TSUNAMI

SYLLABUS:

GS 1 > Geography >> Important Geophysical Phenomena

REFERENCE NEWS:

On Wednesday at 11:25 local time, a powerful **8.8 magnitude earthquake—**ranked the sixth most severe in recorded history—struck off Russia's far eastern **Kamchatka Peninsula,** triggering **widespread tsunami alerts.** The massive undersea quake generated waves that moved across the Pacific, prompting evacuations of over two million people in countries including Japan, Hawaii, and the U.S. west coast. Tsunami warnings were also issued in several other nations, including China, the Philippines, Indonesia, New Zealand, Peru, Chile, and Mexico.

TSUNAMI:

A **tsunami** is a series of ocean waves caused by the **sudden displacement of a large volume of water**, typically in oceans or large lakes. The term "tsunami" originates from the Japanese words tsu (harbor) and nami (wave), meaning "harbor wave."

Tsunamis are typically triggered by the following natural phenomena:

- **Submarine Earthquakes**: When tectonic plates **suddenly shift** under the seafloor, the ocean water above is displaced.
  - **2004 Indian Ocean Tsunami** — caused by a 9.1 magnitude earthquake off the coast of Sumatra.
- **Volcanic Eruptions:** Underwater or island volcanoes can cause large-scale water displacement.
  - **1883 Krakatoa eruption** (Indonesia) caused tsunamis over 30 m high.
- **Landslides** (Submarine or Coastal): Massive landslides into the ocean displace water rapidly.
  - **1958 Lituya Bay megatsunami** in Alaska — triggered by a landslide caused by an earthquake.
- **Glacial Calving / Icebergs:** Sudden fall of icebergs into oceans or fjords may trigger small-scale tsunamis.

- **Meteorite Impacts**: Large extraterrestrial objects hitting the ocean can create giant waves.

Feature	Description
Wavelength	Extremely long: up to **200 km** or more
Wave Speed	Up to **800–900 km/h** in deep oceans
Wave Height (Amplitude)	Usually **<1 meter** in deep sea, rises dramatically near shore
Period (time between waves)	Can range from **5 minutes to over an hour**
Multiple Waves	Tsunamis come in **series**, often with second or third wave being most destructive
Inundation	Water surges inland causing widespread destruction

IMPACT OF TSUNAMIS:

Human Casualties and Displacement

- **2004 Indian Ocean Tsunami:** One of the deadliest in history, it killed over **230,000 people** across **14 countries**, including **India, Indonesia, Sri Lanka, and Thailand**.
- Entire communities were wiped out; in **Aceh, Indonesia**, over **167,000 people** died.
- Millions were displaced, leading to long-term refugee crises and mental health trauma.

Economic Loss

- The **2004 tsunami** caused estimated economic losses of over **US$10 billion**.
- Infrastructure, such as roads, ports, and communication networks, was destroyed.
- In **Japan**, the **2011 Tōhoku earthquake and tsunami** resulted in losses of over **US$235 billion**, making it the **costliest natural disaster in history**.

Environmental Degradation

- Tsunamis erode coastlines, destroy mangroves and coral reefs, and contaminate freshwater with salt water.
- In the 2004 tsunami, over **60% of coral reefs** in affected areas were damaged, affecting marine biodiversity.
- Fertile agricultural land was rendered barren due to salinisation.

Damage to Infrastructure and Nuclear Risk

- The **2011 Japan tsunami** caused a meltdown at the **Fukushima Daiichi Nuclear Power Plant**, creating a global nuclear crisis and long-term environmental contamination.

- Power, water, and health infrastructure collapsed, affecting post-disaster recovery.

Socio-Psychological Impact

- Survivors often suffer from **PTSD, anxiety**, and depression.
- Loss of family, community, and livelihood creates **long-term psychological and social disruption**.
- Educational disruption for children due to destruction of schools.

Impact on Tourism and Local Economy

- Tsunamis disrupt coastal tourism-based economies for years.
- Post-2004, countries like Sri Lanka and Thailand saw a **drastic fall in tourism**, affecting GDP and employment.

