



India Disaster Report 2019 - 2024



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Resilient India : Disaster free India

National Institute of Disaster Management
Ministry of Home Affairs, Govt. of India



INDIA DISASTER REPORT 2019-2024



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National Institute of Disaster Management

(Ministry of Home Affairs, Government of India)

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Website: <https://nidm.gov.in>

INDIA DISASTER REPORT 2019-2024

ISBN No: 978-81-69202-57-2

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Edition: 2026

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Citation:

Vyas M., Guleria S., Singh R., (2026) India Disaster Report (2019-2024). National Institute of Disaster Management, Delhi, India. Pages 265

Published by:

National Institute of Disaster Management, Ministry of Home Affairs, Government of India, Delhi-110042

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Foreword

India's disaster risk landscape has undergone a profound transformation in recent years, shaped by the increasing frequency and intensity of climate-induced hazards, rapid urbanisation and other anthropogenic factors. The India Disaster Report (IDR) 2019–2024 Compendium is an important knowledge product that documents this evolving risk profile and captures critical lessons emerging from disasters across the country during this period.



The years 2019 to 2024 witnessed a wide spectrum of disasters, including cyclones, floods, heatwaves, landslides, avalanches, industrial accidents, infrastructure failures, fires, crowd disasters and emerging climate-linked extremes. These events not only tested India's disaster management systems but also demonstrated the growing maturity of institutions, early warning mechanisms, response capacities and community resilience. At the same time, they revealed certain gaps in preparedness, land-use planning, infrastructure safety, governance, and last-mile risk communication.

This report consolidates evidence from major disasters and systematically analyses observed practices, gaps, and lessons learned, with a strong emphasis on actionable recommendations. By adopting a lessons-learned approach, the IDR 2019–2024 moves beyond event documentation to support informed decision-making, risk-informed development, and continuous system strengthening. The inclusion of both natural and human-induced disasters reflects the expanding understanding of disaster risk as articulated in the Sendai Framework for Disaster Risk Reduction.

A key message emerging from this report is that disasters in India are increasingly shaped by the interaction of hazards with exposure and vulnerability. Climate change is no longer a distant threat but a present reality influencing heatwaves, floods, cyclones, glacial hazards and compound risks. Urbanisation, infrastructure expansion in fragile ecosystems, and industrial growth demand stronger integration of disaster risk reduction into development planning. The report highlights that early warning systems, when linked with preparedness and community action, have saved lives and reduced losses.



(Madhup Vyas)

आपदा प्रबंधन महाविचार: पूरा भारत भागीदार



Executive Summary

The India Disaster Report (IDR) 2019–2024 presents a consolidated assessment of disaster occurrences, impacts, and response mechanisms across the country during a period marked by increasing climate variability, rapid urbanisation, and growing exposure of populations and infrastructure to natural and human-induced hazards. The report draws upon detailed case studies, sectoral analyses, and institutional experiences to examine evolving disaster risk patterns and to identify critical gaps and opportunities for strengthening disaster risk management in India.

During the reporting period, India experienced a wide range of disasters, including cyclones, floods, heatwaves, landslides, forest fires, industrial accidents, and urban emergencies. These events collectively underline the growing intensity, frequency, and spatial spread of disasters, largely influenced by climate change, environmental degradation, and unplanned development. Hydro-meteorological hazards accounted for the majority of disaster impacts, with floods, cyclones, and heatwaves causing significant loss of life, damage to infrastructure, disruption of livelihoods, and environmental degradation.

A key observation emerging from the analysis is the increasing occurrence of compound and cascading disasters, wherein a single hazard triggers multiple secondary impacts such as infrastructure failure, public health emergencies, and prolonged socio-economic disruption. Urban areas, in particular, have emerged as high-risk zones due to dense populations, ageing infrastructure, inadequate drainage systems, and limited compliance with safety regulations. Simultaneously, ecologically fragile regions have witnessed heightened vulnerability due to deforestation, land-use change, and unsustainable development practices.

The report highlights notable progress in India's disaster management ecosystem, especially in the areas of early warning dissemination, large-scale evacuation, and inter-agency coordination during major cyclonic and flood events. The expanding role of the National Disaster Response Force (NDRF), State Disaster Response Forces (SDRFs), Armed Forces, and civil administration has contributed to improved response efficiency and reduced mortality in several instances. Technological advancements in weather forecasting, satellite-based monitoring, and communication systems have further strengthened preparedness and response capabilities.

However, the assessment also identifies persistent challenges that require focused policy attention. These include uneven implementation of the Incident Response System (IRS) across states, limited integration of disaster risk reduction into development planning, absence of a uniform damage and loss assessment framework, and inadequate enforcement of land-use regulations and building safety norms. Post-disaster recovery efforts often remain response-driven, with limited emphasis on long-term resilience and risk-informed reconstruction.

The findings of the report underscore the importance to strengthen disaster governance by anticipatory and preventive risk management. Priority areas identified include mainstreaming disaster risk reduction into sectoral policies, strengthening urban resilience, enhancing climate-resilient infrastructure, promoting nature-based solutions, and institutionalising community-based disaster preparedness. The report also highlights the importance of capacity building at the local level, improved data management systems, and stronger inter-agency coordination for effective disaster risk governance.

The India Disaster Report (2019–2024) serves as an important knowledge resource for policymakers, practitioners, and stakeholders involved in disaster risk management. It provides evidence-based insights

to support the formulation of resilient development strategies aligned with the Sendai Framework for Disaster Risk Reduction (2015–2030), the National Disaster Management Plan, and India’s broader climate adaptation and sustainable development goals.

Moving forward, strengthening resilience will require sustained political commitment, institutional coordination, and integration of disaster risk reduction into all stages of development planning. The lessons documented in this report offer a strong foundation for enhancing national and sub-national capacities to manage future disasters in an increasingly uncertain risk environment.

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DISASTER YEAR 2019

Cyclone Fani, 2019

Introduction

Cyclone Fani, designated as an Extremely Severe Cyclonic Storm (ESCS) by the India Meteorological Department (IMD), was the first major cyclone of the 2019 season and the most powerful to hit Odisha since the catastrophic 1999 super cyclone. It developed over the southeastern Bay of Bengal, originating as a tropical depression west of Sumatra on 26 April 2019 and was named BOB 02 under IMD protocols.

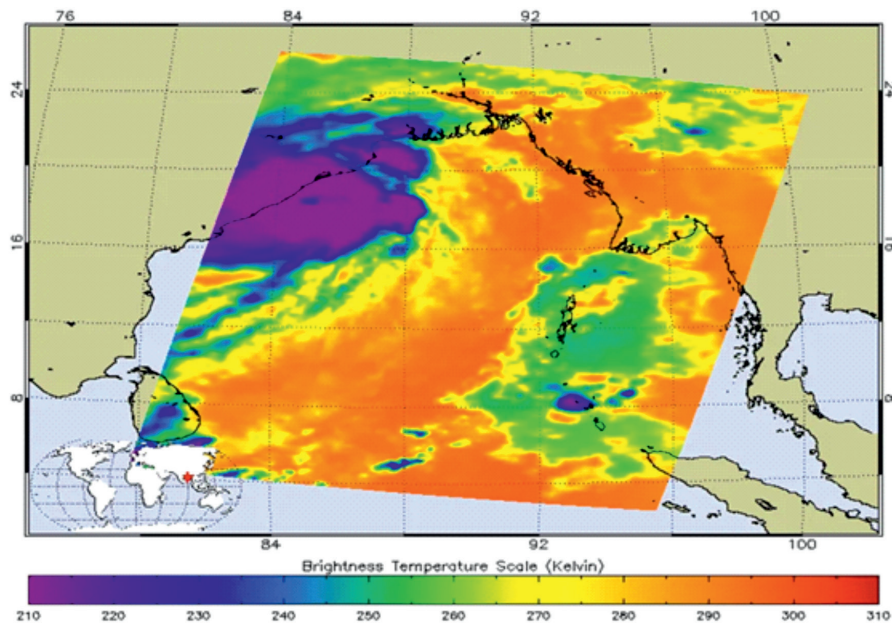


Fig - 1 : Cyclone Fani in the Bay of Bengal, Temperatures within tropical Cyclone Fani off the coast of India, imaged 20 December 2025 by NASA's AIRS on May 2. Purple indicates cold clouds carried high into the air by thunderstorms. Blue areas, including the cyclone's eye, are warmer. Green is shallow rainclouds; orange is cloud free. Credits: NASA/JPL-Caltech

Source :- <https://www.nasa.gov/earth/climate-change/nasas-air-images-cyclone-fani-before-landfall/>

Initial intensification was delayed due to vertical wind shear rapid changes in wind speed and direction with altitude but as environmental conditions improved, particularly with warm sea surface temperatures and reduced shear, Fani underwent rapid intensification into an ESCS.

On 2 May 2019, Fani peaked with wind speeds equivalent to a Category 4 hurricane (209–251 km/h), before making landfall near Puri, Odisha, on 3 May. The system weakened after landfall to a Very Severe Cyclonic Storm. In response, Indian authorities executed one of the largest pre-emptive evacuations in the nation's history, relocating

over 1.1 million people from high-risk areas a move widely praised by the United Nations Office for Disaster Risk Reduction (UNDRR) for its effectiveness in saving lives.

Despite extensive preparedness efforts, Cyclone Fani resulted in significant human and economic losses. As of 8 July 2019, at least 89 fatalities were reported 72 in India (including 64 in Odisha) and 17 in Bangladesh mainly due to strong winds, falling trees, structural collapse, and lightning, as per the IFRC. The estimated economic loss stood at around ₹58,000 crore (USD 8.1 billion), making Fani the fourth most devastating natural disaster in India in terms of fatalities in 2019.

Fani lasted from 26 April to 5 May 2019, severely affecting Odisha. The name “Fani,” meaning “hood of a snake,” was proposed by Bangladesh, in accordance with WMO naming conventions. Cyclones in April are uncommon; IMD records (1891–2017) show only 14 severe cyclones in the Bay of Bengal during April over 126 years, with only one prior landfall in India making Fani the second such case.

For context, the last major April cyclone in the region was Cyclone Nargis in 2008, which devastated Myanmar. Odisha’s vulnerability to cyclones is well-documented, with the 1999 super cyclone claiming over 15,000 lives. Fani became the fourth major cyclone to strike India’s east coast in the past 30 years. According to Global Catastrophe Recap (2019), Odisha bore the brunt of the damages, contributing to the majority of the cyclone’s estimated USD 8 billion in losses.

Impact

Cyclone Fani originated as a tropical depression near Sumatra and was first identified by the Joint Typhoon Warning Center (JTWC) on 26 April 2019. Gaining strength as it moved westward, it was classified as an Extremely Severe Cyclonic Storm by 30 April. At its peak, Fani reached near-Category 5 intensity, causing extensive damage across coastal Odisha.



Fig - 2 : A roadside stall collapses in the winds

Source :- <https://www.theguardian.com/world/gallery/2019/may/03/cyclone-fani-hits-indias-east-coast-in-pictures#img-62> #img-6

India recorded 72 fatalities, with 64 in Odisha alone primarily due to falling trees, debris, and stress-related medical emergencies. Notable incidents included fatalities caused by structural collapses and psychological distress, such as a heart attack in a cyclone shelter.

The districts of Puri and Khordha were among the worst affected. Heritage sites and institutions sustained notable damage Jagannath Temple incurred losses of ₹51 million (USD 738,000), and KIIT University faced damages of ₹300 million (USD 4.3 million). The Shree Jagannath Temple Administration (SJTA) estimated losses of ₹12.5 million for electrical systems and ₹32.4 million for civil works.

Overall, damage in Odisha was estimated at ₹120 billion (USD 1.74 billion), with the state government projecting a need of ₹170 billion (USD 2.46 billion) for long-term reconstruction and recovery.



Fig - 3 : Petrol station destroyed by Cyclone Fani on the outskirts of Puri

Source:- <https://www.theguardian.com/world/gallery/2019/may/03/cyclone-fani-hits-indias-east-coast-in-pictures#img-6>

In response, Rs. 10 billion (USD 145 million) was provided as Central assistance. While Andhra Pradesh reported no fatalities, the districts of Srikakulam and Vizianagaram suffered losses of ₹586.2 million (USD 8.5 million). South Central Railway reported damage worth ₹29.8 million (USD 432,000).

Odisha was the worst affected, with over 20,367 villages across 14 districts impacted, affecting 16 million people and damaging 188,000 hectares of crops. The state estimated total losses at ₹9,336.26 crore, including ₹6,643.63 crore for infrastructure and ₹2,692.63 crore for relief and recovery. A request for ₹5,227.68 crore was submitted to the NDRF, and ₹1,357.14 crore was allocated for immediate response.

Damage assessments reported 5,56,761 houses were affected, along with the loss of 2,650 large animals, 3,631 small animals, and over 5.3 million poultry birds. Twelve serious injuries were recorded. A central team later assessed the overall damage at ₹11,942.68 crore.

Rescue and Relief Operations

In the immediate aftermath of Cyclone Fani, the Eastern Naval Command launched a large-scale relief operation, focusing on severely affected areas such as Puri district. Two Dornier aircraft conducted aerial reconnaissance, confirming widespread damage, particularly in and around Puri town. The Flag Officer Commanding-in-Chief also conducted an aerial survey and visited INS Chilka to oversee relief efforts.

With wind speeds up to 200 km/h, Cyclone Fani caused extensive damage across Odisha before weakening over West Bengal. In coordination with the state and district administration, the Navy implemented a three-pronged relief mission, prioritizing Puri and adjacent areas. Relief materials containerised as 'bricks' and 'pallets' included

dry food, medicines, clothing, blankets, cleaning agents, tools for debris clearance, and lighting equipment. This joint military-civil response enabled swift and efficient distribution of aid to affected communities.

Damage Assessment

Cyclone Fani devastated 14 districts in Odisha, with Puri, Cuttack, and Kendrapara being the worst-affected. In total, 159 administrative blocks, 52 Urban Local Bodies (ULBs), and 18,168 villages were impacted. Approximately 16.53 million people about 36% of the state's population were directly affected.

The housing sector suffered immense damage, with 5,08,467 residential structures either partially or fully destroyed. In Puri district alone, 1,89,095 kutcha houses were reported damaged.

The livestock sector also incurred major losses. A total of 8.78 million animals were affected, including 24.41 lakh large animals, 9.89 lakh small animals, and 53.47 lakh poultry birds. Of these, 37.33 lakh perished comprising 2,210 large animals, 2,488 small animals, and 37.28 lakh poultry birds.

Power infrastructure experienced catastrophic failure. The cyclone destroyed 5 towers of 400 kV, 27 towers of 220 kV, and 21 towers of 132 kV. Four major 220 kV substations Chandaka, Bidanasi, Samagra, and Mendhasala and four 132 kV substations in Puri, Nimapada, Mancheswar, and Ransinghpur were also damaged. Additionally, 5,030 km of 33 kV lines, 38,613 km of 11 kV lines, 64,304 distribution transformers, and 79,485 km of low-tension (LT) lines were affected.

Telecommunication infrastructure collapsed in many areas. Several telecom towers fell, resulting in a complete breakdown of mobile, landline, and internet connectivity particularly in Khordha and Bhubaneswar during the cyclone's immediate aftermath.



Fig - 4 : Damaged sign lies on a street in Puri

Source :- <https://www.theguardian.com/world/gallery/2019/may/03/cyclone-fani-hits-indias-east-coast-in-pictures#img-6>

Cyclone Fani destroyed summer crops, orchards, and plantations over 1,52,985 hectares. Public health infrastructure suffered damage to 1,031 facilities, including hospitals and health centres. The education sector saw damage to 5,244 primary and 1,547 secondary school buildings.

The cyclone damaged 980.69 km of embankments with 29 breaches and damaged 218 bridges, 4 of which were washed away. Additionally, 3,290 Community Lift Irrigation Projects across six districts were affected.

Fani destroyed 6,390 traditional fishing boats, 7,240 nets, 279 fish ponds (66.92 ha), 3 harbours, 6 landing centres, and multiple fish farms and hatcheries.

