance, run-up elevation, and tsunami wave height, as well as its destructive influence on human settlements, fisheries, agriculture, and public infrastructure. Low-lying coastal areas experienced extensive inundation and sediment deposition, leading to the displacement of thousands and severe loss of livelihood resources. The lack of public awareness and preparedness significantly contributed to the human toll, particularly among children. The paper highlights the critical need for integrated coastal zone management, community-based disaster preparedness, and infrastructure resilience to mitigate the impacts of future tsunamis and related coastal hazards in the region.

Keywords: Inundation Distance - Run-up Elevation - Coastal Erosion - Human Loss - Fisheries Damage - Infrastructure Destruction - Agricultural Impact - Sediment Deposition - Disaster Preparedness - Coastal Vulnerability - Rehabilitation.

Introduction:

A disaster is any event that causes significant damage, ecological destruction, loss of human life, or a breakdown in health services on a scale that requires an extraordinary response from outside the affected community. Disasters are broadly classified into two types: human-made and natural. Different countries face various kinds of disasters, both natural and human-made, resulting in severe losses of life, property, environment, and infrastructure. In the absence of community preparedness for disaster mitigation and management, people and regions vulnerable to such events face the risk of devastation and extinction. Among the many natural disasters that have occurred in India, the tsunami of December 26, 2004, which struck the eastern coast from Chennai to Kanyakumari, stands out as one of the most catastrophic. This giant wave originated under the sea near Indonesia. Thousands of people, primarily those living in coastal settlements, fell victim to this disaster. Since it was an unfamiliar phenomenon, the unsuspecting and uninformed fishing communities—who had never encountered or even heard of tsunamis before—were particularly vulnerable and suffered heavily.

Tsunamis are ocean waves generated by large and sudden disturbances of the ocean floor, often caused by undersea earthquakes, volcanic eruptions, massive landslides (either underwater or from above), or meteor impacts. In deep water, tsunamis can travel at speeds of up to 800 km/h, as their speed is proportional to water depth (the phase speed equals the square root of the product of gravity and water depth). Tsunamis can travel thousands of kilometers from their point of origin, causing death and destruction far from the original earthquake epicenter. Although the Indian subcontinent is in a seismically active region, tsunamis along India's coastlines have been rare, though not unprecedented. Over the past 200 years, the Indian coastline has experienced at least four significant tsunami events. While tsunamis are more common in the Pacific region, destructive tsunamis have also occurred in the Indian and Atlantic Oceans (Altinok, 2000). One of the earliest recorded tsunamis to affect India was caused by the volcanic eruption of Krakatoa in Indonesia on August 27, 1883.

On December 26, 2004, a massive undersea earthquake occurred northwest of Java and Sumatra in a highly seismic zone. The earthquake, with a magnitude of 9.0 on the Richter scale, struck at a relatively shallow depth of approximately 10 kilometers below the ocean floor. It was followed by another quake measuring 7.3 on the Richter scale, located 81 kilometers off Pulo Kunji, Great Nicobar, India. These events triggered a massive tsunami that devastated several countries in South Asia and East Africa, including Indonesia, Sri Lanka, India, Thailand, Somalia, Myanmar, the Maldives, Malaysia, Tanzania, Bangladesh, Kenya, and Seychelles. The earthquake's high magnitude (9.0 on the Richter scale at 3.4° N, 95.7° E) and its shallow epicenter caused a tsunami, also known as a seismic sea wave, in the northeastern Indian Ocean Basin. The waves traveled across the Bay of Bengal, transforming into a series of destructive oscillations that struck numerous countries, including Malaysia, Sri Lanka, India, Thailand, Myanmar, the Maldives, and Somalia in Africa. The tsunami waves that hit South and Southeast Asia in the early hours of December 26, 2004, claimed the lives of at least 283,000 people and displaced another 1.1 million in the region.

In India, the tsunami affected nearly 2,260 kilometers of the mainland coastline—including Tamil Nadu, Kerala, Andhra Pradesh, and Puducherry—as well as the Andaman and Nicobar Islands. Tidal waves as high as 10 meters penetrated up to 3 kilometers inland, killing at least 10,749 people and impacting more than 2.79 million people across 1,089 villages. Tamil Nadu was the worst affected state on the Indian mainland, reporting over 8,010 deaths. Thirteen districts were hit by the tsunami, with Nagapattinam, Kanyakumari, and Cuddalore being the most severely affected, registering death tolls of 6,065, 828, and 617 respectively. According to the Government of Tamil Nadu (GoTN), a total of 984,564 people were affected, over 8,000 lives were lost, and 126,182 homes were damaged or destroyed. More than 3,400 people were reported missing. About 1,000 kilometers of Tamil Nadu's coastline were affected, with seawater penetrating 1 to 1.5 kilometers inland. The tsunami caused extensive damage to approximately 19,168 hectares of agricultural land. In addition to the tragic loss of life, Tamil Nadu suffered significant livelihood losses, including boats and fishery assets, livestock, the collapse of the fisheries sector, disruptions to traditional markets and other coastal livelihoods, and damage to vital resources such as pasture and grazing lands. The tsunami also caused severe damage to social infrastructure, community assets, harbors, as well as transport, power, and communication systems.