Global Response and Awareness

- The Indian Ocean tsunami led to the establishment of the **Indian Ocean Tsunami Warning System** (IOTWS).
- Tsunami simulation drills and early warning systems have since improved in countries like **India, Japan, and Indonesia**.

MEASURES TAKEN BY INDIA TO MITIGATE TSUNAMI:

Indian Tsunami Early Warning Centre (ITEWC)

- **Established in 2007** by the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad.
- Equipped with **real-time seismic and sea-level data**, and uses advanced modelling tools to provide accurate tsunami forecasts.
- Provides **alerts within 10 minutes** of a significant undersea earthquake.
- Covers not only India's coastline but also acts as a **Regional Tsunami Service Provider** (RTSP) for the Indian Ocean.

Coastal Observation and Monitoring Systems

- Deployment of **Deep-ocean Assessment and Reporting of Tsunamis (DART)** buoys, tide gauges, and seismic stations along the Indian coast.
- These instruments monitor underwater seismic activities and changes in sea level to detect tsunami generation.

Coastal Vulnerability Mapping

- Detailed **Tsunami Hazard Maps** prepared for coastal districts.
- Helps in identifying vulnerable zones and planning safe zones and evacuation routes.

Public Awareness and Community Preparedness

- **Mock drills** are conducted regularly in coastal states like Tamil Nadu, Odisha, and Andhra Pradesh.

- **Disaster preparedness education** is integrated into school curriculums in vulnerable coastal regions.

Structural and Policy Measures

- **Coastal Regulation Zone (CRZ) guidelines** restrict construction in vulnerable areas.
- Construction of **multipurpose cyclone shelters** that also function as tsunami shelters.
- Strengthening of embankments and planting **mangrove forests** as bio-shields.

International Cooperation

- India is a member of **UNESCO's Intergovernmental Oceanographic Commission (IOC)** and contributes to global tsunami monitoring through the **Indian Ocean Tsunami Warning and Mitigation System (IOTWMS)**.
- Regular participation in **regional drills like IOWave** to test the effectiveness of early warning systems.

Use of Satellite and Digital Technologies

- Real-time alerts sent via **mobile networks, TV, radio, sirens, and satellite-based dissemination systems** (e.g., INSAT).
- Use of **GIS and remote sensing** for impact assessment and evacuation planning.

WAY FORWARD:

Strengthen Early Warning Systems (EWS)

- **Invest in real-time seismic networks**, GPS buoys, tide gauges, and tsunami detection systems like DART.
- Use **AI and machine learning** for faster and more accurate predictions.
- Japan's Meteorological Agency provides tsunami alerts within 3 minutes using a multi-layered EWS.

Coastal Zoning and Land Use Planning

- Implement **Coastal Regulation Zones (CRZ)** to prevent unplanned construction in hazard-prone areas.
- Promote **green buffers** (like mangroves and casuarina plantations) as natural shields.
- Indonesia's Aceh province integrated no-construction zones post-2004 tsunami to protect coastal ecosystems.

Community Awareness and Preparedness

- Conduct **regular public drills, school safety programs, and signage** for evacuation routes.
- Use **SMS alerts, sirens, radio, and social media** for rapid communication.
- Chile's "Blue Line" project marks safe evacuation routes on roads and buildings.

Infrastructure Resilience

- Build **multi-hazard resilient shelters** in vulnerable areas.
- Promote **elevated housing and flexible structures** in coastal zones.
- The Philippines employs resilient housing designs that withstand tsunamis and typhoons.

International and Regional Cooperation

- Participate in **regional tsunami warning systems** like **Pacific Tsunami Warning Centre (PTWC), Indian Ocean Tsunami Warning and Mitigation System (IOTWMS)**
- Share data, technology, and expertise across borders.
- The **UNESCO-IOC's Tsunami Ready Programme** certifies communities globally based on readiness standards.

Integration with Climate Resilience and Disaster Policies

- Integrate tsunami mitigation into broader **disaster risk reduction (DRR)** and **climate adaptation plans**.
- Align national strategies with **Sendai Framework for Disaster Risk Reduction (2015–2030)** and **SDGs**.