The storm's environmental impact was equally alarming. Over 900,000 trees were uprooted in forest and sanctuary areas, and an additional 500,000 trees outside forest zones were either destroyed or severely damaged, altering local ecosystems and contributing to longer-term ecological degradation.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Early Warning & Forecasting	Accurate and timely cyclone forecasting by IMD with advance warnings issued several days prior to landfall	Last-mile communication gaps in rural and coastal areas	Early warnings are effective only when communicated clearly and locally	Strengthen community-level dissemination using local language alerts, mobile messaging, and community volunteers
Evacuation & Preparedness	Evacuation of over 1.1 million people, one of the largest in India	Overcrowding in shelters; inadequate facilities for elderly, women, and persons with disabilities	Planned evacuation significantly reduces mortality	Expand cyclone-resilient shelters and integrate inclusive evacuation planning
Institutional Coordination	Effective coordination among State Government, NDRF, Armed Forces, and district administration	Limited uniform application of Incident Response System (IRS)	Clear command structure enhances operational efficiency	Strengthen IRS implementation through regular drills and capacity building
Infrastructure Resilience	Severe damage to power lines, telecom networks, housing, and	Infrastructure not designed for extreme wind speeds	Critical infrastructure remains highly vulnerable to cyclonic hazards	Enforce cyclone-resilient building codes and retrofit critical lifelines

	public infrastructure			
Communication Systems	Collapse of telecom and electricity networks post-landfall	Lack of redundancy in communication systems	Communication failure hampers response and relief operations	Develop redundant and satellite-based emergency communication systems
Community Participation	Strong involvement of local communities and volunteers in evacuation and relief	Limited formal training for community responders	Communities are first responders during disasters	Institutionalize Community-Based Disaster Risk Management (CBDRM)
Relief & Response Operations	Rapid deployment of relief teams and essential supplies	Logistics bottlenecks in remote areas	Pre-positioning improves response effectiveness	Strengthen decentralized stockpiling and logistics planning
Damage & Loss Assessment	Large-scale assessment conducted post-disaster	Lack of standardized damage assessment methodology	Uniform data is essential for planning recovery	Adopt standardized Damage and Loss Assessment (DaLA) framework
Recovery & Reconstruction	Timely restoration of basic services	Limited application of Build Back Better principles	Recovery must reduce future risk, not recreate vulnerability	Mandate BBB principles in housing and infrastructure reconstruction
Governance & Policy	Strong political and administrative leadership	Disaster risk not fully integrated into development planning	DRR must be mainstreamed into development processes	Integrate DRR into sectoral policies and development plans

Kerala Floods, 2019

Introduction

Kerala, located along India's southwestern Malabar Coast, is a narrow land strip between the Western Ghats and the Arabian Sea. It stretches about 570 km long, with a width ranging from 11 to 121 km, covering nearly 15% of the state's area. Kerala is the 21st largest Indian state by area (38,863 km²) and 13th by population, housing 33.4 million people (2011 Census). The state is divided into 14 districts, with Thiruvananthapuram as its capital.



Fig - 5 : Image Courtesy: Money Control

Source :- <https://www.newsclick.in/Floods-India-Karnataka-Kerala-Maharashtra-Landslide>

Known as “God’s Own Country,” Kerala is famous for its scenic landscapes, lush greenery, and abundant water resources, including 44 rivers and 61 dams. These water bodies support its ecosystems and form the foundation of its agriculture and hydrology.

In August 2018, Kerala witnessed one of the most catastrophic floods in a century, impacting nearly the entire state. According to official records presented during a special one-day session of the Kerala Legislative Assembly, the disaster claimed 483 lives and displaced 59,296 individuals, who were sheltered in 305 operational relief camps. The flood devastated approximately 57,000 hectares of agricultural land as of 13 August 2018. The districts of Pathanamthitta, Alappuzha, Kottayam, Idukki, Ernakulam, Palakkad, Wayanad, and Thrissur bore the brunt of the destruction, reporting the highest damages in terms of life, livelihood, and infrastructure.

While still recovering from the 2018 floods, Kerala faced another severe rainfall event in August 2019, causing floods, landslides, and debris flows. The India Meteorological Department issued Red Alerts for nine districts, Orange for three, and Yellow for two districts. Preemptive evacuations and additional relief camps helped reduce casualties. By 19 August 2019, 121 deaths were reported due to rain-related incidents during this second flood.



Fig - 6 : An aerial view of flood-hit areas of Aluva in Kochi.

Source:- <https://www.financialexpress.com/india-news/kerala-flood-2019-latest-news-images-videos-karnataka-rains-live-updates-wayanad-landslide-rahul-gandhi/1672356/>

Floods have long shaped Kerala's history. A major flood in 1341 CE dramatically altered the state's geography, creating a natural harbor near Kochi that helped establish it as a key maritime trade center. Previously, Muziris (now Kodungallur) was the main spice trade port, but frequent floods and invasions led to its decline and Kochi's rise. This geomorphological change significantly influenced Kerala's trade and urban development.

Historical Perspective on Major Floods in Kerala

Kerala, with its dense river network and strong dependence on the southwest monsoon, has endured several catastrophic floods that have profoundly shaped its socio-environmental history, most notably in 1924, 1961, and 2018. The 1924 flood, remembered as the "Great Flood of 99" (Kollavarsham 1099), was triggered by an exceptionally intense monsoon beginning on 15 July, with extreme rainfall between 16 and 18 July, including a one-day record of 484 mm at Devikulam and multi-day totals nearing 900 mm at Devikulam and Munnar, causing rivers to overflow and resulting in widespread loss of life, agricultural destruction, and infrastructural damage; this disaster also prompted a remarkable humanitarian response led by Mahatma Gandhi, whose nationwide appeal through Young India and Navjivan raised significant relief funds. The 1961 floods resulted from unusually prolonged and intense monsoon rains from late June to early August, with rainfall about 56% above normal, initially affecting southern districts before spreading statewide by mid-July, severely inundating the Periyar sub-basin, submerging highways, disrupting transportation and emergency services, and overwhelming river systems and reservoirs. In August 2018, Kerala experienced its worst flooding in nearly a century, comparable only to 1924, as exceptionally heavy rains led to 483 confirmed deaths, large-scale displacement of nearly one million people, and severe impacts across all 14 districts, which were placed under Red Alert; the disaster was declared a Level 3 Calamity, marked by the unprecedented simultaneous opening of 35 out of 54 dams, including all floodgates of the Idukki Dam for the first time, compounded by widespread landslides in hilly districts such as Idukki and Wayanad, and managed through extensive rescue and relief operations coordinated by state and national agencies.



Fig - 7 : Rescuers evacuate people from a flooded area to a safer place in Aluva in the southern state of Kerala, India, August 18, 2018.

Source:- (REUTERS photo)

Causes of Flooding in Kerala

The South Asian monsoon, spanning June to September, is a critical climatic system shaping the hydrometeorology of the Indian subcontinent. Driven by shifting wind patterns, it delivers nearly 70% of India's annual rainfall, often causing flash floods and riverine inundation. Kerala's rainfall, averaging around 3,000 mm annually, is largely dependent on the southwest monsoon, with about 90% occurring during the monsoon months. The state's steep slopes, hilly terrain, and dense river networks increase runoff and surface flow, making it vulnerable to flooding even from moderate rainfall variations.

In 2018, Kerala's early monsoon brought below-normal rainfall, triggering concerns over water scarcity and prompting potable water distribution in several districts. This dry spell abruptly ended with a sudden surge in heavy rains in late July and early August, driven by broader climatic dynamics, which ultimately resulted in widespread flooding across the state.

The 2018 Kerala floods were triggered by a low-pressure system (depression) that developed in the northwest Bay of Bengal near the Odisha coast. This system intensified monsoon currents over the Arabian Sea, causing strong convection over Kerala. The resulting heavy rainfall over a short period overwhelmed the state's rivers and drainage systems beyond their carrying capacity, leading to severe flooding.

According to meteorological data, Kerala received a total of 2,310.2 mm of rainfall during the 2018 monsoon season 13% above the normal average. Three districts reported excess rainfall:

- Palakkad: 2,125.9 mm (39% above normal)
- Thiruvananthapuram: 1,039.9 mm (20% above normal, and the lowest among Kerala districts)
- Kozhikode: 3,466.6 mm (34% above normal, the highest rainfall recorded)

Additionally, the districts of Kasargod and Kannur also reported cumulative rainfall exceeding 3,000 mm during the same period. The spatial and temporal concentration of this above-average rainfall, combined with the state's geographic vulnerability, culminated in one of the most catastrophic flooding events in Kerala's modern history.

Impact of the 2019 Kerala Floods

By 19 August 2019, the devastating floods in Kerala had resulted in 121 confirmed fatalities across various districts of the state. The widespread inundation and associated secondary hazards directly impacted over 200,000 individuals, necessitating the establishment of 1,318 relief camps to accommodate displaced populations.

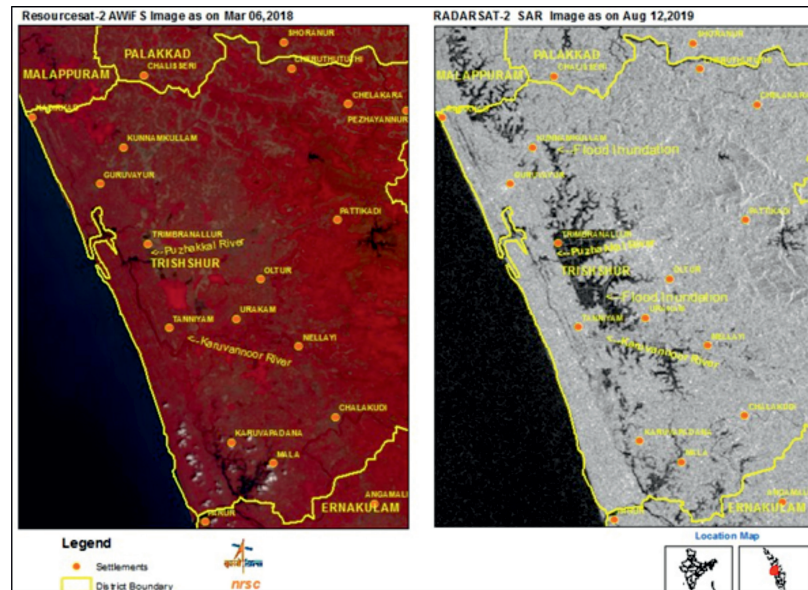


Fig - 8 : Pre and Post condition of Kerala floods 2019

Source :- NRSC Flood inundation maps

The 2019 floods caused major disruptions, including the temporary closure of Cochin International Airport until 3 PM on 11 August due to flooded runways and infrastructure. Between 8 and 19 August, Kerala State Disaster Management Authority reported 1,789 houses completely destroyed and 14,542 partially damaged, highlighting the vulnerability of rural and hilly residential areas.

About 80 landslides occurred over two days, triggered by saturated soils in high-altitude regions, further threatening communities and hampering relief efforts. The hardest-hit districts were Wayanad, Malappuram, Kozhikode, Kannur, Palakkad, Thrissur, and Ernakulam, where flooding, landslides, and infrastructure damage severely disrupted life and services. Repeated floods over the years have increased these districts' vulnerability and complicated recovery.

Search and Rescue, Relief, and Recovery Operations

The Kerala State Disaster Management Authority (KSDMA), along with the State Police, Indian Air Force, local communities, volunteers, and coastal fishermen, conducted extensive search and rescue operations in flood-affected areas. These efforts ensured timely evacuations and delivery of relief. However, heavy rainfall and landslides in the hilly regions of Wayanad, Malappuram, and Kozhikode hampered access and delayed response.

Animal rescue was also a priority, especially in remote, flooded areas like Wayanad and Nilambur. Local NGOs and welfare groups were instrumental, with Humane Society International/India leading major relief efforts in Nilambur, distributing essential aid.

- Over 500 kg of dog food
- Approximately 5,000 kg of cattle feed
- Around 2,500 kg of goat feed

These supplies provided critical sustenance for livestock and companion animals that had been left stranded and unfed due to the disaster.



Fig - 9 : Rescue operations underway in Nilambur, Malappuram. (Photo | EPS)

Source:- <https://www.newindianexpress.com/states/kerala/2019/Aug/09/flood-emergency-kerala-state-disaster-management-authoritys-survival-tips-2016549.html>

In response to the humanitarian crisis, the Government of Kerala, as reported by Press Trust of India (PTI) on 14 August 2019, announced a package of immediate financial assistance to the affected population. Key financial relief measures included:

- Rs. 10,000 for all flood-impacted families to cover urgent needs
- Rs. 4 lakh for individuals whose homes were completely destroyed or rendered uninhabitable
- Rs. 10 lakh for those who lost both their residential property and land as a result of floods and landslides

In parallel with the state's initiatives, the public showed strong solidarity through generous donations to the Chief Minister's Distress Relief Fund (CMDRF), which collected Rs. 4,368.2 crore by 15 August 2019. This remarkable civic response highlighted widespread support for disaster recovery.

These combined multi-agency and community-led actions covering human rescue, animal welfare, emergency relief, and financial aid were crucial in stabilizing the post-disaster situation and supporting Kerala's move toward long-term rehabilitation.

Underlying Issues Exacerbating Flood and Landslide Disasters in Kerala

Landslides and the Soil Piping Phenomenon

Landslides are a critical secondary hazard linked to Kerala's flood-prone topography. A 2016 study by G. Shankar and Dr. L. Kuriakose, in collaboration with the National Centre for Earth Science Studies (NCESS) and the Kerala State Disaster Management Authority (KSDMA), identified widespread soil piping subsurface erosion forming underground tunnels in nearly all districts except Thiruvananthapuram, Kollam, and Alappuzha. This process weakens soil stability, particularly on steep slopes exceeding 30 degrees, making landslides more likely.

The floods of 2018 and 2019 highlighted the seriousness of this threat. Mapping showed many casualties and infrastructure damage were caused by soil piping-induced landslides, especially in Idukki, Wayanad, and Malappuram, despite prior warnings. Researchers warned that soil piping, if ignored, could progressively degrade productive land and pose risks to human settlements and biodiversity in the Western Ghats. This situation demands enhanced geotechnical surveillance, slope stability assessments, and the development of early warning systems for landslide-prone regions.

Unsustainable Development Practices in the Western Ghats

Unsustainable human activities have significantly increased flooding and landslide risks in Kerala. Rapid deforestation, loss of green cover, unregulated construction, and intensive mining especially in the Western Ghats have undermined the region's ecological stability. The expansion of settlements into steep, fragile slopes without proper clearance or engineering has weakened natural drainage and slope stability. Poorly designed roads and infrastructure in hilly areas further destabilize the soil, making slopes vulnerable during heavy rainfall.

Illegal stone quarrying and open-pit mining accelerate soil erosion, increase runoff, and weaken subsurface geology. Scientists warn that ongoing mining in sensitive zones like Idukki and Wayanad raises the risk of catastrophic landslides. Despite warnings and media attention, enforcement of environmental laws remains inconsistent. This calls for integrated land-use planning, stricter regulation, and resilient development approaches that balance ecological protection with disaster risk reduction.

Lessons Learnt from the Kerala Floods

The Kerala flood disasters of 2018 and 2019 have underscored the importance of community solidarity, scientific planning, and sustainable development in mitigating the impacts of natural hazards. Key lessons drawn from the events include:

- Community Cohesion is fundamental during emergencies. The swift, coordinated response of the local population, particularly the fishing community, highlighted the value of local knowledge and social capital.
- Scientific Dam Management is essential during monsoon periods to prevent flooding from reservoir overflows.
- Unregulated changes in land use and land cover, such as deforestation, encroachments, and hill-cutting, significantly exacerbate disaster risk.

- Wetlands and natural water channels must be protected to ensure natural drainage systems remain functional.
- Mining and quarrying activities must be strictly prohibited in ecologically sensitive zones, particularly the Western Ghats.
- A push toward sustainable housing models and climate-resilient construction is required.
- Citizens must be encouraged to adopt environmentally conscious lifestyles.
- Above all, the need for enhanced preparedness and rapid response mechanisms has become more evident than ever.

Preparedness for Future Disaster Resilience

Disaster response strategies must be informed by evidence-based learnings from past events. Kerala's flood experiences emphasize the need for robust policies and institutional frameworks aimed at disaster risk reduction and resilience building. The following strategic areas require priority attention:

1. Land Use Regulation and Policy Enforcement

There is an urgent need for stricter land use regulations and enforcement mechanisms at all levels policy, implementation, monitoring, and advocacy. Comprehensive planning and regulation must guide construction, development, and land conversion activities, especially in environmentally vulnerable zones.

2. Operationalization of Disaster Management Guidelines

India's disaster governance is guided by several instruments, including the Disaster Management Act (2005), the National Disaster Management Plan (2016), and a range of NDMA guidelines and State-level action plans. These frameworks must be translated into effective implementation, and inter-agency coordination must be institutionalized at both the national and sub-national levels.

3. Improved Forecasting and Communication Protocols

While meteorological forecasting has advanced significantly, its real-time dissemination and ground-level response remain areas for improvement. Agencies such as the India Meteorological Department (IMD), Central Water Commission (CWC), and Indian National Centre for Ocean Information Services (INCOIS) must coordinate more effectively to develop state- and district-level early warning systems and standard operating procedures (SOPs) for communication and action.

4. Disaster-Resilient Critical Infrastructure

Public investments in critical infrastructure such as airports, railway stations, and hospitals—must be safeguarded through site-specific disaster management plans. Past events have shown how key response facilities like the Cochin, Chennai, and Visakhapatnam airports were rendered inoperable during crises, severely hampering relief efforts. These facilities must integrate risk reduction features into their design and operations.

5. Strengthening Incident Response Systems (IRS)

Effective disaster management demands seamless coordination among multiple stakeholders. The Incident Response System (IRS), issued by NDMA in 2010, provides a structured approach for multi-agency response during disasters. Although several states have adopted IRS frameworks, implementation remains patchy. Greater efforts are needed to:

- Train responders and administrators in IRS operations,
- Institutionalize the Unified Command system to harmonize operations across the armed forces, NDRF, police, fire services, and civil authorities,
- Avoid overlaps and confusion during response operations.

6. Capacity Building and Support to Civil Society

Non-Governmental Organizations (NGOs) play a pivotal role in disaster response and rehabilitation, offering flexible, localized solutions. Governments must facilitate their engagement by:

- Providing institutional support and funding channels,
- Granting tax exemptions to donors on par with official relief funds (e.g., PMRF and CMDRF),
- Encouraging collaborative public-private-NGO partnerships for disaster resilience.

