Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), vol 12, special issue. 2024
http://dx.doi.org/

Chapter 4

Tsunami disaster in India, mitigation and their impacts

Desastre del tsunami en India, mitigación y sus efectos

Sahdev, [1,*] Dr. Bharat Lal Sahu, [2] Dr. Shobhana Ramteke [3]

[1, 3] School of Studies in Environmental Science, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh – 492010

[2] Department of Chemistry, Guru Ghasidas Vishwavidyalaya (A Central University), Bilaspur, CG, India

Email - *sahdevsahurkb@gmail.com

ABSTRACT

A tsunami is a natural disaster. This disaster affects India as well as the whole world. The main causes of tsunami disasters are earthquakes, volcanic eruptions, landslides, and extra-terrestrial occultations. Its types are local, and regional, distance tsunamis. The history of the tsunami in India dates back from 1762 to 2004. About 18,000 people died in the 2004 tsunami. Tsunami-affected areas in India are West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, etc. It has caused human, animal, Mineral Resources, Surface WaterResources, Forest and Biomass, Coastal Environment, Terrestrial Environment, Loss of life and property, Disease, Impact on environment and biodiversity, and Economic cost, harm. In this review, causes, damages, management, mitigation, etc. have been discussed tsunami.

Keywords: Tsunamis, causes, scales, historic tsunamis in India, impacts, management, mitigation.

RESUMEN

Tsunami es un desastre natural. Este desastre afecta tanto a la India como al mundo entero. Las principales causas de los desastres causados por tsunamis son los terremotos, las erupciones volcánicas, los deslizamientos de tierra y las ocultaciones sobrenaturales. Sus tipos son tsunamis locales y regionales, remotos. La historia del tsunami en la India se remonta a 1762 a 2004. Unas 18.000 personas murieron en el tsunami de 2004. Las áreas afectadas por el tsunami en la India son Bengala Occidental, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, etc. Ha causado daños humanos, animales, recursos minerales, recursos hídricos superficiales, bosques y biomasa, medio ambiente costero, medio ambiente terrestre. Pérdida de vidas y

propiedades, enfermedades, impacto en el medio ambiente y la biodiversidad, y costos económicos. Esta revisión analiza las causas, los daños, la gestión, la mitigación, etc. de Tsunami.

PALABRAS CLAVE: Tsunami, causas, escala, tsunami histórico en India, impacto, gestión y mitigación.

INTRODUCTION

The tsunami in the Indian Ocean on December 26, 2004, was one of the most devastating natural disasters in the world. The Tsunami of Santo Stefano, triggered by an earthquake measuring 9.1 on the Richter scale (the third strongest ever recorded), killed about 230,000 people in 14 countries around the Indian Ocean; among the victims were citizens of over 60 countries. The tsunami spread across the North Pacific and North Atlantic [1, 2] and was arguably the most catastrophic and deadly tsunami in recorded history [3]. A large number of Deep-ocean Assessment and Reporting of Tsunami (DART) stations have been deployed in optimal alignment with subduction zones around the entire Pacific Ocean; DARTs are now also used in the Indian and Atlantic oceans [3, 4]. Numerous high-resolution cable downstream stations have been installed off the Pacific coast of Japan; Similar geophysical stations are also deployed near the coast of Vancouver Island, Canada [5]. "Tsunami" is originally a Japanese word ("Tsu" - harbor, "Nami" - wave) and is only widely known in the Pacific Ocean and seems to have occurred occasionally in the Indian and Atlantic Oceans in the past [6]. When earthquakes occur at the bottom of the sea, huge amounts of water are displaced from the bottom of the sea and these water-induced displaced waves propagate in all directions with a longer wavelength from 400 to 500 km and an enormous speed of 700 to 800 km/h. But when tsunamis hit the coasts, their speed (up to 40-50 km/h) and their wavelengths (too few meters) decrease phenomenally, and on the contrary, their amplitude (run-up) increases up to at 8-12m. Such tsunami waves with a speed of 40-50 km/h not only hit the coasts hard but also flood large areas on the coastal plains and cause serious damage to animate and inanimate things [6]. These wild tsunami waves are generated in the oceans by massive underwater earthquakes, landslides, and volcanic eruptions, as well as the fall of huge ice caps, meteorites, etc. [6]. However, despite the recent advances, tsunamis remain a major threat to coastal infrastructure and human life. Destructive tsunami events continue to kill people and create enormous damage [3].