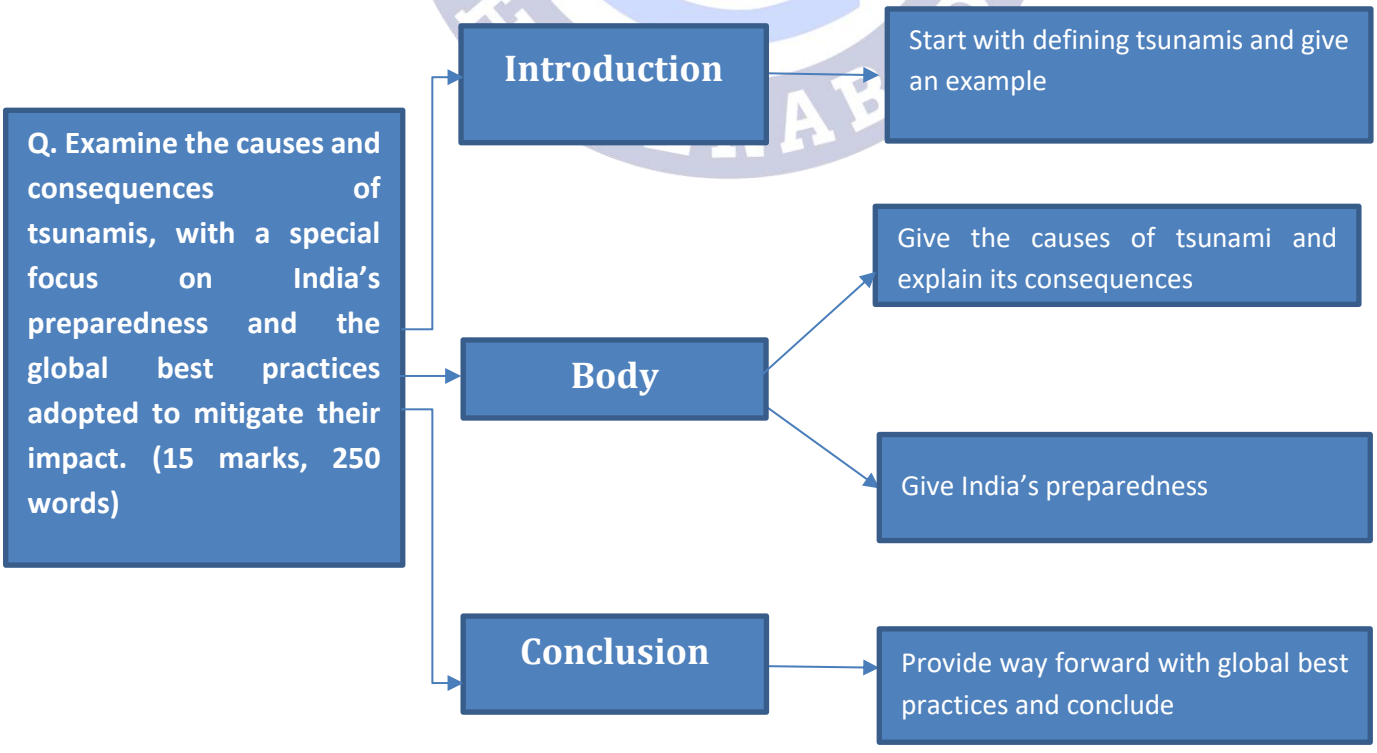
Research, Innovation and Data Sharing

- Promote **R&D on submarine earthquakes**, early shock wave indicators, and geospatial tsunami modelling.
- Encourage **open data sharing** and cross-country hazard mapping.

PRACTICE QUESTION:

Q. Examine the causes and consequences of tsunamis, with a special focus on India's preparedness and the global best practices adopted to mitigate their impact. (15 marks, 250 words)

APPROACH:



MODEL ANSWER:

Tsunamis are large, powerful sea waves generated primarily by undersea earthquakes, volcanic eruptions, landslides, or meteorite impacts. They are characterized by long wavelengths, high speeds (up to 900 km/h), and destructive coastal surges. The recent 8.8 magnitude earthquake near Russia's Kamchatka Peninsula, triggering widespread tsunami alerts, demonstrates the persistent threat posed by such natural disasters.