7. Empowering Local Communities

The involvement of Kerala's fishing community during rescue operations serves as a powerful reminder of the need to empower local populations as first responders. Governments should:

- Build local capacity through community-based disaster preparedness (CBDP) programs,
- Develop systems that allow institutional support to grassroots initiatives during emergencies,
- Recognize and formally integrate community action into disaster management frameworks.

8. Coordinated Fund-Raising and Media Responsibility

Media houses play an influential role in mobilizing resources during crises. However, uncoordinated fundraising campaigns can lead to confusion among donors. There is a need for:

- Unified appeals by media platforms in collaboration with credible NGOs and government agencies,
- Transparent mechanisms to track fund utilization,
- Systems that encourage large-scale donors to contribute based on humanitarian need, rather than political considerations.

Conclusion

The Kerala floods have highlighted the need for critical examination of the interactions between natural hazards, human interventions, and governance systems. Moving forward, building resilient communities and sustainable infrastructure, underpinned by scientific foresight, inclusive planning, and collaborative governance, will be key to mitigating the impact of future disasters.

Bihar Floods, 2019

Introduction

Bihar is one of India's most flood-prone states, situated within the vast Ganga-Brahmaputra floodplain. About 73% of its land is vulnerable to flooding, making up nearly 17.2% of India's total flood-affected area. A key contributing factor to this risk is that nearly 65% of the river catchments affecting Bihar originate in upstream regions of Nepal and Tibet, while only about 35% lie within the state.



Fig - 10 : Araria (Bihar): Flood water inundates Bihar's Araria, on July 13, 2019.

Source :- <https://www.zeebiz.com/india/photo-gallery-bihar-flood-2019-pics-flood-water-inundates-araria-105543/105548>

Bihar is crossed by several major rivers, including the Ghaghra, Gandak, Budhi Gandak, Bagmati, Kamala, Bhutani Balan, Kosi, and Mahananda. The Kosi River, known as the "Sorrow of Bihar," is infamous for its unpredictable course changes and heavy sediment load, causing frequent monsoon devastation.

In July 2019, severe floods affected 13 districts and over 8 million people, triggered by heavy rainfall in Nepal's Himalayan region. Sudden surges in rivers originating from the foothills overwhelmed Bihar's river systems. After a hot, drought-like spell in May and June, torrential monsoon rains pushed five major rivers Bagmati, Burhi Gandak, Kamla Balan, Adhwara, and Khirai beyond danger levels, causing widespread flooding in northern Bihar.

The rising floodwaters breached embankments, damaged roads, destroyed small bridges, and devastated agricultural fields particularly paddy, maize, and jute crops. This severely affected rural communities reliant on farming and small-scale trade.

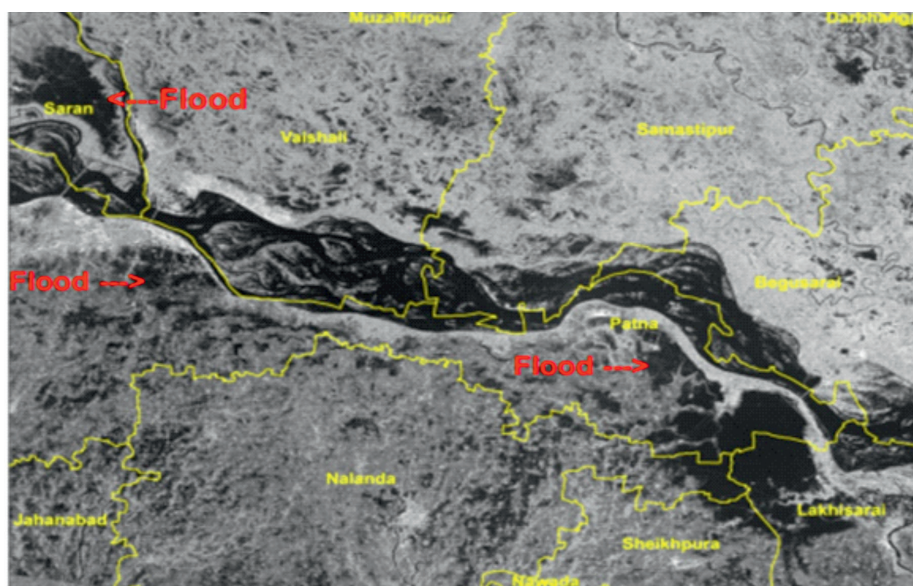


Fig - 11 : 30 September 2019 (Sentinel 1 SAR)

Source: https://www.nrsc.gov.in/sites/default/files/pdf/DMSP/webinputs_bihar_floods-Sep2019.pdf

By 30 July 2019, about 8.84 million people across the affected districts were impacted, with an official death toll of around 130. The highest casualties were reported in the following districts:

- Sitamarhi: 37 deaths
- Madhubani: 30 deaths
- Darbhanga: 14 deaths
- Saharsa: 1 death
- Araria: 12 deaths
- Sheohar: 10 deaths
- Purnea: 9 deaths
- Kishanganj: 7 deaths
- Muzaffarpur and Supaul: 4 deaths each

Interestingly, Katihar and West Champaran, though affected by the floods, reported zero casualties, indicating effective local preparedness and response.

The 2019 Bihar floods highlighted the region's vulnerability to transboundary river flooding and underscored the urgent need for cross-border cooperation, improved scientific forecasting, and community-based disaster risk reduction.

Historical Records of Floods in Bihar

According to data from the Flood Management Improvement Centre (FMIC) and Bihar's Water Resources Department (WRD), Bihar is India's most flood-prone state, with 73.06% (68,800 sq. km) of its area identified as flood-affected. Nearly 76% of northern Bihar's population lives under constant flood risk.

Bihar's vulnerability stems from its proximity to Nepal, where major rivers like the Kosi, Gandak, Burhi Gandak, Bagmati, Kamla Balan, Mahananda, and Adhwara originate in the steep, young Himalayas. These rivers carry large discharge volumes and heavy sediment loads, depositing them across Bihar's plains. About 65% of their catchment

areas lie in Nepal and Tibet, with the remaining 35% within Bihar.

A review by Kale (1997) highlighted that northern Bihar experienced the highest flood frequency over 30 years, with particularly severe floods in 1978, 1987, 1998, 2004, and 2007. The 2004 flood was especially devastating, inundating 23,490 sq. km and causing 800 deaths, despite relatively low water levels in the Ganga River.

Bihar's recurrent floods result from transboundary hydrological influences, intense rainfall, sediment-heavy rivers, and weak embankments. Despite mitigation efforts, floods continue to cause major losses in life, agriculture, and infrastructure. This ongoing vulnerability stresses the urgent need for coordinated river basin management, embankment strengthening, and improved early warning systems, particularly through cooperation with Nepal.

Potential Causes of Flooding in Bihar

The state of Bihar is highly vulnerable to recurrent flooding, primarily due to its geographical location and topographical characteristics, which make it susceptible to both transboundary river systems and seasonal monsoon extremes. One of the most influential contributing factors is the hydrological relationship with Nepal, whose mountainous terrain plays a critical role in the flood dynamics of northern Bihar.

Transboundary Hydrological Influence

Nepal's steep mountainous terrain receives intense monsoon rainfall that rapidly drains into major Himalayan rivers like the Narayani, Bagmati, and Kosi. These rivers subsequently flow into low-lying plains of Bihar, often generating high discharge levels that place pressure on existing embankments. To protect upstream structures such as the Kosi Barrage, controlled releases are made through sluice gates during periods of high inflow. While necessary from an operational perspective, these releases can significantly increase flood intensity in downstream areas of Bihar.

A stark example occurred in August 2008 when the Kosi River breached its eastern embankment near Kusaha, Nepal, during a peak discharge event. The breach caused the river to divert into an old, abandoned channel it hadn't used for over a century. This sudden shift inundated large parts of northern Bihar and southeastern Nepal, affecting around 2.7 million people. Approximately 95% of the river's flow was diverted through this new channel, highlighting the severe risks of channel avulsion and embankment failures in the region.

Sediment Load and Catchment Response

According to the Bihar State Disaster Management Authority (BSDMA), rivers flowing into Bihar from Nepal carry extremely high sediment loads. These sediments accumulate in the alluvial plains, raising riverbeds and reducing the capacity of river channels, which significantly heightens the risk of overbank flooding during peak monsoon flows. The intense rainfall concentrated in just three months causes these rivers to swell dramatically sometimes up to 50 times their average flow leading to frequent and severe flood events.

At the national level, Bihar bears a disproportionate share of India's flood burden, accounting for 30–40% of total flood-related damages and housing nearly 22.1% of the flood-affected population. Out of its 38 districts, 28 are classified by BSDMA as flood-prone or highly flood-prone, underscoring the persistent vulnerability of the state to flooding.

Extreme Rainfall Events and Sudden Flooding

A major trigger of the 2019 floods was the occurrence of extreme rainfall events over a short period in both Nepal and Bihar. Notably, Nepal's Simara weather station recorded 478.4 mm of rainfall on 11–12 July 2019 about 82% of its average total July rainfall of 580.2 mm in just three days. This intense precipitation led to the opening of all 56 sluice gates of the Kosi Barrage on 13 July, releasing roughly 300,000 cusecs of water into downstream Bihar, significantly escalating flood risks.

Simultaneously, intense rainfall was recorded across northern Bihar. According to the India Meteorological Department (IMD), districts such as:

- East Champaran received 214.92 mm, Sitamarhi recorded 154.55 mm, Muzaffarpur observed 125.15 mm, all within a 24-hour period on 12–13 July 2019, breaking a 54-year-old record for single-day rainfall in the state.

Further, on 14 July 2019, extreme rainfall was again observed at the block level, including:

- Kishanganj block: 186.8 mm in five hours
- Kochadham block: 164.2 mm
- Thakurganj block: 163 mm
- Bagadurganj block: 162 mm

These high-intensity short-duration rain events overwhelmed the river systems and local drainage infrastructure, further exacerbating flood conditions across northern Bihar.



Fig - 12: Araria (Bihar): Flood water inundates Bihar's Araria, on July 13, 2019.

Source : <https://www.zeebiz.com/india/photo-gallery-bihar-flood-2019-pics-flood-water-inundates-araria-105543/105546>

Impact of the 2019 Bihar Floods

The 2019 floods had a catastrophic impact on the state of Bihar, with the capital city Patna experiencing some of the most severe consequences. Approximately 80% of households in Patna were inundated as the city received nearly 40% of its seasonal monsoon rainfall within just 48 hours. Four major rivers Ganga, Son, Gandak, and Punpun surpassed their danger levels, intensifying urban flooding.

One of the most alarming incidents during the 2019 floods was the inundation of Nalanda Medical College and Hospital the second-largest public healthcare facility in Patna where critical areas such as the Emergency and ICU wards were submerged under knee-deep water. With roads rendered impassable, rescue boats and municipal cranes were deployed to evacuate residents, while a prolonged power outage across large parts of the state further worsened the crisis.

The flood threat intensified when 2.75 lakh cusecs of water were released from the Indrapuri barrage on the Son River, causing sharp rises in the Ganga and its tributaries.

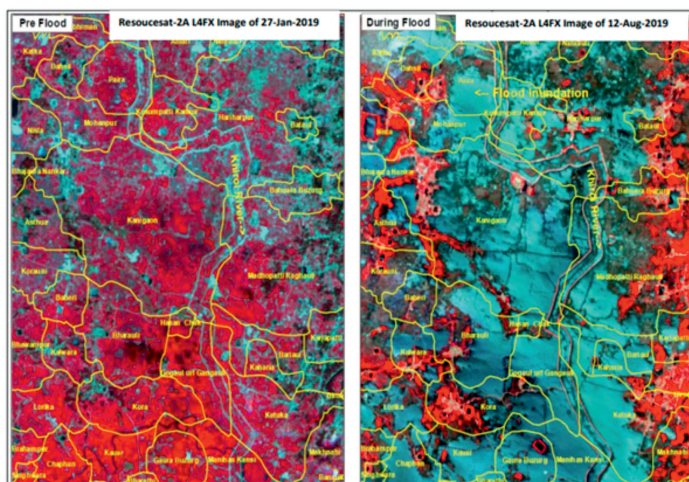


Fig - 13: Satellite images showing detail view of flood inundation in part of Darbhanga District (2019)

Source : <https://bhuvan.nrsc.gov.in/pdf/Flood-Hazard-Atlas-Bihar.pdf>

Damage to seven embankments in Nalanda and Jehanabad districts expanded the inundated area. By 30 July 2019, approximately 8.84 million people across 13 districts were affected, with 130 fatalities reported. Extensive damage to agriculture, roads, and bridges accompanied the disaster, impacting 1,269 panchayats and highlighting the vast scale of the flood event.

In a parliamentary response dated 20 September 2020, the Union Minister of Agriculture and Farmers' Welfare, Shri Narendra Singh Tomar, disclosed that Bihar alone suffered crop damage over 2.6 million hectares in 2019, out of a national total of 11.43 million hectares affected by hydrological hazards.

Further, the Minister of State for Home Affairs, Shri Nityanand Rai, reported in November 2019 that the Bihar floods caused 113 human deaths, 80 livestock fatalities, damage to 45,355 homes, and destruction of 2.61 lakh hectares of cultivated land. Across eight flood-affected states in 2019, the disaster resulted in 989 human deaths, 9,804 livestock deaths, damage to 54.8 lakh hectares of cropland, and destruction of 494,284 houses.



Fig - 14 : MUZAFFARPUR, July 18, 2019 (Xinhua)

Source :- Photo taken on July 17, 2019 shows flooded residences in Muzaffarpur district, Bihar, India. Many residents have been left homeless by recent flood caused by incessant rain in India's eastern state of Bihar.

Relief Measures by Government and Civil Society

In response to the 2019 Bihar floods, a large-scale relief operation was launched involving the NDRF, SDRF, Indian Army, and local authorities. Key actions included deploying 26 companies, mobilizing 125 rescue boats, supplying drinking water, distributing food in relief camps, and closing schools in Patna as a precaution. The IMD provided regular weather updates, while NDMA shared flood safety advisories on social media.

Additional support included two Indian Air Force helicopters for evacuation and relief, heavy-duty dewatering pumps from Coal India, and the establishment of 442 community kitchens staffed by 876 personnel and 9 NDRF teams. Twenty NDRF teams worked across key districts, rescuing 3 individuals, evacuating over 17,700 people and 46 livestock, retrieving 60 bodies, and providing medical care to nearly 10,000 affected people.

The National Crisis Management Committee (NCMC), led by Cabinet Secretary Shri Rajiv Gauba, closely monitored the situation. The Central Government sanctioned ₹400 crore from the National Disaster Response Fund (NDRF) and ₹213.75 crore under the State Disaster Response Fund (SDRF) to support Bihar's relief and rehabilitation efforts.

Lessons Learnt

Floods remain a persistent and worsening challenge in Bihar. The 2019 floods destroyed 7.54 lakh hectares of farmland dramatically higher than 0.34 lakh hectares in 2018 and 2.61 lakh hectares in 2017. Historical records from 1953 to 2017 reveal that floods have affected 2.24 million hectares of agricultural land, causing economic losses exceeding ₹768 crore.

Key lessons highlight the urgent need for:

- Flood-resilient housing designs, especially in seismically vulnerable areas
- Long-term strategies that combine climate-resilient infrastructure, sustainable land use, and effective disaster preparedness measures to reduce future risks and losses.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Early Warning & Forecasting	IMD issued heavy rainfall alerts; flood warnings disseminated	Limited integration of rainfall forecasts with dam operations	Forecasts must be linked with real-time reservoir management	Establish integrated flood forecasting and reservoir operation protocols
Dam & Reservoir Management	Simultaneous opening of multiple dams	Lack of coordinated reservoir operation guidelines	Uncoordinated dam releases aggravate downstream flooding	Develop basin-level reservoir operation rules and real-time decision systems
Preparedness & Planning	Emergency response initiated after flood onset	Insufficient pre-monsoon preparedness and scenario planning	Preparedness must be anticipatory rather than reactive	Institutionalize seasonal preparedness and simulation exercises

Institutional Coordination	Multi-agency response by State, Armed Forces, NDRF	Limited inter-departmental coordination at operational level	Clear command structure improves response efficiency	Strengthen Incident Response System (IRS) implementation
Urban & Land Use Planning	Extensive flooding in low-lying and reclaimed areas	Encroachment of floodplains and wetlands	Unplanned development increases flood risk	Enforce floodplain zoning and regulate land-use change
Environmental Degradation	Landslides intensified due to deforestation and slope instability	Weak enforcement of environmental regulations	Ecological stability is critical for disaster risk reduction	Strengthen hill-area regulations and ecosystem restoration
Community Participation	Fishermen and local volunteers played key rescue roles	Community actions not institutionally supported	Communities are first responders	Institutionalize Community-Based Disaster Risk Management (CBDRM)
Response & Relief Operations	Large-scale evacuation and relief camps established	Logistical challenges in remote and hilly areas	Pre-positioning of resources is essential	Strengthen decentralized relief logistics
Public Health & Safety	Disease outbreaks and sanitation issues reported	Limited preparedness for post-flood health risks	Public health must be integrated into disaster planning	Strengthen disease surveillance and WASH preparedness
Recovery & Reconstruction	Rapid infrastructure restoration	Limited application of Build Back Better (BBB) principles	Recovery should reduce future risk	Enforce BBB in housing and infrastructure reconstruction
Damage & Loss Assessment	Extensive damage assessment conducted	Lack of standardized assessment framework	Uniform assessment improves recovery planning	Adopt standardized Damage & Loss Assessment (DaLA) tools
Governance & Policy	Strong political and administrative response	Weak integration of DRR into development	Risk-informed governance is essential	Mainstream DRR into state planning and budgeting

Karnataka Floods, 2019

Introduction

Beginning on 1 August 2019, the state of Karnataka in southern India faced severe flooding due to intense monsoon rainfall. The India Meteorological Department (IMD) issued Red Alerts for several coastal and inland regions as a precautionary measure. As per the Press Trust of India, at least 61 people lost their lives, and approximately 700,000 individuals were displaced across the state, with many relocated to relief camps. By 14 August 2019, more than 6.97 lakh individuals had been evacuated.