Figure: 1 Indian Ocean tsunami

Source: https://www.business-standard.com/article/current-affairs/fourteen-years-on-what-have-we-learned-from-the-indian-ocean-tsunami-118122700182_1.html

CAUSES

1. Earthquakes: The surface of the earth is made up of tectonic plates and when these plates undergo tectonic activity (propagation, subduction, and transformation) they can lead to tsunamis. However, not all earthquakes cause a tsunami. For an earthquake to trigger a tsunami, certain conditions must be met. Some of them are like earthquakes that must happen under the ocean, it must be strong, there must be surface fracturing (shallow depth) and the earthquake must cause vertical movement of the seabed [8].

2. Volcanic eruption: Volcanic explosions cause impulsive disturbances and therefore can move large amounts of water and cause large tsunamis. A tsunami can also occur when a caldera volcano collapses after an eruption and the overlying water suddenly falls. Pyroclastic flows (dense mixtures of hot boulders, pumice, ash, and gas) from volcanic slopes that plunge into the oceans can push water outward, causing a tsunami. Underwater volcanoes can also trigger a tsunami. However, such tsunamis are rare [8].

3. Landslides: Landslides occurring along the coasts can force a large amount of water into the sea thus causing a disturbance in water resulting in a tsunami. Underwater landslides also cause tsunamis when the material loosened by the landslide moves violently, pushing the water in front of it [8].

4. Extra-terrestrial occurrences: A tsunami caused by extra-terrestrial collisions has not taken place in recent history but it is believed that if celestial bodies like asteroids or meteors strike the ocean, a large volume of water would be displaced causing a tsunami [8].

TYPES

Local tsunamis: These affect areas within 100 km (60 miles) of the event that caused the tsunami (earthquake, etc.). These tsunamis can be more devastating because they arrive within 10-60 minutes of the occurrence of the tsunami event. Such tsunamis provide insufficient time for evacuation [8].

Regional tsunamis: These tsunamis cause damage in areas between 100km and 1000km from the event that triggered the tsunami. Sometimes they can even damage areas outside the 1000km radius. These tsunamis occur between one and three hours after the event that triggered the tsunami. They offer a little more time than local tsunamis to take protective measures. However, one to three hours may not be enough for a safe evacuation in an area of 1,000 km [8].

Distant tsunamis: Also called fairytale tsunamis or ocean tsunamis. They come from 1,000 km from the affected coast. They travel across vast oceans and can cover entire ocean basins. As it takes time to reach the shore, there is more time for a safe evacuation. It covers a large landmass causing widespread destruction [8].

SCALES OF INTENSITY AND MAGNITUDE

As with earthquakes, several attempts have been made to set up scales of tsunami intensity or magnitude to allow comparison between different events [9, 10].

Intensity scales: The first scales used routinely to measure the intensity of tsunamis were the Sieberg – Ambrasevs *scale (*1962), used in the Mediterranean Sea, and the *Imamura-Iida intensity scale* (1963), used in the Pacific Ocean. This last scale was modified by Soloviev (1972), who calculated the tsunami intensity "I" using the following formula:

$$I = \tfrac{1}{2} + \log_2 H_{au}$$

Where *H au* is the "tsunami height," averaged along the nearest coastline, with the tsunami height defined as the rise of the water level above the normal tidal level at the time of occurrence of the tsunami [9, 11]. This scale, known as the *Soloviev-Imamura tsunami intensity scale,* is used in the global tsunami catalogs compiled by the NGDC/NOAA [12], and the Novosibirsk Tsunami Laboratory as the main parameter for the size of the tsunami.

This formula yields:

- $I = 2$ for $H_{au} = 2.8$ metres
- $I = 3$ for $H_{au} = 5.5$ metres
- $I = 4$ for $H_{au} = 11$ metres
- $I = 5$ for $H_{au} = 22.5$ metres etc.

In 2013, following the intensively studied tsunamis of 2004 and 2011, a new 12-point scale, the Integrated Tsunami Intensity Scale (ITIS-2012), was proposed, aligning as closely as possible with the earthquake intensity ESI2007 and modified EMS [9, 13, and 14].