Causes of Tsunamis

1. **Undersea Earthquakes**: Most common cause, accounting for nearly 80% of tsunamis. The 2004 Indian Ocean tsunami was triggered by a 9.1 magnitude earthquake off the coast of Sumatra.
2. **Volcanic Eruptions**: Sudden collapses or explosions of submarine volcanoes can displace large volumes of water. Krakatoa eruption (1883) caused a tsunami killing over 36,000 people.
3. **Landslides (Submarine or Coastal)**: Rapid movement of large sediment masses displaces water. Lituya Bay tsunami (Alaska, 1958) was triggered by a landslide, producing a wave over 500 meters high.
4. **Meteorite Impacts**: Rare but capable of causing megatsunamis by displacing ocean water.

Consequences of Tsunamis

1. **Human Casualties and Displacement**: The 2004 tsunami killed over 230,000 people globally, including 12,405 in India (as per official estimates).
2. **Destruction of Infrastructure**: Ports, homes, roads, and power grids are severely damaged. The 2011 Japan tsunami caused $235 billion in damages.
3. **Ecological Impact**: Saltwater intrusion damages agriculture, contaminates freshwater sources, and devastates marine biodiversity.
4. **Economic Loss**: Loss of livelihoods (fisheries, tourism), need for rehabilitation. Tamil Nadu lost over ₹7,000 crore in damages during the 2004 tsunami.
5. **Long-term Psychological Trauma**: Affected populations suffer from PTSD, especially children and survivors in displacement camps.

India's Preparedness

1. **Indian Tsunami Early Warning Centre (ITEWC)**: Established in 2007 under INCOIS; issues warnings within 10 minutes of detection. Recognised by UNESCO as a Tsunami Service Provider.
2. **Deep-Ocean Assessment and Reporting of Tsunami (DART) Buoys**: 4 DART buoys and 36 tide gauges deployed to monitor sea level changes.
3. **Coastal Community Awareness and Mock Drills**: NDMA and INCOIS regularly conduct drills across coastal states (e.g., Indian Ocean-wide Tsunami Mock Exercise).

4. **Coastal Regulation Zone (CRZ) Norms**: Enforces construction restrictions near shorelines to prevent vulnerability.
5. **Bio-shield Projects**: Mangrove plantations and casuarina shelterbelts developed across the eastern coast (e.g., Pichavaram Mangroves, Tamil Nadu).

Global Best Practices

1. **Japan's Tsunami Alert and Infrastructure Systems**: Advanced sea walls, vertical evacuation buildings, and integrated real-time seismic systems.
2. **Chile's "Blue Line" Evacuation Program**: Demarcated blue lines on roads guiding people to higher ground in coastal towns.
3. **UNESCO's Intergovernmental Oceanographic Commission (IOC)**: Coordinates global tsunami early warning systems through regional service providers.
4. **Community-Based Early Warning Systems**: Indonesia and the Philippines involve local communities with smartphone alerts and evacuation training.
5. **Sendai Framework for Disaster Risk Reduction (2015–2030)**: Promotes international cooperation, capacity-building, and infrastructure resilience in disaster-prone areas.

Way Forward

1. **Strengthen Local Preparedness Plans** with school-level drills and public signage.
2. **Invest in Smart Infrastructure** such as tsunami-resistant housing and evacuation towers.
3. **Enhance Cross-Border Data Sharing** between Bay of Bengal and Pacific nations.
4. **Promote Scientific Research** in tectonic mapping and oceanographic modeling.
5. **Incentivize Nature-Based Solutions** like coral reef and mangrove restoration for coastal protection.

Tsunamis, though infrequent, have catastrophic potential. While India has made commendable strides in early warning and preparedness, continuous global learning, infrastructure resilience, and community awareness are crucial to mitigate future tsunami risks effectively.