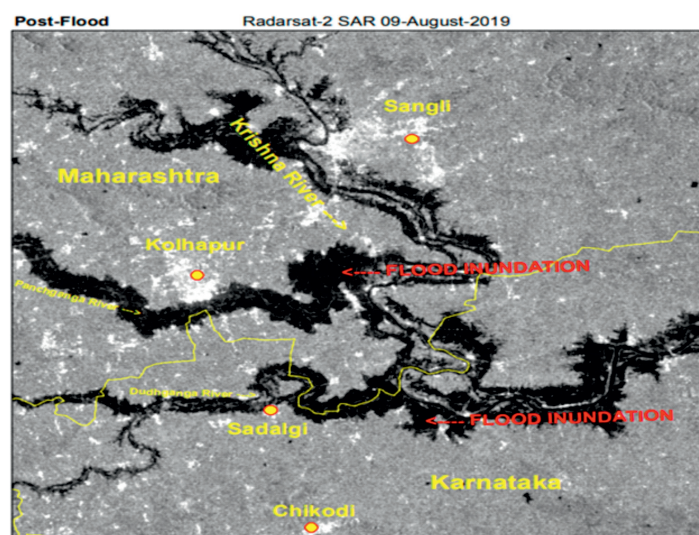


Fig - 15 : Floods were reported in Karnataka and Maharashtra due to heavy rains and release of water in Krishna River Catchment areas inundating vast tracts of land. NRSC/ISRO has analysed microwave datasets of Radarsat and Sentinel SAR during 6th, 9th, and 12th August 2019.

Source : https://www.nrsc.gov.in/sites/default/files/pdf/DMSP/Mh_Ka_Flood2019_web.pdf

To support affected families, the Chief Minister of Karnataka announced an ex-gratia payment of ₹5 lakh for the families of the deceased. Rainfall activity remained moderate to heavy along coastal Karnataka, with Honavar recording 84 mm, Karwar 50 mm, and Mangaluru 24 mm attributed to an offshore trough along the west coast.

Causes

Heavy monsoon rains caused severe flooding in north interior Karnataka, affecting districts like Dharwad, Belagavi, Kalaburagi, and others. Rivers and streams overflowed, submerging homes, schools, and infrastructure.

In Belagavi, 58.1 mm of rain in 24 hours flooded low-lying areas like Chikkodi, forcing residents onto rooftops. Roads were damaged, including National Highway 4 near Sutagatti Ghat, which stranded many vehicles. A landslide near Jamboti swept away parked vehicles. In Dharwad and Kalaburagi, streams damaged key roads, disrupting connectivity with Maharashtra.

Impact

The flood situation worsened due to ongoing heavy rainfall and water releases from full-capacity reservoirs. The

Kalyana Karnataka region saw its heaviest rainfall since 1992, severely impacting districts such as Yadgir, Raichur, Ballari, Bidar, Vijayapura, Bagalkote, Belagavi, Dakshina Kannada, Udupi, Uttara Kannada, Gadag, Koppal, Haveri, and Dharwad.

According to the Karnataka State Natural Disaster Management Centre, floodgates of major dams like Linganamakki, Supa, Varahi, Harangi, Hemavathi, Krishna Raja Sagar, Kabini, Bhadra, Tungabhadra, Ghataprabha, Malaprabha, Almatti, and Narayanapura were opened to control rising water levels. This caused widespread village submergence, creation of temporary islands, and extensive damage to crops and infrastructure.

- During the floods, the Bhima, Krishna, and Kagna rivers rose sharply, causing damage and triggering alerts in Kalaburagi, Yadgir, and Raichur.
- The Kagna River at Malkhed in Kalaburagi flowed dangerously, leading to alerts from the Central Water Commission.



Fig - 16: A group of people on a raft in Karnataka floods 2019 for rescue

Source : <https://www.thenewsminute.com/karnataka/karnataka-floods-2019-update-flood-affected-districts-106920>

Preliminary Damage Assessment

- 54 relief camps were operational across seven districts, housing 7,776 displaced people.
- 43 animal deaths were reported.
- 800 houses sustained structural damage.
- Agricultural crop loss covered approximately 1,04,418.82 hectares.
- Horticultural losses extended to 3,481.93 hectares.

The Meteorological Department forecasted continued heavy rainfall and thunderstorms across coastal and interior Karnataka. As a result, emergency operations were intensified.

Rescue and Relief Efforts

The National Disaster Response Force (NDRF) was deployed for rescue operations in submerged and isolated areas, including:

- Rescuing stranded people in Haragadde and Karakalagadde (Raichur), where a temporary island formed due to sudden water release from the Krishna River.
- Coordinating with the state government and local agencies to evacuate residents, supply food and water, and manage shelters.

Meanwhile, the state government ensured funds were available for relief efforts and launched reconstruction plans in flood-affected districts.



Fig - 17 : Karnataka floods.

Source : <https://thewire.in/environment/karnataka-floods-five-dead-nearly-26000-evacuated>

Institutional Response and Financial Assistance

The 2019 southwest monsoon floods in Karnataka triggered a large-scale emergency response involving both State and Central Governments. While the primary responsibility for disaster management lies with the state, the Government of India supports these efforts through the State Disaster Response Fund (SDRF) and the National Disaster Response Fund (NDRF) following established protocols.

Due to limited resources in the SDRF, both Karnataka and Bihar requested advance releases and additional financial assistance. The Home Minister, after reviewing the severity of the situation, approved:

- ₹1,200 crore as advance assistance from NDRF for Karnataka.
- ₹213.75 crore as second installment of the Centre's SDRF share for Bihar.

The Centre's total financial support for flood-related damages in both states amounted to ₹1,813.75 crore.

Flood-Affected Areas and Disaster Declaration

In Karnataka, 80 taluks across 22 districts were declared flood-affected due to damage to crops, infrastructure, livestock, and lives. Severely hit districts included:

- Belagavi, Bagalkote, Raichur, Kalaburagi, Yadgir, Vijayapura, Gadag, Dharwad, Haveri, Shivamogga, Udupi, Dakshina Kannada, Kodagu, Chikkamagaluru, and Mysuru.

At least 26 people died within a week. Three IAF helicopters rescued 37 people in Belagavi, Gadag, and Raichur, and 1,500 food packets were airdropped in remote villages.

Infrastructure Disruption

The floods and continuous rainfall triggered 30 landslides in just five days between Hassan and Subramanya Road. This prompted the South Western Railway to suspend several train services, including:

- Yesvantpur–Karwar Express,
- KSR Bengaluru–Kannur/Karwar Express,
- Mangaluru Junction Express via Mysuru,
- Yesvantpur–Mangaluru Central Express.

The Hassan–Mangaluru section became particularly vulnerable, with rainfall in the ghat section nearly doubling the previous year’s cumulative levels.

Pre-Flood Preparedness and Rapid Response

Prior to the onset of the monsoon, the State Government had undertaken extensive preparedness activities, including the formation of a High-Level Committee tasked with assessing district-level vulnerability and ensuring institutional readiness.



Fig - 18 : A senior citizen being airlifted by the Indian Air Force from the terrace of a house in a village hit by the Karnataka floods

Source : <https://indianexpress.com/article/cities/bangalore/bengaluru-traffic-weather-bbmp-airport-police-rains-live-news-karnataka-floods-rescue-5890736/>

As floods worsened, real-time weather alerts from IMD and KSNDMC helped pre-position rescue teams, including: NDRF, SDRF, Civil Defence, Karnataka State Reserve Police (KSRP), and Fire and Emergency Services.

A strong inter-agency response evacuated nearly 7 lakh people to relief camps.

Table 1 - Joint Rescue Operations: Multi-Agency Deployment

Sl. No	Agency/Force	Teams/Units Deployed
1	Fire Force + SDRF + Home Guards + Civil Defence + QRT + KSRP + Garuda Force	43 teams
2	National Disaster Response Force (NDRF)	19 teams
3	Indian Army	17 columns + 2 specialized teams
4	Indian Navy	4 teams + 1 helicopter
5	Indian Air Force	4 MI-series helicopters
6	Indian Coast Guard	5 teams

Source: Karnataka State Disaster Management Authority (KSDMA)

Damage Assessment (as of 14 August 2019)

Damages due to Karnataka flood, data released by Karataka Chief Minister's Office (Indian Express, 14 August 2019)

- Human fatalities: 61
- Persons missing: 15
- Animal deaths: 859
- Evacuated individuals: 697,948
- Animals rescued: 51,460
- Relief camps established: 1,160
- People housed in relief camps: 396,617
- Houses damaged: 56,381
- Districts/Talukas affected: 103 talukas in 22 districts
- Agriculture and horticulture crop loss (preliminary): 6.9 lakh hectares

Dam Water Management in the Krishna Basin

According to the South Asia Network on Dams, Rivers, and People (SANDRP), most reservoirs in the Krishna basin were near full capacity by early August 2019, coinciding with above-normal monsoon rains. This combination led to widespread flooding in northern and central Karnataka.

In response, Karnataka's government and KSDMA adopted a revised strategy: reservoirs should not exceed 85% capacity, and inflow–outflow levels would be actively managed to prevent emergency releases during peak rainfall. This aims to reduce flood risks through controlled reservoir operations.

Real-Time Monitoring of Water Levels

To improve dam safety and decision-making, Karnataka has implemented a real-time digital water level monitoring system for dams in the Krishna and Cauvery basins. WhatsApp groups of field engineers, dam operators, and officials share water updates every three hours for quick response.

Additionally, data from about 7,000 weather stations statewide are used to forecast rainfall and reservoir inflows, allowing timely water releases to reduce downstream flood risks.

Village-Level Disaster Management Plans (VDMPs)

Recognizing the need for community-level preparedness, Karnataka identified 912 flood-vulnerable gram panchayats across 13 districts to develop Village Disaster Management Plans (VDMPs). These plans focus on establishing village disaster management teams, conducting risk awareness campaigns, mapping evacuation routes and shelters, and ensuring access to early warning alerts.

Experts and authorities have also raised concerns about riverbank encroachments along the Krishna River, which worsen flooding by blocking natural drainage and reducing river capacity.

Conclusion

The 2019 Karnataka floods served as a significant turning point in the state's approach to disaster risk reduction and flood management. The crisis underscored the indispensable role of early warning systems, pre-monsoon preparedness, and coordinated multi-agency response mechanisms in minimizing human and economic losses. The synergy between the state and central governments, along with the armed forces and specialized disaster response units, was instrumental in delivering timely relief and evacuation operations.

The disaster also catalyzed notable institutional and policy reforms, particularly in the areas of reservoir regulation, real-time data sharing, and village-level disaster preparedness. These measures, including the establishment of communication networks among dam engineers and the formulation of localized disaster management plans, offer a replicable model for climate-resilient flood governance.

Nevertheless, the floods also highlighted enduring challenges such as unregulated land use, riverbank encroachments, and inadequate enforcement of zoning regulations, which continue to heighten the vulnerability of flood-prone communities. Moving forward, there is an urgent need to integrate disaster risk reduction (DRR) into the broader framework of development planning, ensure sustainable water resource management, and enhance local institutional capacities. Only through a holistic and proactive approach can the state build long-term resilience against the increasing frequency and intensity of hydro-meteorological hazards.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Early Warning & Forecasting	IMD and CWC issued rainfall and flood forecasts	Limited last-mile dissemination in rural areas	Forecasts must translate into actionable warnings	Strengthen local-level dissemination through Panchayats and community networks
Embankment Management	Multiple embankment breaches reported	Weak maintenance and delayed repair	Structural flood control alone is insufficient	Shift from embankment-centric to basin-level flood management
Preparedness & Planning	Relief measures activated post-inundation	Limited pre-monsoon preparedness	Preparedness must be anticipatory	Strengthen seasonal flood preparedness planning

Institutional Coordination	NDRF, SDRF, Army deployed effectively	Coordination challenges at district level	Clear command structures improve response	Strengthen Incident Response System (IRS) implementation
Urban Flooding	Affected region was severely inundated	Poor drainage and encroachment of wetlands	Urban flooding is a growing risk	Integrate flood risk into urban planning and drainage design
Community Preparedness	Community-led evacuation observed in some areas	Limited training and formal integration	Communities are key first responders	Promote Community-Based Disaster Risk Management (CBDRM)
Relief & Shelter Management	Large number of relief camps established	Overcrowding and sanitation challenges	Relief infrastructure must meet minimum standards	Upgrade relief camp design and WASH facilities
Health & Sanitation	Waterborne diseases reported post-flood	Insufficient preventive health measures	Health preparedness is integral to disaster response	Strengthen disease surveillance and medical preparedness
Damage & Loss Assessment	Extensive damage recorded across sectors	Absence of standardized assessment methods	Reliable data is essential for recovery planning	Adopt standardized Damage and Loss Assessment (DaLA) frameworks
Livelihood & Agriculture	Large-scale crop loss and livestock deaths	Limited livelihood recovery mechanisms	Livelihood resilience is critical	Promote climate-resilient agriculture and crop insurance
Recovery & Reconstruction	Relief-focused recovery approach	Limited Build Back Better integration	Recovery must reduce future flood risk	Mainstream BBB principles in housing and infrastructure
Governance & Policy	Post-disaster assistance mobilized	Long-term flood mitigation remains weak	Flood risk requires structural and policy reforms	Strengthen basin-level flood governance and planning

Heat Wave, 2019

Introduction

The 2019 heatwave in India was one of the most severe heatwaves faced. It affected large parts of North, Central, and Eastern India during May-July, 2019. The event was characterised by prolonged heatwave to severe heatwave conditions, with temperatures exceeding 45°C in several regions and reaching up to 50.8°C in Churu (Rajasthan). The intensity, duration, and spatial spread of the heatwave were significant, reflecting changing climate patterns and delayed monsoon onset. Such extreme temperature conditions resulted in widespread thermal stress, impacting public health, water availability, and livelihoods across multiple states.

Bihar was one of the worst-affected states, recording the highest number of heatwave-related deaths in the country in 2019. As per official data reported through PIB release on heatwave mortality (NCRB data), the state recorded 215 deaths due to heat/sunstroke in 2019 accounting for highest loss of life among all states. The high mortality reflects the combined effect of prolonged exposure, high temperatures, and limited adaptive capacity, particularly among vulnerable populations. The event highlighted the challenges related to early warning dissemination, public health preparedness, and local heat action planning, especially in the Indo-Gangetic plains.

Historical Trends of Heatwave Incidents in Bihar

An analysis of historical temperature data indicates that Bihar has experienced recurrent heatwave episodes, with varying degrees of intensity across different districts:

Table 2- Historical Trends of Heatwave across Bihar

Sl. No.	Location	Observations
1	Gaya	Historically, Gaya experienced short-duration heatwaves between 1975 and 1997. The highest recorded temperature was 46.6°C on 22 and 24 May 1998. Data for the years 2000 and 2001 were not available.
2	Patna	Between 1975 and 2004, Patna experienced moderate heatwave spells, usually lasting 3–4 days, except in 1975, 1979, 1992, and 1998, when durations were longer. The highest maximum temperature was 46.1°C on 16 June 1995.
3	Bhagalpur	The 1975–1987 period saw increased frequency and persistence of heatwaves. In recent years, frequency declined. The peak temperature recorded was 46.4°C in 1982.
4	Purnea	A long spell of heatwave occurred from 1–8 June 1979, with a maximum temperature of 43°C on 6 June 1979.

Source: Sharma, J.K., Srivastava, K., & Bhatnagar, N.P. (2009). A study of Heat wave/severe heat wave over Bihar and Jharkhand, *Mausam*, 60(1), 89–93. DOI: 10.54302/mausam.v60i1.1059.

Causes of the 2019 Heatwave in Bihar

India recorded its seventh warmest year in 2019, with mean surface temperatures +0.36°C above the 1981–2010 average, as per IMD. Bihar's geography from the Chota Nagpur Plateau to the alluvial plains gives it a humid subtropical climate, making it highly susceptible to extreme summer heat and prolonged heatwaves.

Despite their severe impact on health, agriculture, and infrastructure, heatwaves are often under-recognized as disasters due to their gradual onset and less visible damage compared to sudden events like floods or cyclones.