Magnitude scales: The first scale that actually calculated the magnitude of a tsunami rather than its intensity at a specific location was the potential energy-based ML scale proposed by Murty and Loomis [9, 14]. Due to the difficulties in calculating the potential energy of the tsunami, this scale is rarely used. Abe introduced the tsunami magnitude scale Mt, calculated from,

$M_t = a \log h + b \log R + D$

Where h is the maximum amplitude of the tsunami wave (in m) measured with a gauge at a distance R from the epicenter, a, b and D are constants used to match the Mt scale to the moment magnitude scale as closely as possible [9, 14].

HISTORICAL TSUNAMIS IN INDIA

The Indian coastal belt has not experienced many tsunamis in the past. Waves accompanying seismic activity were reported in the northern Bay of Bengal. Tsunamis were reported during an 1881 earthquake that had its epicenter near the center of the Bay of Bengal. The 1941 Bay of Bengal earthquake caused devastation in the Andaman region. This was unusual since most tsunamis are generated by shaking occurring on or near the sides of continental slopes. During the earthquakes of 1819 and 1845 near the Rann of Kutch, there were rapid movements of water in the sea [15]. There have been no waves reports of these earthquakes along the coast overlooking the Arabian Sea and tsunamis are unlikely to have been triggered. Further west, in the Persian Gulf, the Makran earthquake of 1945 (magnitude 8.1) unleashed a tsunami 12 to 15 meters high. This caused a huge flood, with a significant loss of life and property in Ormara and Pasi. The estimated height of the Gulf of Cambay tsunami was 15 meters, but no damage report is available. The estimated wave height was around 2 meters in Mumbai, where boats were pulled from their moorings and casualties occurred [15].

Table: 1 A list showing the Tsunami that affected Indian coast prior to Sumatra Earthquake of December 26, 2004, is given in the below table.

Date	Cause	Impact	Source
12th April 1762	Earthquake in the Bay of Bengal	A tsunami wave of 1.8m on the Bangladesh coast	[15]
31st	A 7.8 magnitude	The entire East coast of India including the	[15]

December 1881	earthquake beneath the car Nicobar	Andaman & Nicobar coast was affected by the tsunami	
27th August 1883	Eruption of Krakatoa volcano (Sunda Strait) Indonesia	The East coast of India was affected and a 2 m Tsunami was reported in Chennai.	[15]
26th June 1941	An 8.1 Magnitude earthquake in Andaman	The East Coast of India was affected by a tsunami.	[15]
27th November 1945	27th November 1945 (21 Hour UTC) in the Makran subduction zone (Baluchistan, Pakistan) (24.5N & 63.0E) with Mw of 8.1	The West coast of India was affected by Tsunami.	[15]
26th December 2004	The strongest tidal wave registered in India reached a height of 17.30 meters	Chennai was one of the major cities to be affected by the tsunami. The death toll in India alone was above 18,000.	[16]

TSUNAMI PRONE AREAS IN INDIA

The government has identified a list of areas prone to tsunamis in India on the eastern coast. These include - Puri, Kakinada, Machilipatnam, Nizampatnam-Vetapalem, Chennai, Cuddalore-Pondicherry, Rameshwaram, Thoothukudi, Alappuzha-Chavara, and Kochi [16].

You should know that tsunamis aren't common in India due to their geography. However, India isn't immune to tsunamis. Records show the tsunami-affected areas in India suffered a major blow. These tsunamis originated in the Indian Ocean [16].