Tsunami Sand Deposits

The catastrophic tsunami wave carried sand and pebbles from the beach and ocean floor, depositing them inside buildings, on rooftops, and across the ground along the coast of the district. Tsunami-related pebble deposits were widely observed throughout the study area. The sandy deposits along the coastal tract were eroded and transported from both the foreshore and backshore regions. Pebble deposits caused by the tsunami were noted in several locations—Colachel, Kotilpadu, Muttom, Midalam, Azheekal, Manakudi, Keezhamanakudy, and Kanyakumari—extending inland from 50 meters to 700 meters, with deposit thickness ranging from approximately 4 cm to 12 cm. The massive tsunami wave not only eroded the land but also had the power to transport large objects, including cars, household items, and even parts of concrete structures.

At the mouth of the Manakudy estuary, the bridge connecting Manakudy and Keezhamanakudy was displaced, with its concrete blocks—each weighing several tonnes—pushed to either side of the banks. A Catholic church in Keezhamanakudy was also completely demolished by the wave. Most of the landforms along the southwest coast of Kanyakumari district experienced morphological changes due to the tsunami's impact. Over the past two decades, coastal erosion in this region has become increasingly evident, leading to the loss of beaches and the gradual retreat of the shoreline. The land-sea interface has become fragile, showing continuous signs of erosion and degradation over time, threatening the coastal communities. Due to the absence of effective anti-erosion structures, seawater enters these villages annually, causing flooding and damage. The residents are engaged in a losing battle to protect their homes, which are being gradually consumed by ongoing sea erosion.

Inundation Distance

Inundation distance is defined as the distance from the shoreline to the inland limit of tsunami penetration. In the study area, this distance varied significantly—from less than 50 meters to more than 700 meters—depending on the location. The variation was influenced by several factors such as land slope, underwater topography (bathymetry), orientation of the coastline, and the presence of Rubble Mount Sea (RMS) walls or groins (Henry et al., 2010). Inundation was minimal from Thengapattanam to Enayam, where RMS walls measuring up to 10 meters in height and a series of offshore rocky hillocks provided natural protection. This region, located in the northwest part of the study area, experienced only low-intensity tsunami waves.

Tsunami inundation distances across the study area varied. The three major riverine ecosystems—Thengapattanam estuary, Valliayar estuary (Kadiapattanam), and Manakudy estuary—experienced water inundation extending over 3 kilometers inland. Smaller channels, such as the Pampar estuary near Colachel and the Pantri estuary near Rajakkamangalam, witnessed inundation distances ranging from approximately 0.5 to 1.0 kilometers. Although Rajakkamangalam is an elevated area, it experienced inundation on either side of the Pantri estuary. In Colachel, tsunami water entered through the Pampar estuary and flowed into

the AVM canal, leading to severe casualties and significant human loss. Low-lying coastal areas like Keezhamanakudy, Chothavilai, and Azheekal beach reported extensive inundation distances. Natural harbors with greater depths, such as those in the Colachel and Kotilpadu areas, also experienced substantial inundation. Since these estuaries were exposed to ebb tides, the tsunami waves arrived with violent eddies and turbulent surges, causing extensive damage to the surrounding regions (Shuto, 1991).

Run-up Elevation

Run-up elevation is defined as the height above mean sea level that a tsunami reaches at its furthest point of inland penetration. In the study area, run-up elevations varied from less than 2 meters to as high as 10 meters. Higher run-up elevations were recorded in the regions between Kanyakumari and Chothavilai, Azhikal and Muttom, and Kotilpadu and Colachel. The variation in run-up elevation is influenced by the same factors that affect inundation distances, including the slope of the land, nearshore bathymetry, coastal orientation, and the presence of protective structures. Run-up elevation is also closely related to the inundation distance and the underwater topography of the nearshore zone. Around Colachel and nearby areas, run-up elevations reached approximately 6 meters, as evidenced by watermarks observed in buildings and other civil structures. In the eastern parts of the study area, particularly at Keezhamanakudy and Azhikal, the run-up elevation extended to altitudes of about 10 meters.

Tsunami Height

Tsunami height is defined as the vertical distance from the seabed (bottom topography) in the nearshore environment to the top surface of the wave. Changes in tsunami height with distance from the shoreline provide valuable information about how the wave loses energy as it moves inland. Casualties and the extent of disaster are closely linked to the height of the tsunami.

In the study area, the height of the catastrophic wave gradually decreased from the eastern end to the western end—that is, from Kanyakumari to Thengapattanam. However, the severity of damage did not always correspond directly to wave height. For example, although the Kanyakumari coast experienced relatively high tsunami waves—reportedly reaching the height of the Thiruvalluvar statue (approximately 171 feet above mean sea level)—the impact and damage were comparatively less. In contrast, regions between Manakudy and Chothavilai, Azhikal and Kadiapattanam, and Kotilpadu and Colachel experienced more severe destruction and higher casualties. This disparity is attributed to significant variability in nearshore bathymetry, the orientation of the coastline, and the diffraction patterns of the tsunami waves.