Definition of Heatwave and Severe Heatwave Conditions

The classification of heatwave intensity by the IMD is based on the normal maximum temperature of a location and its deviation from the climatological norm. The thresholds for declaring heatwave and severe heatwave conditions are as follows:

Normal Maximum Temperature of the Station	Heatwave	Severe Heatwave
< 40°C	+5°C to +6°C above normal	+7°C or more above normal
≥ 40°C	+4°C to +5°C above normal	+6°C or more above normal

Source :- Sharma, J.K., Srivastava, K., & Bhatnagar, N.P. (2009). A Study of Heat Wave/Severe Heat Wave over Bihar and Jharkhand. *Mausam*. https://www.researchgate.net/publication/257940402_A_study_of_Heat_wavesevere_heat_wave_over_Bihar_and_Jharkhand

The combination of elevated baseline temperatures, persistent meteorological anomalies, and climate variability have been the principal drivers of the intensifying frequency and severity of heatwaves in Bihar and other parts of eastern India.

Impact of the 2019 Heatwave in Bihar

The 2019 heatwave had severe consequences across several Indian states, resulting in a substantial number of deaths and heat-related illnesses. According to official records:

- As of 31 May 2019, Maharashtra reported 8 fatalities and 456 cases of heat illness.
- Telangana recorded at least 17 deaths, while Andhra Pradesh reported 3 deaths and 433 instances of heat stroke.

The deadly effects of the extreme heat were also visible in transit on 10 June 2019, three passengers were found deceased aboard a train approaching Jhansi, with preliminary reports suggesting heat exposure as the likely cause. A fourth passenger, who was critically affected, later succumbed to heat-related complications at a hospital.



Fig - 19 : A senior citizen being airlifted by the Indian Air Force from the terrace of a house in a village hit by the Karnataka floods Commuters cover themselves to shield against the scorching sun, in Patna, Bihar, on Monday, June 17, 2019.

Source : - (Parwaz Khan /HT PHOTO) <https://www.hindustantimes.com/patna/over-100-reported-dead-as-central-bihar-reels-under-intense-heat/story-vpomt0EMbH5DvF3fR87hIL.html>

In Bihar, the situation was especially critical. By 18 June 2019, the death toll from heat-related causes had reached 184, according to Al Jazeera News.

The heatwave also broke or neared temperature records in several Indian cities:

- At one point, 11 of the 15 hottest locations on Earth were reported to be in India.
- On 2 June 2019, Churu (Rajasthan) recorded a temperature of 50.8°C (123.4°F)—just 0.2°C below the nation's all-time record of 51°C, set during the 2016 heatwave.
- Allahabad (Prayagraj) exceeded its previous record of 48.9°C (120°F) on 9 June 2019.
- On 10 June 2019, Delhi recorded a temperature of 48°C (118°F), establishing a new monthly high. That same day, the city's peak power demand surged to a record-breaking 6,686 MW, highlighting the strain on energy infrastructure during extreme heat events.

These figures underline the growing severity and widespread impact of heatwaves in India, exacerbated by climate change, urban heat islands, and limited public awareness of heatwave health protocols.

Relief and Recovery Operations: Bihar Heatwave 2019

In the aftermath of a severe heatwave that claimed 184 lives across Bihar mostly in Aurangabad, Gaya, and Nawada, where temperatures exceeded 45°C both state and central governments initiated urgent relief measures. In an unprecedented step, Gaya's District Administration invoked Section 144 of the CrPC to restrict public movement during peak hours. Additionally, all government schools were closed, and outdoor activities were suspended to prevent further casualties and health concerns.



Fig - 20 : People try to relax under the shade of trees as heatwaves scorch India.

Source :- (Image: Alamy) Source: <https://dialogue.earth/en/climate/indias-bihar-has-a-plan-for-extreme-heat-why-are-so-many-people-dying/>

Bihar Chief Minister Shri Nitish Kumar announced an ex-gratia of ₹4 lakh for families of those who died due to heatstroke (Source: Bihar CMO). The state also issued public advisories urging precautions between 11 a.m. and 4 p.m., the peak heat hours. At the national level, Union Health Minister Dr. Harsh Vardhan termed the situation “deeply concerning” and advised people to avoid outdoor movement during extreme heat. He noted that Bihar, along with Rajasthan and Madhya Pradesh, experienced temperatures above 46°C, with over ten Indian locations recording the world’s highest temperatures on multiple days.

Way Forward: Strategic Preparedness for Heatwave Resilience

To build long-term resilience against recurring heatwave events, a multi-sectoral and phased approach is essential. The following strategic interventions are recommended:

1. Capacity Building and Institutional Preparedness

- Identification and training of Incident Commanders to lead heatwave response at the district and sub-district levels.
- Clear delineation of roles and responsibilities for various departments and agencies across all phases of the heat season.

2. Phased Action Plan

- Phase I: Pre-Heat Season (February–March)
Awareness campaigns, vulnerability mapping, infrastructure preparedness (e.g., shade structures, drinking water facilities).
- Phase II: During Heat Season (April–June)
Real-time heat alerts, heat illness surveillance, deployment of medical and emergency services.
- Phase III: Post-Heat Season (July–October)

Evaluation of response effectiveness, updating heat action plans, and training refreshers for frontline workers.

3. Public Health and Medical Management

- Strengthening systems for the early identification of heat-related illness and ensuring prompt casualty reporting.
- Ensuring availability of emergency medical services with standard treatment protocols for managing heatstroke and dehydration.

4. Data and Surveillance Systems

- Development of robust systems for data collection and analysis on heatwave morbidity and mortality.
- Real-time monitoring tools integrated with meteorological forecasts for early warning dissemination.

5. Risk Communication and Public Awareness

- Dissemination of Information, Education, and Communication (IEC) materials in regional languages through print, electronic, and digital media.
- Engagement of local governance institutions and community-based organizations in promoting heat safety measures.

Conclusion

The 2019 heatwave in Bihar demonstrated the critical need for climate-sensitive public health planning, improved inter-departmental coordination, and community-based risk reduction strategies. With climate models predicting a further increase in the frequency and intensity of extreme heat events, there is an urgent imperative to institutionalize Heat Action Plans across all vulnerable states, ensuring proactive preparedness, rapid response, and inclusive recovery mechanisms.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Early Warning & Heat Alerts	IMD issued heatwave warnings	Limited public awareness and response	Heat warnings must be actionable and widely disseminated	Strengthen heat alert dissemination through local governance and media
Preparedness & Planning	Emergency measures initiated after mortality increased	Absence of a Heat Action Plan in many districts	Heatwaves require pre-season preparedness	Develop and implement District Heat Action Plans

Public Health Response	Hospitals faced surge in heat-related cases	Limited preparedness for heat illnesses	Health systems must be heat-resilient	Strengthen heat illness surveillance and emergency care protocols
Institutional Coordination	Multiple departments responded independently	Weak inter-departmental coordination	Heatwave response requires multi-sectoral coordination	Establish inter-departmental Heat Action Committees
Urban Heat Stress	High mortality in dense urban areas	Lack of green cover and heat-mitigating infrastructure	Urban design influences heat vulnerability	Promote urban greening and heat-resilient planning
Water Availability	Acute drinking water shortages reported	Inadequate contingency planning	Water security is critical during heatwaves	Strengthen drinking water supply and contingency systems
Public Awareness	Low awareness of heat-related health risks	Limited IEC outreach	Awareness reduces heat-related mortality	Conduct targeted IEC campaigns before summer
Occupational Safety	Outdoor workers severely affected	Lack of work-rest guidelines	Occupational exposure increases risk	Enforce heat safety norms for outdoor workers
Data & Surveillance	Heat-related deaths underreported	Absence of standard heat mortality reporting	Reliable data is essential for planning	Establish heatwave surveillance and reporting systems
Relief & Compensation	Ex-gratia provided after fatalities	Delayed recognition of heat deaths	Heatwaves require proactive response	Integrate heatwaves into disaster compensation frameworks
Climate Change Linkages	Rising frequency of heatwaves observed	Limited climate integration in planning	Heatwaves are climate-driven disasters	Integrate heat risk into climate adaptation planning
Governance & Policy	Reactive response approach	Lack of long-term heat mitigation strategy	Heat risk must be institutionalized	Mainstream heatwave management into DM planning

Delhi Anaj Mandi Factory Fire, 2019

On the morning of December 8, 2019, a major fire broke out in a factory in the densely populated Anaj Mandi area of New Delhi, killing 43 people and injuring over 56. The building, used for making school bags and footwear, was operating illegally and housed workers overnight in unsafe conditions. The fire reportedly started around 5:22 a.m. in a luggage unit while over 50 workers were asleep inside. Most victims died from smoke inhalation, as the multi-storeyed structure lacked ventilation and emergency exits.



Fig - 21 : A fire broke out in Delhi's Anaj Mandi on Rani Jhansi feet road. (Express photo by Praveen Khanna)

Source :- The Indian Express <https://indianexpress.com/article/cities/delhi/delhi-police-high-court-anaj-mandi-fire-8377078/>

Upon receiving the distress call, the Delhi Fire Service (DFS) responded promptly, with the first team arriving within five minutes. However, entry was hindered by narrow lanes and iron-grilled windows and doors, which had to be cut open using gas cutters. Around 150 fire personnel led the rescue operation, evacuating 63 people, though 43 were found dead and several others, including two firefighters, were seriously injured. The National Disaster Response Force (NDRF) also joined the operation. Preliminary findings suggested an electrical short circuit as the likely cause, supported by eyewitnesses and initial forensic reports.

Primary Causes of the Delhi Anaj Mandi Factory Fire (2019)

The fire on 8th December 2019 at a luggage manufacturing unit in Anaj Mandi, Central Delhi, was the result of multiple structural, regulatory, and operational lapses. The factory, spanning around 600 sq ft (56 m²), was situated in a congested urban area and lacked basic fire safety measures.



Fig - 22 :The tragic fire incident in Delhi's Anaj Mandi killed 43 people and injured many. (Photo: PTI)

Source: <https://www.indiatoday.in/india/story/anaj-mandi-fire-owners-nearby-factories-shut-shops-fearing-police-investigation-1627023-2019-12-10>

According to the Deputy Chief Fire Officer, the fire began in the early morning hours on the building's second floor and rapidly spread to the third and fourth floors, where many workers were asleep. Eyewitnesses and survivors reported that iron-grilled windows and blocked escape routes trapped the occupants, leading to fatal asphyxiation. A distress call from a trapped worker highlighted the lack of alternative exits amid heavy smoke and fire.

A status report by Delhi Police to the Delhi High Court revealed gross regulatory violations: the premises operated unauthorized industrial-scale activities using commercial (not industrial) power connections, despite housing heavy machinery and flammable materials. The report further cited criminal negligence in maintaining the electrical system, which constituted a major fire hazard.

The premises lacked proper ventilation, compartmentalization, and approved fire safety measures, while accommodating an excessive number of occupants for both work and residence. The fire's origin near the main staircase the only escape route led to dense smoke buildup, severely reducing victims' chances of survival.

This tragedy highlights the urgent need for strict enforcement of urban safety codes and exposes the wider problem of unregulated manufacturing in residential areas, which disproportionately endangers vulnerable workers.

Impacts of the Delhi Anaj Mandi Factory Fire (2019)

The tragic Anaj Mandi fire in New Delhi claimed 45 lives, including nine minors the youngest aged 12 as per the Delhi Police report submitted to the Delhi High Court on 10 January 2020. Six children were also injured.

Most victims, many migrant laborers, died from smoke inhalation. Lok Nayak Jai Prakash (LNJP) Hospital reported 34 dead on arrival, with several showing severe burns, while 15 others were critically injured. Additional treatment was provided at Lady Hardinge, RML, and Hindu Rao hospitals.

Search, Rescue, and Relief Operations

The National Disaster Response Force (NDRF) supported the Delhi Fire Service (DFS) in rescue operations, using gas detectors for floor-by-floor searches. High carbon monoxide (CO) levels, particularly on the third and fourth floors, increased risks for both victims and rescuers.

The rescue efforts faced multiple logistical challenges:

- Entry points were obstructed by locked doors and iron-grilled windows.
- Narrow lanes leading to the building allowed passage of only one fire engine at a time.
- The secondary staircase, a potential escape route, was blocked with raw materials, which further hampered evacuation efforts.
- Gas cutters were employed to breach iron grills and allow access.

An estimated 150 fire personnel were involved in the operation, managing to rescue 63 individuals from the burning structure.

Government Response and Compensation

In the aftermath of the tragedy, high-level interventions were made by both the Union and State Governments:

- The Hon'ble Prime Minister of India expressed grief over the incident, describing it as "extremely horrific," and announced ex-gratia compensation of ₹2 lakh (approx. US\$2,800) for the next of kin of each deceased and ₹50,000 (approx. US\$700) for the injured.
- The Chief Minister of Delhi, Shri Arvind Kejriwal, visited the site to oversee relief efforts and declared compensation of ₹10 lakh (approx. US\$14,000) for the families of the deceased and ₹1 lakh (approx. US\$1,400) for the injured.
- Shri Manoj Tiwari, then President of the Delhi unit of the Bharatiya Janata Party (BJP), also announced a compensation of ₹5 lakh (approx. US\$7,000) for the next of kin of the deceased and ₹25,000 (approx. US\$350) for those who sustained injuries.

Post-Disaster Investigation: Delhi Anaj Mandi Fire

Following the tragic fire on 8 December 2019, investigations revealed the factory was illegally operating in a residential zone without a valid fire safety license. The building's conversion violated multiple safety and zoning regulations. According to the Delhi Fire Department, the facility lacked official clearance and did not meet mandatory fire safety norms.

The Delhi Police Crime Branch took over the investigation and arrested the building owner and factory manager on the same day under IPC Sections 304 (culpable homicide not amounting to murder) and 285 (negligent conduct with respect to fire or combustible matter).

A state government inquiry was also launched, with a report due within seven days. Preliminary findings and eyewitness accounts indicated an electrical short circuit as the likely cause. The presence of large quantities of

plastic and flammable materials intensified the fire and produced toxic smoke, causing asphyxiation of trapped workers.

Success Story: Exemplary Rescue by Fireman Rajesh Shukla

Among the first responders, Fireman Shri Rajesh Shukla demonstrated exceptional bravery by entering the burning building without backup and successfully rescuing 11 individuals. The victims were safely evacuated and later admitted to nearby hospitals including LNJP, RML, Lady Hardinge, and Hindu Rao Hospitals. Shri Shukla sustained orthopedic injuries during the operation and was hospitalized at LNJP Hospital. His courageous and selfless actions have been widely recognized as a shining example of dedication to public service.

Lessons Learnt and Systemic Observations

The National Human Rights Commission (NHRC) described the incident as a “catastrophe waiting to happen”. In its formal communication, the Commission issued notices to the Chief Secretary of the Delhi Government, Delhi Police Commissioner, and the Commissioner of North Delhi Municipal Corporation (NDMC). The NHRC requested a detailed report within six weeks, outlining:

- Disciplinary actions taken against negligent officials,
- Relief and rehabilitation measures for affected families,
- Systemic gaps and corrective measures undertaken.

The Anaj Mandi incident highlighted the following critical structural and administrative issues:

- Unregulated and unplanned urban growth, leading to overcrowded and unsafe localities.
- Lack of adherence to building codes and fire safety laws, particularly in unauthorized commercial establishments.
- Absence of structured evacuation plans in high-risk, high-density zones.
- Inadequate fire service personnel and delayed emergency access due to narrow lanes and blocked entry routes.
- Public unawareness about fire safety procedures and lack of community-level preparedness.
- Insufficient enforcement of mock drills and capacity-building initiatives in vulnerable urban clusters.
- Delayed legal actions and inadequate penalties, which fail to serve as deterrents to regulatory non-compliance.

Conclusion

This incident emphasizes the urgent need for comprehensive urban risk governance, robust fire safety enforcement, and mainstreaming fire resilience in urban planning. Strengthening inter-agency coordination, enhancing public education, and ensuring the accountability of negligent actors must form the cornerstone of Delhi's fire disaster risk reduction strategy.

Bandipur National Park Forest Fire, 2019

Introduction

Between 23rd and 25th February 2019, a large-scale forest fire engulfed vast tracts of land within the Bandipur National Park, located in the southern Indian state of Karnataka. The incident emerged as one of the most significant wildfire events of the year, highlighting the increasing vulnerability of forest ecosystems to fire-related hazards.



Fig - 23 : Massive Bandipur forest fires burning across GS hills region By NaveenNkadalaveni - Own work, CC BY-SA 4.0,

Source :- <https://commons.wikimedia.org/w/index.php?curid=76855181>

According to the India State of Forest Report 2019, over 30,000 forest fire incidents were recorded nationwide that year. The Bandipur fire rapidly escalated, prompting a national-level response. An assessment by the National Remote Sensing Centre (NRSC), Indian Space Research Organisation (ISRO), on 25 February 2019 estimated that around 10,920 acres of forest were consumed by fire within five days.

While forest fires are common in the dry pre-monsoon season, especially in southern India, the 2019 Bandipur incident marked a concerning increase in frequency and unpredictability. Nationwide, over 2,500 forest fire alerts were issued in the first three months of 2019.