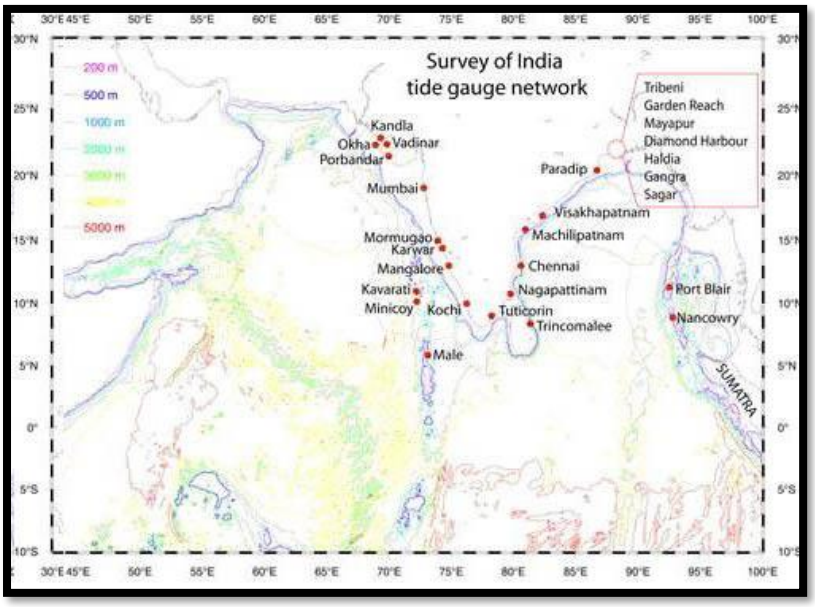

Figure: 2 Tsunami Prone Areas in India

Source: https://ndma.gov.in/Natural-Hazards/Tsunami

IMPACTS ON RESOURCES

Another major issue that will have to be addressed is the impacts of tsunamis on natural resources such as minerals, surface water, groundwater resources, forest, biomass, coastal ecosystem, and coastal and marine biodiversity [6].

Mineral Resources: The mineral resources observed in the area are mostly the places that are predominantly found in the southern parts as far as the Tamil Nadu coast is concerned. During the recent tsunami, a lot of sediments with black minerals, probably scooped out from the continental shelf, were dumped along the Tamil Nadu coast. Similar sediment dumping has been reported from Andhra Pradesh and Kerala coasts also. Now, such dumped marine sediments have both positive and negative effects on the placer mineral resources. While some of the placer deposits might have been blanketed by the tsunami sediments, such newer tsunami sediments might have also brought some host sediments for placers. Hence, both positive and negative effects of such tsunami sediments over the placers need to be assessed [6].

Surface Water Resources: The surface water resources which have been affected by the recent tsunami (2004) are backwaters, creeks, rivers/streams, etc. On the east coast of India, several major backwater ecosystems exist viz: Chilka lake in Orissa, Kolleru in Andhra Pradesh, Puilcat, in Marakkanam, and Vedaranniyam backwaters in Tamil Nadu. These backwater ecosystems are unique and self-styled and the recent phenomenal influx of seawater into these backwaters from the tsunami might have caused a perceptible change in the aquatic environment and would affect the ecosystem at large. Hence, the same warrant detailed studie [6].

Forest and Biomass: As the tsunami-ravaged Tamil Nadu coast, most of the palm trees, bushes, etc. have been uprooted and deflected. Even leaves of the palm trees have dried up to the level of tsunami run-up (4 to 5 m on Nagapattinam coast). Hence, the forest and biomass responses to tsunamis need warranting studies [6].

IMPACTS ON ENVIRONMENT

Coastal Environment: In the context of the above tsunami inundation and dumping of marine sediments/pollutants, the inundated areas viz: beach ridges/swales, creeks, backwaters, etc. need to be studied for the environmental impacts [6].

Terrestrial Environment: The terrestrial ecosystem along the coastal zone, which is inundated by the tsunami, normally receives the wastes which got deposited along with marine sediments. Hence, its impacts also warrant studies to reclaim the soil, forest, and biomass, agricultural fields, etc. [6].

Loss of life and property: Tsunamis can have devastating effects on life and property. This major displacement of water is destroying homes and infrastructure in the affected areas. Many people lose their lives. According to the data, tsunamis have been responsible for the loss of more than 430,000 lives since 1850. Tsunamis cause building collapses, electrocution, gas leaks, explosions, tank damage, and floating debris causing further injury and death [8].

Disease: Tsunami causes floods in the affected areas and destroys the basic infrastructure like the sewage systems. Flooding and contamination caused due to the destruction of sewage systems cause outbreaks of diseases, infections, and illnesses thus causing more death [8].

Impact on environment and biodiversity: Tsunamis not only affect human beings but also cause harm to insects, animals, plants, and natural resources. Plants are uprooted due to violent waves of a tsunami, nesting sites are destroyed, land animals get killed by drowning, and marine life is harmed by the flow of toxic chemicals into the water body. Solid waste and disaster debris are other critical environmental problems faced by a disaster-hit area [8].