Human Losses

Due to the lack of awareness about tsunamis—unlike in the Pacific Ocean region—Kanyakumari District suffered heavy casualties. A total of 801 people lost their lives in the study area, with children being the primary victims. Many individuals drowned or were swept away along with sediments by the powerful waves. Low-lying areas such as Colachel, Kotilpadu, Manakudy, and Azhikal reported a large number of fatalities. Despite the presence of RMS walls and elevated terrain at Manakudy, seawater inundated the area from the adjacent Chothavilai region, flowing eastward and damaging the western parts of Manakudy. The number of deaths and missing persons in each location following the tsunami has been documented. Among the 801 deceased, 334 were children, and 17 were from other districts and states.

Housing and Shelter

In many of the affected villages, all types of houses were completely destroyed by the tsunami waves. Huts, tiled houses, mud houses, and even concrete buildings collapsed during the catastrophic event. Household items such as cooking vessels and furniture were washed away. Houses situated parallel to the coastline were more affected than those oriented perpendicularly. Even newly constructed houses were uprooted in the severely inundated zones. Government-constructed colony houses were completely destroyed in areas like Kotilpadu and Colachel. Detailed records show the number of houses in each hamlet that were fully, partially, or minimally damaged.

Fisheries

The fisheries sector, a major contributor to the local economy, was severely impacted, as a majority of the population along the 68 km-long coastline depends on fishing for their livelihood. December 26, 2004, being a Sunday, was a holiday for fishermen. At the time, numerous vallams (boats) worth ₹1.5 lakh each, equipped with Yamaha engines valued at ₹75,000, and catamarans ranging from 12 to 20 feet with lambadi engines were resting on the beaches. Various types of fishing nets were also laid out near the shore and homes. Due to a lack of awareness about tsunamis, all these assets were placed perpendicular to the direction of the approaching waves, making them highly vulnerable. As a result, catamarans, nets, and other fishing equipment were swept away into the sea, while large amounts of sand were deposited on the shore.

Fishing gear was carried as far as 2 to 3 kilometers inland, into estuaries, where it was damaged or rendered unusable. In total, 15,379 fishermen lost their catamarans, vallams, and mechanized boats. The entire fishing community was forced to rebuild their lives and livelihoods from scratch with new equipment and nets.

Chinnamuttom Harbor, the only fishing harbor in Kanyakumari District, suffered extensive damage. A total of 39 mechanized boats were completely destroyed, while 347 were partially damaged.

Damage to Infrastructure

The ferry service between Kanyakumari and the Vivekananda Rock Memorial and Thiruvalluvar Statue was disrupted by the tsunami. One ferry was completely destroyed and washed away, while two others sustained major damage. The boat jetty was also severely damaged. Sothavilai Beach, a popular tourist destination, was badly affected. Several public facilities such as children's parks, sanitary complexes, and bus shelters were damaged. More than 123 kilometers of roads were destroyed. Additionally, 4 schools, 30 anganwadis, 12 sanitary complexes, 16 public buildings, and 2 churches were fully damaged. Electrical infrastructure also suffered: 2,601 electric poles, 58 km of electric conductors, 1,316 public lights, and 27,294 household power connections were damaged. In Manakudy village, the concrete bridge over the Pazhayar River, connecting Melmanakudy and Keezhamanakudy, was washed away. Four spans of the bridge—each weighing 775 metric tonnes and 140 meters in length—were lifted from their foundations and carried away by the tsunami. Moreover, 23 small industries, 17 coir industries, and 91 small traders were affected in the study area.

Agriculture

Kanyakumari District, located in a tropical region rich in natural greenery and river tributaries, also experienced severe agricultural losses. The intrusion of seawater led to the destruction of vegetation, including herbs and crops. Coconut trees dried up and were expected to take a long time to yield again. In coastal villages, both plantations and agricultural wetlands were completely wiped out. In total, the tsunami affected 282.57 hectares of coconut plantations, 6.47 hectares of paddy fields, 6.57 hectares of banana plantations, 1.4 hectares of palm tree areas, and 0.52 hectares of other crops.

Conclusion

The 2004 Indian Ocean tsunami had a devastating impact on Kanyakumari District, resulting in significant loss of life, widespread destruction of property, and severe disruption to livelihoods, particularly in the coastal communities. The disaster exposed the region's vulnerability to seismic sea waves, highlighting the urgent need for greater awareness, preparedness, and coastal resilience measures. Human casualties were tragically high, especially among children, and critical infrastructure—including housing, roads, public utilities, and fishing harbors—was either damaged or completely destroyed. The fisheries sector, a cornerstone of the local economy, suffered irreversible losses, while agricultural lands were rendered barren due to saltwater intrusion. The tsunami also demonstrated how geographical factors such as coastal orientation, nearshore bathymetry, and the presence (or absence) of protective structures influence the scale of destruction. Moving forward, it is essential to implement effective coastal management strategies, strengthen early warning systems, and invest in long-term rehabilitation and disaster risk reduction to safeguard lives, livelihoods, and ecosystems in this vulnerable region.

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