The Bandipur fire caused severe ecological damage, with an estimated 10,000 to 20,000 acres of forest lost, significantly impacting biodiversity, soil quality, and wildlife habitats. Although largely contained by 24 February, some hotspots remained, threatening adjacent areas. The fire spread into Tamil Nadu's Mudumalai Forest Range, burning an additional 40 acres, where prompt intervention by the Tamil Nadu Forest Department helped prevent further damage to sensitive zones.

Causes of the Bandipur Forest Fire (2019)

The 2019 wildfire in Bandipur National Park was notable not only for its scale but also for its unusually early timing. Unlike previous years when fires typically occurred later in summer, this fire started early due to climatic anomalies and the accelerated growth of dry vegetation, including invasive *Lantana camara*. Preliminary investigations by senior forest officials suggested that the fire was not natural but deliberately set. On 22 February 2019, two local shepherds intentionally ignited the fire to deter a tiger that had been sighted nearby for over a month. Their attempt to protect livestock inadvertently triggered a large-scale wildfire that rapidly consumed thousands of acres of forest land. The perpetrators were later apprehended and charged under the Wildlife Protection Act, 1972, for causing fire within a protected ecological zone.

Impact of the Bandipur Forest Fire

The Bandipur wildfire severely impacted over 15,000 acres of forest between 23–25 February 2019, according to ISRO's NRSC satellite data. Some estimates, including from the Nature Conservation Foundation, put the total affected area up to 17,000 acres, including administrative land. While large mammals like elephants and tigers largely escaped harm, smaller animals such as reptiles, snakes, and hares suffered heavy losses. Thousands of mature trees and vast undergrowth were also destroyed.

The fire began in the Kundakere Range and quickly spread to nearby areas like Barakatte, Guddakere, Himavathi Gopalswamy Hills, Jarkal Kere, and Gowri Kalu Hills. Dense dry vegetation and strong winds fueled the blaze, making containment difficult for forest teams and volunteers. Authorities closed the Gundlupet-Ooty National Highway and halted wildlife safaris as a precaution. Though no major fires had occurred in the prior two years, the 2019 event highlighted growing risks to protected forests from climate change and human activity.

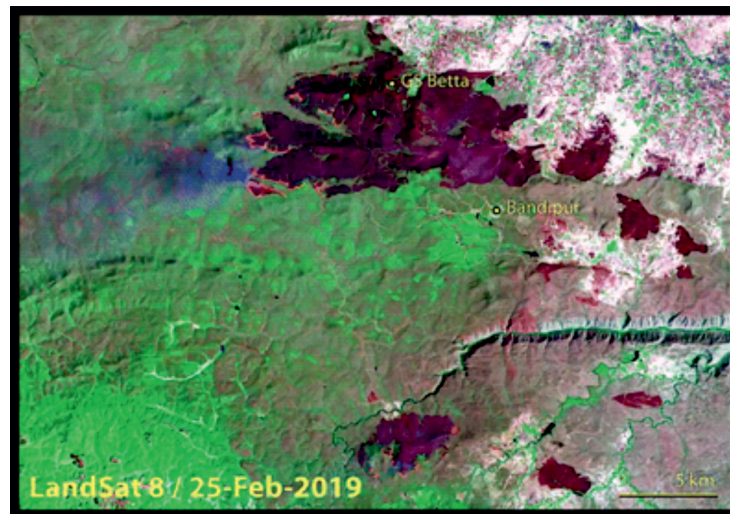


Fig - 24 : LandSat-8 image showing Bandipur forest fire

Source :- By European Space Agency <http://www.esa.int/ESA>, CC BY-SA 3.0 igo, <https://commons.wikimedia.org/w/index.php?curid=77230089>

Response Operations

In response to the escalating Bandipur forest fire, the Karnataka government requested aerial firefighting support from the Indian Air Force. On 25 February 2019, two Mi-17 helicopters were deployed to help contain the blaze, which had been burning for three days, especially in the Gopalswamy Hills Range of Chamarajanagar district.

The aerial operation focused on multiple critical areas:

- Karadikal Hill ranges
- Chammanahalla Top
- Bolagudda region
- Vicinity of Kanive Temple



Fig - 25 : Forest department crew and local people helping to douse the Bandipur forest fire on 24 February 2019. By NaveenNkadalaveni - Own work, CC BY-SA 4.0,

Source :- <https://commons.wikimedia.org/w/index.php?curid=77230848>



Fig - 26 : Burnt Region of Bandipur Forest in February 2019 By NaveenNkadalaveni - Own work, CC BY-SA 4.0,

Source :- <https://commons.wikimedia.org/w/index.php?curid=77231266>

Across the operation, the helicopters completed 10 sorties, collectively releasing an estimated 30,000 liters of water to suppress active fire zones and prevent further spread of the blaze.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Early Detection & Monitoring	Fire detected after significant spread	Limited early detection and surveillance	Early detection is critical to contain forest fires	Strengthen satellite-based monitoring and ground patrols
Cause Identification	Fire triggered by human activity (intentional ignition)	Inadequate monitoring of human activity inside forest areas	Human-induced fires are a major risk	Strengthen forest patrolling and surveillance mechanisms
Preparedness & Planning	Firefighting initiated after spread	Absence of pre-season fire management planning	Fire preparedness must be seasonal and proactive	Prepare annual forest fire management plans
Inter-Agency Coordination	Forest Department led operations with limited external support	Limited integration with district disaster machinery	Forest fires require multi-agency coordination	Integrate forest fire response with district disaster plans
Firefighting Capacity	Manual fire lines and ground staff deployed	Lack of modern firefighting equipment	Ground crews require better tools and training	Equip forest staff with modern fire suppression equipment
Use of Technology	Satellite data used for post-fire assessment	Limited real-time operational use	Technology must support real-time decision-making	Integrate satellite alerts with field response systems
Environmental Impact	Large-scale loss of forest cover and habitat	No rapid ecological impact assessment	Forest fires cause long-term ecological damage	Conduct post-fire ecological assessments and restoration
Wildlife Protection	Wildlife displacement observed	Limited wildlife rescue and protection protocols	Wildlife protection must be integrated	Develop wildlife-specific fire response SOPs

			into fire response	
Community Involvement	Local communities not formally engaged	Lack of community-based fire management	Community participation enhances early detection	Promote community-based forest fire management
Climate Change Linkages	Fire occurred during prolonged dry conditions	Climate risks not fully integrated in planning	Climate change increases forest fire probability	Integrate climate projections into fire management
Recovery & Restoration	Natural regeneration expected	Lack of structured restoration plan	Post-fire restoration is critical	Develop ecological restoration and afforestation plans
Governance & Policy	Forest fire treated as routine seasonal event	Underestimation of disaster risk	Forest fires require disaster-level attention	Include forest fires explicitly in state DM plans

Kerala Landslides, 2019

Introduction

In August 2019, two major landslide incidents occurred within a short span at Kavalappara in Malappuram district and Puthumala in Wayanad district, Kerala. These locations are situated on opposite sides of a segment of the ecologically sensitive Western Ghats, adjacent to the Nilgiri district of Tamil Nadu. These events were part of a series of landslides triggered by extreme weather conditions during the monsoon season.



Fig - 27 : Rescue operation conducted by NDRF

Source :- NDRF

Causes

The landslides were predominantly induced by unprecedented, continuous heavy monsoon rainfall spanning from 4th to 8th August 2019, affecting the northern slopes of the Western Ghats, particularly in the Malappuram and Wayanad districts.

Comprehensive studies conducted by the Geological Survey of India (GSI), the National Centre for Earth Science Studies (NCESS), and the Western Ghats Ecology Panel (commonly referred to as the Gadgil Committee) have identified the affected areas as ecologically fragile and highly vulnerable to environmental disturbances. Notably, several regions such as Wayanad, Banasurasagar, Kuttiyadi, Nilambur (in proximity to Kavalappara), and Meppadi (near Puthumala) were designated as “Ecologically Sensitive Localities.”

The GSI’s investigations concluded that while intense and sustained rainfall served as the immediate trigger, the causative factors for these landslides were multifaceted, encompassing both natural and anthropogenic elements.

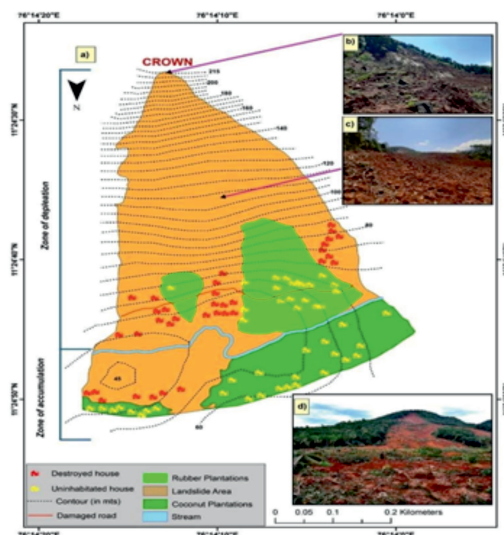


Fig - 28 : a) Detailed map of Kavalappara landslide site prepared on 1:4000 scale b) hard rock exposed in the crown area after the landslide c) body part of the landslide site covered with debris d) overall view of landslide site from crown to toe portion Source: Post landslide Investigation of Shallow Landslide: A case study from the Southern Western Ghats, India - Scientific Figure on ResearchGate.

Key contributing factors include:

- Near-vertical slope excavation and removal of lateral support in landslide-prone areas.
- 'Toe erosion' caused by rivers and streams undermining slope stability.
- Unscientific alteration of original slope configurations for agricultural or construction purposes.
- Inadequate maintenance of natural drainage systems, particularly smaller order streams.
- The presence of weathered rock masses prone to forming unstable wedges and blocks.
- The physical characteristics and thickness of loose slope-forming materials.

Post-2018 flood assessments revealed that about 14.8% of Kerala's area is flood-prone, with some districts facing up to 50% risk. Around 1,500 sq km of the Western Ghats including parts of Wayanad, Kozhikode, Malappuram, Idukki, and Kottayam are highly vulnerable to landslides.

The State Government's Post-Disaster Needs Assessment (PDNA) recorded 209 landslides reported by Forest Divisions and 342 by the Revenue Department after the 2018 monsoon. Many landslides spanned 3–4 km in length and 20–30 m in width, mainly on slopes steeper than 22°, especially between 22° and 28°. Most occurred along forest edges, highlighting forest fragmentation and slope disruption as key causes.

Impacts

According to The Wire (8 August 2019), a massive landslide struck Puthumala after a hillside collapsed. Local reports noted fewer than 20 casualties, thanks to prior minor slope failures the day before that prompted early evacuations. Despite this, the village suffered extensive damage to homes, farmland, and livelihoods.

Seventeen people from seven families died when the landslide engulfed about 10 acres of a private tea estate in Puthumala, Meppadi village panchayat, Wayanad district. The disaster also buried 53 houses, a

mosque, a temple, a shop, and two quarters under mud and debris. The landslide's crown measured roughly 800 feet in height.

Later on the same day, at approximately 7:30 pm, residents of Kavalappara in Pothukal village panchayat, Malappuram district, Kerala, reported hearing a loud, thunderous noise as an entire hillside collapsed amid heavy rainfall. This event buried several dozen homes under the debris. While the volume of the landslide material remains unestimated, the State Minister noted that bodies could be buried up to 50 feet deep in mud.

Meteorological data recorded by the Malappuram subdivision indicated rainfall accumulation of 189.4 mm from August 1 to 7, 2019 approximately 66% above the normal average of 114.3 mm. On August 8, the Nilambur rain gauge, located nearest to Kavalappara, registered the highest rainfall in Kerala for that day.

Way Forward

Dr. Sekhar Lukose Kuriakose, Member of the Kerala State Disaster Management Authority (KSDMA) and Head Scientist at the State Emergency Operations Centre, Government of Kerala, has recommended a comprehensive landslide management strategy comprising the following key measures:

- **Integrated Approach:** Adoption of a multidisciplinary strategy that encompasses land-use planning, sustainable land management practices in agriculture, grazing, and forestry. This approach emphasizes terrain-specific road construction, terracing, and other contour-aligned agricultural and plantation techniques, actively involving local communities in implementation.
- **Policy Reforms:** Implementation of a significant shift in land-use policies, including the designation of specific regions as 'no development zones' or 'construction-restricted zones' to minimize human-induced risks.
- **Hazard Zonation:** Preparation and dissemination of landslide hazard zonation maps at a detailed scale of at least 1:10,000, facilitating effective local-level planning across municipalities and panchayats in hilly terrains.
- **Interdepartmental Coordination:** Local self-government bodies should be mandated to consult relevant technical departments—including the Soil Conservation Department, Mining and Geology Department, and Groundwater Department—prior to undertaking any infrastructure development, to comprehensively assess and mitigate landslide risks.
- **Slope Stabilization:** Promotion and adoption of bio-engineering techniques for slope stabilization to prevent or reduce the incidence of landslides.

These recommendations aim to foster resilience and sustainable development in ecologically sensitive hilly regions, reducing the vulnerability to landslide hazards.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Rainfall & Early Warning	IMD issued heavy to extremely heavy rainfall alerts during monsoon	Alerts not translated into landslide-specific warnings	Rainfall warnings alone are insufficient for landslide risk	Integrate rainfall thresholds with landslide early warning systems
Landslide Susceptibility Mapping	Landslide-prone areas identified in scientific studies	Maps not fully used in planning and evacuation	Scientific data must inform decisions	Mainstream landslide susceptibility maps into district planning
Land Use & Settlements	Settlements located on steep and unstable slopes	Weak enforcement of land-use regulations	Unsafe land use amplifies disaster risk	Enforce hazard zonation and restrict construction in high-risk zones
Environmental Degradation	Quarrying, slope cutting, and deforestation observed	Regulatory oversight inadequate	Ecosystem degradation increases landslide frequency	Strengthen regulation of quarrying and slope modification
Infrastructure Development	Roads and buildings damaged repeatedly	Poor slope stabilisation measures	Infrastructure design must be hazard-sensitive	Adopt hill-area specific engineering guidelines
Evacuation & Preparedness	Evacuations undertaken in some districts	Delayed evacuations in high-risk locations	Timely evacuation saves lives	Establish trigger-based evacuation protocols
Community Awareness	Limited awareness of landslide warning signs	Low risk perception among residents	Community awareness is critical	Conduct targeted community-based DRR programmes
Search & Rescue Operations	SDRF, NDRF and local responders mobilised quickly	Accessibility challenges in hilly terrain	Pre-positioning improves response effectiveness	Pre-position rescue equipment in landslide-prone blocks
Inter-Agency Coordination	Coordination among state agencies improved during response	SOPs for landslides not clearly defined	Clear roles enhance efficiency	Develop landslide-specific SOPs at district level
Damage & Loss Assessment	Damage assessments carried out post-event	Limited linkage with recovery planning	Assessments should inform resilience-building	Integrate recovery planning with D&L assessments

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Recovery & Reconstruction	Reconstruction initiated in affected areas	Risk of rebuilding in unsafe locations	Recovery must reduce future risk	Apply Build Back Better principles
Governance & Policy	Post-disaster reviews initiated	Reactive policy measures	Prevention must precede disasters	Institutionalise periodic landslide risk audits
Climate Change Linkages	Increased intensity of rainfall observed	Climate risks not fully mainstreamed	Climate change amplifies landslide hazards	Integrate climate projections into landslide risk planning

DISASTER YEAR 2020

Hyderabad Flood, 2020

Introduction

Researchers and policymakers have increasingly focused on the vulnerability of cities to urban flooding caused by the impacts of climate change. In recent years, tropical regions, including India, have experienced extreme rainfall events, particularly over megacities (Niyogi et al., 2018;). Notable examples include the Mumbai floods of July 2005 (De et al., 2006), the Chennai floods of December 2015, and the Hyderabad floods of October 2020. The frequency of large-scale extreme events is rising due to anthropogenic climate change and India's expanding urban population. Hyderabad and its neighboring areas experienced an extraordinarily intense rainstorm, with daily rainfall exceeding 30 cm in some areas and high rain rates over a 6-hour period, leading to severe flash floods. Official reports indicate that the heavy rains claimed 40 lives in Hyderabad and affected nearly 40,000 families. The scarcity of land and rising property prices in developing cities have made high-rise buildings a standard feature of modern urban expansion. This shift in urban design increases the roughness parameter in boundary layers, leading to reduced wind speeds within city areas. Additionally, tall structures can generate eddies that affect the surrounding environment.

Overview of the Disaster

Hyderabad (17.37° N, 78.48° E), the capital of Telangana, lies on the Deccan Plateau in north-central India. Spanning 625 square kilometers across three districts Hyderabad, Ranga Reddy, and Medchal-Malkajgiri. The city has grown into India's fourth most populous metropolis, with a population of 6.8 million as of 2011. Over the past decades, Hyderabad's rise as a cyber-hub has driven rapid population growth and urban expansion, leading to an 87% population increase since 2001.



Fig - 29 : Inundation extent in Greater Hyderabad due to rainfall on 14th October 2020

The India Meteorological Department (IMD) weather monitoring station at Begumpet recorded 192 mm of rainfall within 24 hours on October 13, 2020. Prior to this, the highest rainfall ever recorded in Hyderabad by the IMD was 241.5 mm on August 24, 2000. While residential areas account for 44% of Greater Hyderabad, unplanned urbanization and declining water bodies from 2,500 in 1970 to just 190 today have heightened the city's vulnerability to severe weather and flooding. Historically, the 1908 Musi River flood prompted the construction of reservoirs and drainage systems under Sir Visweswarayya. However, inadequate planning and encroachment on water bodies have worsened the city's resilience, necessitating this study to analyze meteorological trends and their impacts.