Economic costs: The tsunami causes soil and water pollution. It increases the salinity of the soil. The mixing of disaster debris with the soil and the high salinity render the soil infertile and unsuitable for cultivation, leading to financial losses for farmers and increased food insecurity [8].

Reconstruction after the tsunami also requires huge financial investments. Thus, the tsunami has enormous economic costs on the economy [8].

STAGES OF TSUNAMI DISASTER MANAGEMENT

Tsunami disaster management can be divided into the following two phases:

(i) The stage before the onset of the tsunami disaster and

(ii) The stage after the tsunami disaster.

(i) Pre-Tsunami Disaster Stage:

The following measures should be taken to reduce the damage caused by the tsunami:

- Prepare maps of the areas affected by the Tsunami.
- Maps of convergent zones of the world should be prepared.
- People should not be allowed to build houses etc. in Tsunami affected areas.
- The speed of tsunamis is very fast (500 to 1000 km/h), but due to their high wavelength and low height in deep seas, they are not felt, so boaters and fishermen should be informed that When a tsunami arrives, go deep into the ocean and do not come towards the shore.
- Tsunami warning devices should be installed on the coasts of oceans and seas.
- Always be ready for rescue work [18].

(ii) Post-Tsunami Disaster Stage:

The loss of life and property can be reduced by taking the following measures in case of disaster:

- People trapped in disaster-prone areas should be immediately taken to safe places.
- Prompt medical treatment and doctors should arrange for the treatment of the injured persons.
- Prompt arrangements for drinking water and food should be made in the tsunami-affected areas. Food and drink should be dropped from the helicopter for the affected people.
- Arrangements should be made for the rehabilitation of the affected people.
- Do not go to Tsunami affected areas unless there is a compulsion, as your presence may hamper the rescue operation.
- Children, old people, and the sick should be helped.
- If water is filled around the houses, then they should not be entered, because the filling of water can weaken the foundation of the houses, and houses can collapse.
- When you want to enter the house again, you should walk carefully.
- Do not use a battery-operated lantern. Candles and matches should not be used. Also, make sure that there is no gas leak in the house.
- One should enter the house keeping in mind that snakes etc. can come inside the house [18].

MITIGATION

Mitigation strategies can help reduce the impact of damage and destruction caused by a tsunami.

Some of them are:-

- Coastal land use planning should include limited development strategies and sustainable development strategies.

- Evacuation strategies should include building tsunami evacuation structures and improving evacuation routes.
- The construction of dykes, breakwaters, anti-tsunami gates, and the development of forest barriers can also help prevent major damage.
- Proper planning must be done before the construction of buildings and the adoption of building codes to avoid damage to life and property.
- Protecting coastal ecosystems such as mangroves and coral reefs can help reduce tsunami risk.
- Development of tsunami forecasting and warning systems.
- Evacuation of the population and necessary community assets from threatened areas and post-tsunami reconstruction planning must be carried out [8].

POLICIES IN INDIA NATIONAL POLICY ON DISASTER MANAGEMENT (NPDM)

- The National Disaster Management Policy (NPDM) has been prepared in line with the Disaster Management Act 2005 to build a safe and disaster-resilient India by developing a holistic, proactive, and disaster-focused system with multiple strategies and technology-oriented. Through a culture of prevention, mitigation, preparedness, and response.
- The NPDM aims to bring transparency and accountability to all aspects of disaster management by involving the community, CBOs, Panchayati Raj Institutions (PRIs), local authorities, and civil society [19].

THE DISASTER MANAGEMENT ACT, 2005.

- The law requires the creation of new institutions and the assignment of specific roles to central, state, and local governments.
- The law creates the legal and institutional framework for effective disaster management.
- Under the provisions of the law, the National Disaster Management Authority (NDMA) was established under the Prime Minister's presidency and the National Executive Committee (NEC) of Secretaries was established to assist the NDMA in the exercise of its functions [19].

CONCLUSION

A tsunami is a natural disaster. This disaster affects India as well as the whole world. The history of the tsunami in India dates back from 1762 to 2004. About 18,000 people died in the 2004 tsunami. Tsunami-affected areas in India are West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, etc. Tsunamis have caused human, animal, environmental and economic damage. The Government of India needs to

monitor all the movements of the sea and pay due attention to the coastal areas to deal with the tsunami. The NGO needs an aware cause to the people living in these areas.

REFERENCES

1. Rabinovich, A. B., Thomson, R. E., & Stephenson, F. E. (2006). The Sumatra tsunami of 26 December 2004 as observed in the North Pacific and North Atlantic oceans. *Surveys in geophysics*, *27*(6), 647-677.
2. Rabinovich, A. B., Candella, R. N., & Thomson, R. E. (2011). Energy decay of the 2004 Sumatra tsunami in the world ocean. *Pure and Applied Geophysics*, *168*(11), 1919-1950.
3. Rabinovich, A. B., Geist, E. L., Fritz, H. M., & Borrero, J. C. (2015). Introduction to "Tsunami Science: Ten Years after the 2004 Indian Ocean Tsunami. Volume II.". *Pure and Applied Geophysics*, *172*(12), 3265-3270.
4. Mungov, G., Eblé, M., & Bouchard, R. (2013). DART® tsunameter retrospective and real-time data: A reflection on 10 years of processing in support of tsunami research and operations. *Pure and Applied Geophysics*, *170*(9), 1369-1384.
5. Rabinovich, A. B., & Eblé, M. C. (2015). Deep-ocean measurements of tsunami waves. *Pure and Applied Geophysics*, *172*(12), 3281-3312.
6. Ramasamy, S. M. (2005). Tsunami in the Indian contest-certain issues and strategies. *Tsunami: The Indian context Ramasamy SM and Kumanan CJ (Eds), Allied, New Delhi*, 1-14.
7. https://www.business-standard.com/article/current-affairs/fourteen-years-on-what-have-we-learned-from-the-indian-ocean-tsunami-118122700182_1.html
8. IAS EXPRESS, Tsunami (Causes, Effects, and Mitigation) (2021), https://www.iasexpress.net/article-tsunami-upsc/
9. https://en.wikipedia.org/wiki/Tsunami#cite_note-65
10. Gusiakov V. "Tsunami Quantification: how we measure the overall size of tsunami (Review of tsunami intensity and magnitude scales)" (PDF). Retrieved 2009-10-18.
11. Soloviev, S., & Go, N., 1974 (English transl. 1984), "Catalogue of tsunamis on the western shore of the Pacific Ocean", Canadian Translation of Fisheries and Aquatic Sciences, No. 5077, (310 p).
12. Center, National Geophysical Data. "NGDC/WDS Global Historical Tsunami Database – NCEI". Retrieved 3 November 2016.
13. Lekkas E.; Andreadakis E.; Kostaki I. & Kapourani E. (2013). "A Proposal for a New Integrated Tsunami Intensity Scale (ITIS-2012)". Bulletin of the Seismological Society of America. 103 (2B): 1493–1502. Bibcode:2013BuSSA.103.1493L. doi:10.1785/0120120099.
14. Katsetsiadou, K.N., Andreadakis, E. and Lekkas, E., 2016. Tsunami intensity mapping: applying the integrated Tsunami Intensity Scale (ITIS2012) on Ishinomaki Bay Coast after the mega-tsunami of Tohoku, March 11, 2011. Research in Geophysics, 5(1).

15. https://tsunami.incois.gov.in/TEWS/stsunamihistory.jsp
16. https://www.godigit.com/guides/natural-disasters/tsunami-prone-areas-in-india
17. NATIONAL DISASTER MANAGEMENT AUTHORITY GOVERNMENT OF INDIA , https://ndma.gov.in/Natural-Hazards/Tsunami
18. Sanchaita, Hindi Library India https://www.hindilibraryindia.com/disaster-management/%E0%A4%B8%E0%A5%81%E0%A4%A8%E0%A4%BE%E0%A4%AE%E0%A5%80-%E0%A4%86%E0%A4%AA%E0%A4%A6%E0%A4%BE-%E0%A4%AA%E0%A5%8D%E0%A4%B0%E0%A4%AC%E0%A4%82%E0%A4%A7%E0%A4%A8-%E0%A4%95%E0%A5%87-%E0%A4%9A%E0%A4%B0/18459
19. Pramod Kumar, (2013). Planning and management for disasters tsunami, https://www.slideshare.net/pramod1392/tsunami-23104954

Received: 11th November 2022; Accepted: 20th April 2023; First distribution: 25th April 2023