Impact

Loss of Lives

Over 40 fatalities were reported due to heavy rains

Displacement

More than 37,000 families were affected, with many losing their homes or being displaced.

1. **Infrastructure Damage:** Roads, bridges, and public infrastructure was severely damaged, disrupting transportation and access across the city.
2. **Economic Losses:** The floods caused extensive damage to property, vehicles, and businesses, with estimated losses running into hundreds of crores.
3. **Waterlogging:** Prolonged waterlogging in low-lying areas disrupted daily life and heightened health risks.
4. **Health Hazards:** Stagnant water led to concerns about waterborne diseases, adding to the public health burden.
5. **Power Outages:** Widespread electricity cuts occurred to prevent electrocutions, leaving many areas without power for days.
6. **Decline in Water Bodies:** Encroachments and poor urban planning exacerbated the flooding as the city's natural drainage systems and water bodies were overwhelmed.

Reason

Hyderabad witnessed heavy rainfall, with torrential downpours flooding many parts of the city and disrupting normal life. Historically, the city has experienced floods 11 times since 1572 AD, primarily due to the Musi River. Today, while Hyderabad operates within a system of catchments, its chaotic drainage and poor waste management have exacerbated the impact of such events.

Response

The Municipal Administration and Urban Development Department of Telangana has launched the Strategic Nala Development Programme (SNDP) to tackle flooding issues in Hyderabad through innovative methods rather than traditional approaches.

A feasibility report has been prepared for the entire Hyderabad Urban Agglomeration, covering 1,452 square kilometers. This includes six GHMC zones, the Cantonment Board, Osmania University (OU), and 26 municipalities or municipal corporations within the Outer Ring Road (ORR).

The report outlines the project cost for immediate implementation, focusing on areas lacking an adequate drainage network, frequent flooding points, and affected properties. The program addresses a road network of 24,242 kilometers and incorporates 260 kilometers of existing drainage channels (Nalas).

Challenges

Residents in many parts of Hyderabad woke up to widespread flooding, with daily life disrupted for many. Several low-lying areas were submerged due to heavy rains and overflowing water bodies (Tandon A.,2020).



Fig - 30 : Roads and houses at Hafeez Baba Nagar in Hyderabad submerged in water due to heavy rain

Source :- Photo by special Arrangement

Recommendation

- Need for a disaster management plan
- Hyderabad and even Telangana state do not have a disaster management plans.
- They are not fully utilising the doppler radar, which can give advance and precise warnings.
- “The focus is on disaster response, even while allowing unplanned growth,” said Marri Shashidhar Reddy, former vice chairman of the National Disaster Management Authority (NDMA).

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Rainfall & Early Warning	IMD issued heavy rainfall alerts	Alerts not translated into city-level action	Early warning must trigger preparedness	Link rainfall alerts to urban flood SOPs
Urban Drainage	Severe waterlogging and inundation	Encroached and inadequate drains	Drainage failure magnifies floods	Modernise stormwater drainage systems
Lake & Wetland Management	Overflow of urban lakes	Loss of interconnectivity	Natural buffers reduce flood impact	Restore lakes and feeder channels
Land Use	Flooding of residential colonies	Construction on natural drains	Land-use drives flood risk	Enforce zoning and protect nalas
Emergency Response	SDRF and local agencies responded	Access constraints	Preparedness improves response	Pre-monsoon preparedness audits
Climate Linkages	Extremely intense rainfall	Climate risks not mainstreamed	Urban floods are climate-driven	Integrate climate adaptation in city planning

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Cyclone Amphan, 2020

Introduction

India's east coast is highly vulnerable to tropical cyclones, which occur almost annually during the pre- and post-monsoon seasons. These cyclones typically form over the Bay of Bengal and the Andaman Sea, known as some of the most powerful atmospheric systems globally, playing a crucial role in the region's climate.

The increasing frequency and intensity of cyclones are emerging as a significant consequence of climate change. Cyclones, which are low-pressure systems that form over warm tropical waters, can bring about severe weather conditions including gale-force winds, heavy rainfall, and storm surges. These storms often cover hundreds of miles and are capable of causing extensive flooding, leading to loss of life and property.

In the Bay of Bengal, tropical cyclones are classified based on the intensity of wind speeds at their centers. This region is notably prone to cyclones, with a high number of tropical cyclones occurring worldwide. One of the recent examples is Cyclone Amphan, which affected the Bay of Bengal and caused widespread damage in coastal areas.

Cyclones have a particularly devastating impact on the eastern and western coasts of India, including the coastal regions of West Bengal, Odisha, and Bangladesh. For instance, Cyclone Amphan made landfall on May 20, 2020, near West Bengal. As the cyclone moved inland, its intensity decreased, but the damage along the coast remained severe. The coastal areas of West Bengal, Odisha, and Bangladesh were heavily impacted, facing not only strong winds but also substantial rainfall and the risk of flooding due to storm surges (Kumar, 2021).

Impacts

- **Economical & Social Impacts**

It caused the loss of human lives (72 persons in India and 12 in Bangladesh), high destruction, and damage to public property, which cost ~1 lakh crore INR (13.46 billion USD) and the destruction of around 1 million houses as per the initial reports of damage assessment.

- **Environmental Impacts**

The Amphan cyclone largely affected the agricultural land (78.2%), followed by inland water body (9.3%), forest (7.0%), mangrove (3.8%), built-up (1.4%), and others (0.3%) in eastern India, and Bangladesh after its landfall with different intensities.

The severe impact of the cyclone within the closest proximity to the cyclones' trajectory (50 km² proximity of cyclone), and experienced the catastrophic impact due to high concentration of population and variations in built-up structures.

- **Ecological Impacts**

The cyclone passed through the Sundarbans and affected a large proportion (~3703.77 km²) of the world's largest mangrove system. Although Amphan cyclone-affected ~36.7 km² of mangrove forest with severe to very high levels of impact, the mangroves contributed to reducing the cyclonic wind speed and breaking the waves generated by the storm surges during the landfall due to the strong structure of the plants (Kumar, 2021)



Fig - 31 : Inundation extent in Greater Hyderabad due to rainfall on 14th October 2020 Water Breaches an Island in North 24 Parganas.
Source :- Photo by Sudhansu Maity

• Health Impact

Cyclonic impact leads to a transition in season phenomenon and increases the susceptibility of cough, cold, and fever by weakening the immune system of the human body, developing similar symptoms to COVID-19 infections. Furthermore, there are high chances of compromising the necessary physical distancing measures during the evacuation process to a safe zone, which increases the risk of COVID-19 infections.

Possible causes

A considerable rise in SST ($>32^{\circ}\text{C}$) in the southern Bay of Bengal contributed to the formation of super cyclone Amphan, which moved northwards and affected a large proportion of area in eastern India and Bangladesh after landfalls (20 May 2020) with very high torrential precipitation (140– 250 mm day⁻¹), and extremely high wind speed ($>150\text{ km h}^{-1}$). Cyclones cause widespread destruction to life and property as they move from their formation point towards land, during landfall, and afterward, impacting both coastal and inland areas. They also bring significant changes to oceanic, atmospheric, meteorological, and land conditions, which are now being closely monitored using global multi-satellite systems.

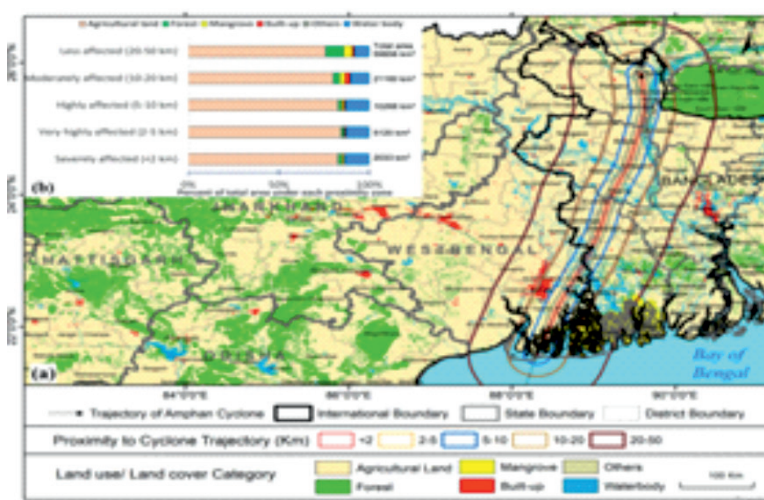


Fig - 32 : Impact of Amphan Cyclone on ESA CCI-based land use/land cover within different proximities to cyclone trajectory, and b) area statistic

Source :- <https://doi.org/10.1007/s41976-021-00048-z>

Consequences of the Passage of Amphan Cyclone in the COVID-19 Pandemic Scenario

The world has been facing the severity of the COVID-19 pandemic since late February 2020, which engulfed major parts of the world. In India, the state government of Odisha and West Bengal released directives for evacuation in affected districts in order to maintain social distance amid COVID-19. Only 33% capacity of the shelters in Odisha while 40% capacity of the shelters (500,000 shelters for 200,000 population) in West Bengal were used for evacuees to maintain the physical distance among them. Apart from permanent shelters, governments have also used temporary shelters in schools, community centers, and temporary medical centers (BBC). Bangladesh also managed to evacuate its citizens by maintaining a physical distance and ensuring 12,000 temporary shelters with a capacity of 5.19 million populations for 2.2 million evacuees with proper supplies of food and emergencies. The timely evacuation of ~4.2 million people living along the coast and in the proximity of cyclone trajectory in India and Bangladesh, and the presence of the world's largest contiguous Sundarbans mangrove, contributed in decreasing the intensity of the Amphan cyclone after landfall. Despite the efficient arrangements to deal with the Amphan cyclone, it caused a death toll of 84 persons and very costly damage to properties due to strong cyclonic winds.

Responses

A super cyclone “Amphan” developed in the Bay of Bengal in mid of May, 2020 caused massive destruction to eastern India especially West Bengal & Odisha. National Disaster Response Force (NDRF) deployed its self-contained rescue & relief teams in the coastal areas of West Bengal & Odisha in view of Cyclonic Storm ‘Amphan’.

20 NDRF teams were deployed in the coastal areas of Odisha like Balasore, Jagatsinghpur, Jaipur, Kendrapara, Puri & Bhadrak. NDRF teams worked day & night to bring the normalcy and proved its worth by removing 515 uprooted trees, 30 Electric Poles and cleared 354.5 Kms of road. Teams also assisted State administration in mass evacuation of more than 2.37 lakh people to safer places.

38 NDRF teams were deployed at coastal areas of West Bengal like Kolkata, Nandigram, Kontai-1 Block & Digha, (East Medinapore), Arambagh (Hooghly), Uluberia & Domzur (Howrah), Sandeshkhali, Hasnabad & Hingalganj (24 Pargana, North), Pathar Pratima, Naamkhana, Gosaba, Kakdweep & Sagar Island (24 Pargana, South) and Rajarhat.

NDRF teams evacuated 7650 livestock to safer places. Teams removed 7392 uprooted trees, 1150 Electric Poles and cleared 3152.5 Kms of road. Teams also assisted State administration in mass evacuation of more than 8.13 lakh people to safer places. (NDRF, 2021)

According to Government of West Bengal, over 3,00,000 people were evacuated by using HAM radio volunteer to around 100 shelters which were school, office building, and an average rate of 3,000 people per shelters in West Bengal, including 2,00,000 from district North 24 Parganas and more than 40,000 from South 24 Parganas district. The National Disaster Response Force reported that over 5,00,000 people evacuated from States of Orissa and West Bengal. In comparison with Cyclone Bulbul which occurred in 2019, an estimated 1.8 lakh people were evacuated to cyclone shelters.



Fig - 33 : HAM Radio Volunteers Urging people to shift to Cyclone Shelters.

Source :- Ambarish Nag Biswas

To maintain social distancing norms, shelters could fill one-third of their capacity. COVID-19 and Social distancing norms reduced 50,000 to 20,000 capacities in shelters in West Bengal. In West Bengal, schools and government institutions/organizations were used for cyclone shelters accompanying more than 2,000 shelters.



Fig - 34 : Residents Affected Cyclone Amphan Shifted to Shelters in West Bengal

Source :- ANI News

Challenges

1. Humanitarian Impact:

Casualties and Displacement: The cyclone resulted in at least 86 fatalities in West Bengal, primarily due to electrocution and collapsed structures. Approximately 2.4 million people were displaced in India, with significant evacuations in West Bengal and Odisha.

2. Economic Losses:

Financial Damage: Amphan caused economic losses estimated at \$14 billion in India, making it the costliest tropical cyclone ever recorded in the North Indian Ocean.

3. Infrastructure and Utilities:

Destruction of Property: The cyclone damaged or destroyed over a million homes in West Bengal alone.

Power and Communication Disruptions: Widespread power outages occurred due to downed power lines and poles, leaving many areas without electricity for extended periods. Communication networks were also severely affected, complicating relief efforts. (BBC)

4. Environmental and Agricultural Damage:

Flooding and Crop Loss: Storm surges and breached embankments led to extensive flooding, particularly in the Sundarbans region. Approximately 88,000 hectares of rice paddies and 200,000 hectares of vegetable and sesame crops were damaged, impacting the livelihoods of many farmers.

5. COVID-19 Complications:

Evacuation Challenges: The pandemic complicated evacuation procedures, as maintaining social distancing in shelters reduced their capacity. This dual crisis strained resources and heightened the vulnerability of affected populations.

Recommendation

One of the important suggestions is the arrangement for permanent disaster shelters in near future for the coastal people. Though few temporary cyclone shelters are available at present these are not sufficient to protect the majority of people.

It is suggested that repair and maintenance of the damaged embankments should be given priority to protect the affected areas.

The important measure is to provide an early warning systems well in advance, before 3-4 days of occurrence of cyclonic storms.

The local governments must take more initiative and play proactive role in disaster management. While distributing relief materials and financial support by the local institutions there were some biases in selecting the victims. People in the coastal areas reported that the financial support provided by the government is too meagre to mitigate the suffering.

The government provides only Rs.20, 000 for the victims whose houses were fully damaged and Rs. 28,000 for part of their wages for 100 days of work under the Mahatma Gandhi National Rural Employment Guarantee Scheme (MNRGS).

It is suggested to get more financial support from the government.

Suggestions include:

(1) Planting trees beside the river to protect from strong wind and

(2) Providing training for capacity building; in the two districts - North and South 24 Parganas.

Further, it is suggested from the affected people that more relief material is needed from the government. This suggestion, therefore, bears significant importance. Many of the affected people were in favor of permanent solutions rather than taken and temporary measures.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons Learned	Recommendations
Forecasting	Accurate cyclone prediction by IMD	Shelter preparedness strained (COVID context)	Early warning saves lives	Strengthen multi-hazard shelter planning
Evacuation	Large-scale evacuation conducted	Pandemic-related constraints	Evacuation planning must be adaptive	Integrate health protocols in shelters
Infrastructure	Massive damage to power and housing	Vulnerable structures	Resilient infrastructure reduces losses	Expand cyclone-resilient housing
Livelihoods	Severe impact on fisheries & agriculture	Delayed livelihood recovery	Livelihood restoration is key	Early livelihood support packages
Recovery	Rapid response initiated	BBB inconsistently applied	Recovery must reduce future risk	Enforce Build Back Better

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Locust Attack, 2020

Introduction

India's Locusts have a history spanning thousands of years. The earliest recorded mention dates back 3,500 years, inscribed on an ox bone in Oracle Script (Jiaguwen), the oldest known Chinese script, with the question: "Will locusts appear in the field; will it not rain?" (Guo F, Chen Y, Lu B, 1991). References to locusts are found in the religious texts of all major faiths. In the Persian Zoroastrian Vendidad, locusts are classified as one of the Xrafstra (evil) creations of Angra Mainya (Destructive Spirit). The Old Testament of the Bible describes locust invasions, with the Book of Nahum (Chapter 3, Verse 15) highlighting their rapid multiplication. The Book of Deuteronomy (Chapter 28, Verse 42) warns of swarms overtaking trees and crops, while Verse 38 states that despite sowing many seeds, the harvest will be minimal due to locusts. In the ancient Sanskrit epic, The Mahabharata, Karna warns the Pandavas that the Kauravas will attack them like a swarm of locusts. The Holy Quran also references locusts, describing them as one of five plagues sent by Allah upon Egypt.

Locusts are migratory insects and a type of pest. They are part of the Acrididae family of grasshoppers. (Uvarov, 1927). Locusts are a type of short-horned grasshopper, but they differ from other grasshoppers due to their ability to undergo physiological and behavioral changes, a phenomenon known as phase polyphenism. Specifically, they can alter their morphology, including color and shape, in response to population density shifts, provided that favorable meteorological conditions are present (Lomer C.J., 2001).

Desert Locust threat and past history

Historically, the Desert Locust has always been a major threat to man's well-being. The Desert Locust is mentioned as curse to mankind in ancient writings viz., locust problems in Southwest Asia have a long history and probably began when crops were first cultivated. Several species of locust occur in the region but the Desert Locust (*Schistocerca gregaria*) is by far the most important. Locusts are mentioned in Sanskrit literature in particular in the epic poem Mahabharata where Karna includes locusts in a "poetically beautiful" speech when he encounters his rival Arjuna on the battlefield. The earliest known Sanskrit text dates to about 400 BCE but the poem is thought to have existed as early as 750 BCE. Equally ancient mention is made in the Iranian Zoroastrian Vendidad where the locust is one of the xrafstra or evil creations of Angra Mainyu. Locusts are mentioned in the Al-Araf chapter 7 of the Koran. The magnitude of the damage and loss caused by the locusts is very gigantic beyond imagination as they have caused the starvation due to its being poly phagous feeder, and on an average small locust swarm eats as much food in one day as about 10 elephants, 25 camels or 2500 people. Locust do cause damage by devouring the leaves, flowers, fruits, seeds, bark and growing points and also by breaking down trees because of their weight when they settle down in masses.

It has been estimated that in India damage to crops caused by locusts was about Rupees 10 crore during 1926–31 plague cycle. During 1940–46 and 1949–55 locust plague cycles, the damage was estimated at Rs. 2.00 crore each and it was Rs. 50.00 lakhs during the last locust plague cycle (1959–62). Although no locust plague cycles were observed after 1962 but large scale upsurges were reported during 1978, 1993, 2019 and 2020.

Locusts and grasshoppers have three successive developmental stages: egg, nymph and adult.

The nymph (or hopper) stage can be further divided into growth stages called instars.

The eggs are almost always laid in the ground; after hatching, the nymphs develop into instars separate by moults and finally become immature adults after development (the last moult). Locusts aren't dangerous as long as they

are individual or small isolated groups of insects, in what is called the “solitary phase”. When their population grows to large numbers – the subsequent crowding induces behavioural changes and transformation from the “solitary” to “gregarious” phase – that they start forming swarms. A single swarm contains up to 40-80 million adults in one square km and these can cover a distance up to 150 km in one day. The above large-scale breeding and swarm formation, however, takes place only when conditions turn very favorable in their natural habitat

Overview of the Disaster

The main locust breeding areas located in the Yemen, Oman, Southern Iran, Horn of Africa, Pakistan’s Baluchistan and Khyber Pakhtunkhwa provinces recorded extensive rains in March-April, 2020. This led to large-scale breeding and unusual rise in the population of the locust, an outcome of bizarrely heavy rains in the region.

Locusts arrived first in Rajasthan during the first fortnight of April, 2020. The Union Agriculture Ministry’s Locust Warning Organization then observed “low-density I & II instar gregarious/ transient hoppers” at Jaisalmer and Suratgarh in Rajasthan and Fazilka in Punjab touching the Indo-Pakistan border. Afterward, there has been influx of swarms from the main springbreeding areas. Swarms have come not only to western Rajasthan, but also moved to the eastern parts of the state and even Madhya Pradesh and Maharashtra. Probably, much of this movement, it seems, was aided by the strong westerly winds from Cyclone Amphan in the Bay of Bengal.

The breeding will happen mainly in Rajasthan. So far, the swarms haven’t caused much harm, since the rabi crop has already been reaped and farmers are yet to start kharif sowings. But, presently locust swarms in Rajasthan, Punjab, Haryana and Madhya Pradesh are threatening major damage to standing cotton crops and vegetables. About 90,000 hectares in 20 districts of Rajasthan have already been impacted by the locust swarms.

These pests have ruined cotton crops spread over 700 hectares of land in Bikaner district of Rajasthan, alone. While the insects have spread across at least four states, Rajasthan has certainly been the most affected one. In fact, the Locusts Warning Organization (LWO) has already carried out spraying of pesticide over 21,675 hectares of land in Rajasthan. Besides, 12 districts of Madhya Pradesh are affected by the swarms. The attack could possibly spread out further, and many states like Uttar Pradesh, Telangana, Chhattisgarh, and Odisha have already started issuing warnings with respect to the strength of the attacks. Scientists of Desert Regional Centre, ZSI, and Jodhpur have surveyed locust infested area in Phalodi region of Jodhpur on 27th and 28th May, 2020 to assess population structure of the swarms.

Impact

Estimating the Economic Damage from Locust Upsurges The findings of this article should mostly be viewed as reduced form (intent-to-treat or ITT) effects of a locust attack on wheat yields.

Rajasthan:

- Approximately 38,308 hectares across 22 of the state’s 33 districts were affected by locust swarms.

Madhya Pradesh:

- Locusts damaged crops in 12 districts, leading to substantial agricultural losses.

Gujarat:

- In December 2019, locusts attacked approximately 17,000 hectares, damaging crops such as rape seed and cumin.

Uttar Pradesh, Punjab, Haryana, and Maharashtra:

- These states were under threat from locust swarms, with reports of crop damage in various regions.

Government Response

- The Indian government, in collaboration with state authorities, undertook extensive locust control operations. The State Governments of Haryana, Madhya Pradesh, Maharashtra, Uttar Pradesh, and Uttarakhand reported crop damage of less than 33% in 6,520 hectares, 4,400 hectares, 806 hectares, 488 hectares, and 267 hectares respectively.

Reasons

The Locust Warning Organization LWO (including all field units), a central government agency responsible for issuing alerts and tracking and regulating locust attacks, conducts periodic surveys to detect the presence of desert locusts and ecological conditions in the scheduled desert region of Rajasthan, Gujarat and Haryana, which are vulnerable to swarms. The evaluation is to determine whether the locust numbers have crossed the economic threshold level (ETL) of 10,000 adults / ha and 5-6 hoppers / bush which may require control. These surveys are conducted regularly throughout the year, but most importantly from May to November when desert locust activity due to congenial breeding conditions is considered at its peak. Which coincides with the Rajasthan and Gujarat monsoon season, the contingency plan says. Gujarat Department of Agriculture officials said the locust threat is a natural occurrence which varies in intensity each year. In the evening and the morning, the locusts remain inactive. Most swarms fly through Rajasthan and Pakistan into Gujarat, relying on the wind to fly over long distances. India is at greatest risk of invasion by swarm just before the monsoon begins. In the Arab Peninsula and the Horn of Africa, the swarms normally originate.

Issues/Challenges/Concerns

1. Agricultural Damage:

- The locust swarms caused extensive damage to crops, threatening food security and the livelihoods of farmers.

2. Food Security Threats:

- The invasion posed a significant threat to the country's food security, especially during the COVID-19 pandemic.

3. Control and Management Difficulties:

- Coordinating effective control measures across multiple states was challenging, requiring significant resources and inter-agency collaboration.

4. Environmental and Ecological Concerns:

- The widespread use of pesticides to control locust populations raised concerns about environmental and ecological impacts.

Preventive Measures

"So far, surveyed 10,000 hectares of the area, of which we found locusts on 7,000 hectares. The insects were destroyed in over 5,000 hectares by spraying pesticides of around 4,900 litres," said Punamchand Parmar, Additional Chief Secretary, and Gujarat State Agriculture Department. The severity of the attacks may have been less than in rabi season 2019-20 if the monsoon is fine, and if there are no control operations. It is points out that the first and most important incursions since 1993 took place last year.

Over 4.30 lakhs of infested areas were handled with tractor-mounted sprayers and other vehicles by local authorities in Rajasthan and Gujarat. Fortunately, even ancient organophosphate insecticides, such as Malathion, are effective against locust (96 percent ultra-low aerial application volume). About a liter of the chemical is required, including the trees where they rest for the night, to treat a hectare of their breeding areas. Pesticides

are abundantly available to control swarms. Control operations also require equipment procurement, field team training, supply pre-positioning in key breeding areas, and contingency plans updating. The activities under the new lock-down system are not legally limited. However, there is also not a lot of time to waste. While insecticides regulated the outbreak of the locust, some state agriculturists lost all their crops and could require re-planting, said the Department of Agriculture of the Government. Approximately 285 villages have been swarmed by locusts, and farmers will receive compensation of 18,500 rupees (\$257) per hectare, state minister of agriculture R.C. Faldu said on Twitter.

Recommendations

Advanced planning and preparedness

- State Governments of Rajasthan, Gujarat, Haryana and Punjab are kept informed about the probable locust threat well in time. They are advised to keep their field functionaries in readiness to cope up with the situation.
- Training programme for State functionaries, BSF and LWO staff.
- Contingency plan to be updated regularly.
- Meeting with other stakeholders are held for planning the survey and control strategy as and when required.
- Permission for holding monthly meetings between the locust officers of India and Pakistan (June–November) to be obtained from Ministry of External Affairs.
- Procurement of pesticides to maintain buffer stock.
- Conducting Cholinesterase test for the staff engaged in locust control work to see any adverse effects of pesticides.
- Locust Unit at Directorate's Headquarter, Faridabad and Locust Warning Organization, Jodhpur monitor the global ecological conditions and locust situation along the Red Sea coast and winter /summer breeding areas of Southwest Asia region (Pakistan, Iran and Afghanistan) which can cause possible threat to India. National Locust situation is also monitored and reviewed periodically.

Preparation of survey schedule

- An annual meeting of officers and officials of Locust Warning Organization (LWO) is held usually in April or May wherein the locust survey schedule and contingency plan is discussed and finalized to combat the impending locust threat by undertaking the survey and surveillance work in Schedule Desert Area of Rajasthan and Gujarat.
- The surveys are conducted in the entire border/ coastal areas along with Indo-Pak border in the States of Gujarat and Rajasthan.

Updating of contingency plan

- The contingency plan is updated to ascertain the requirement and availability of the resources required for locust control e.g. emergency fund, pesticides, communication equipment, vehicles, aircraft, trained manpower, survey and control equipment, protective clothing, first-aid kits, etc.
- Review of available resources with LWO is done in every six months so that nothing could remain unnoticed for effective control campaign in case of locust threat. The contingency plan is updated based on the resources and locust threat perception obtained through field surveys and FAO forewarning.
- If any shortcoming is observed during updating of the contingency plan, higher authorities are made aware

of the matter and immediate steps are taken to resolve the same. The updating is done by a team consisting of Joint Director (E) and Plant Protection Adviser at Directorate H.Q. Faridabad, Officer In charge, LWO Jodhpur, In-charges of Locust Circle Offices

Testing of the contingency plan

Mock drill exercise in full scale is organized in the beginning and ending of the summer breeding seasons i.e. in the months of May/June, November & December every year to test the practically ground implementation of the prepared contingency plan and to plug the gaps if any. The said mock drill will be organized by LWO, Jodhpur and at all 10 LCO's every year.

Actions taken before locust high alert or swarm incursion

- All the plant protection equipment's are checked for their working conditions. If required, repairing of the same is done to make them fully operational.
- Similarly, all the vehicles are tested for their working conditions and needful is done.
- Mock drill to be organized before commencement of the locust season to ensure the capability of all infrastructures required at the time of Desert locust control operation.
- Refresher trainings to the locust staff and staff of State Department are organized.
- An emergency meeting among the State Chief Secretaries and Senior Officers of DAC&FW/ Directorate of PPQ&S is organized to finalize immediate deployment of resources in the threat prone areas.
- Telephonic discussions with the State agriculture authorities like Secretary Agriculture, Director of Agriculture and District Collectors of threat prone districts for arranging immediate assistance and cooperation to fight with locust emergency.
- Intensify the Desert Locust surveys in threat prone areas to detect any locust swarm invasion.
- Regular liaison with FAO through e-mail or telephone.
- In-charges of LWO, Jodhpur and other field functionaries are instructed to take stock of the situation by deploying the teams in threat prone areas for conducting survey and control operation.
- Control rooms to be established at district level.
- Meetings with District Collectors to be organized to discuss the prevailing locust situation and steps taken to control the locust infestation.
- Indian Air force to be sensitized on requirement of Helicopters for undertaking the aerial spraying against locust swarms.
- Meteorological Department is approached to provide daily wind pattern during locust emergency.
- Public awareness is created through electronic and print media.
- District and Village level committees are formed to monitor progress of the locust control programme

Role of additional stakeholders

1. Ministry of Home Affairs

To advise BSF authorities to extend help and to provide facilities in border surveys, arranging Indo-Pak border meetings and extend help in reporting of locust population/swarm through BSF staff.

2. Ministry of Defence

To provide wireless sets (High Frequency and Very High Frequency), trained manpower during locust emergency.

3. Ministry of Earth Sciences

India Meteorological Department to provide relevant meteorological data.

4. Ministry of Civil Aviation

To grant permission from Air Traffic Control (ATC) for flying aircraft during locust control operation.

5. Ministry of External Affairs.

Permission to participate in Indo-Pak locust officer's border meeting along with BSF.

6. Ministry of Information and Broadcasting

To collaborate with Locust Warning Organization concerning media and news coverage of the locust emergency. The designated and appropriate spokespersons from LWO will do the needful.

7. Departments of State Government

The State Departments are sensitizing to report following:

- To report locust information to LWO.
- To provide assistance in form of vehicles and manpower during locust control campaign.
- To conduct survey, surveillance and control of locust in cropped areas.
- To create awareness among public and farmers about locust.
- To provide facilities to LWO staff during locust survey and control campaign.

8. State Department of Health

- To administer baseline ChE tests of pesticide spray operators at the beginning of the campaign.
- To follow during the campaign, the health of these operators and administer final ChE test.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons Learned	Recommendations
Early Warning	FAO & national alerts issued	Limited local preparedness	Biological hazards need preparedness	Strengthen locust surveillance
Agriculture Response	Spraying operations conducted	Delayed response in some regions	Speed is critical	Pre-position control equipment
Inter-State Coordination	Central coordination activated	Information lag	Regional coordination essential	Strengthen inter-state SOPs
Livelihood Impact	Crop losses widespread	Compensation delays	Timely compensation reduces distress	Streamline DBT compensation
Climate Linkages	Unusual breeding conditions	Climate drivers underestimated	Climate variability increases biological hazards	Integrate climate-agriculture risk planning

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Cyclone Burevi, 2020

Introduction

Cyclone, hurricane and typhoon are regionally specific names for a low-pressure weather system over tropical or subtropical waters characterized by thunderstorms, torrential rain and high wind speeds. Cyclone intensity is predicted to increase as a consequence of climate change.

Cyclone are further classified according to wind speed and location.

- Tropical depression-sustained wind speed of 63km/h or less
- Tropical storm – maximum sustained wind speed ranging from 63 – 117 km/h (WHO, 2018)

Bay of Bengal

The Bay of Bengal is the Indian Ocean's second-largest subdivision after the Arabian Sea. It has a surface area of 2,600,000 Square km and stretches over a maximum length of 2,090 km and a maximum width of 1,610 km. This bay has an average depth of 2,600 m and a maximum depth of 4,694 m. The Bay of Bengal is the world's largest water body referred to as a bay.



Fig - 35 : The critical Bay of Bengal region.

Source :- <https://www.worldatlas.com/r/w960-q80/upload/92/e3/99/bayofbengal.png>

The Bay of Bengal forms the northeastern part of the Indian Ocean and is shared by countries of South and Southeast Asia. It is separated from the Andaman Sea to the east by the Andaman and Nicobar Islands, while its southern boundary extends between Sangaman Kanda in Sri Lanka and Sumatra in Indonesia. The bay is bordered by India to the west and northwest, Bangladesh to the north, Myanmar to the east, Sri Lanka to the southwest, and Indonesia to the southeast, with India's Andaman and Nicobar Islands lying along its eastern margin. The region is ecologically significant, hosting the world's largest mangrove forest i.e., Sundarbans as well as the world's longest beach.

Cyclone Burevi

Cyclonic storm 'Burevi' originated as a low-pressure area over the South Andaman Sea on 28th November 2020. It gradually intensified into a depression on 30th November and a cyclonic storm by 1st December over the Southwest Bay of Bengal. Moving west-northwest, it crossed Sri Lanka near Trincomalee on 2nd December with wind speeds of 80-90 kmph. It then entered the Gulf of Mannar, weakened into a depression by 4th December, and further into a low-pressure area by 5th December. The system caused heavy rainfall over Andaman & Nicobar Islands and widespread heavy to extremely heavy rainfall in Tamil Nadu from 2nd to 4th December.

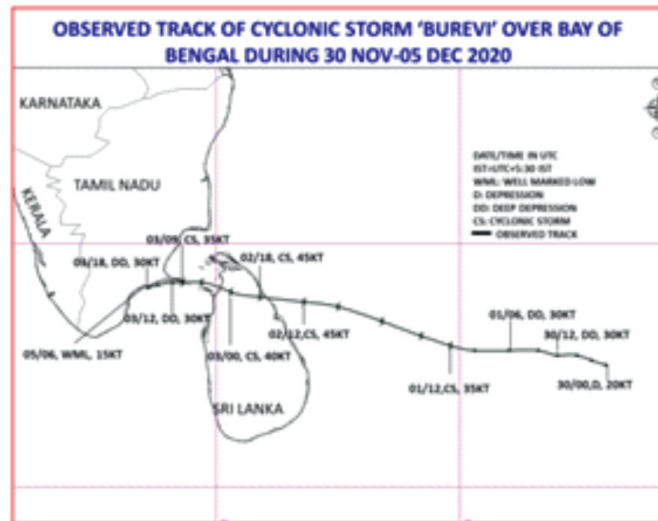


Fig - 36 : Observed Track of Cyclonic Storm "BUREVI" Over of Bengal during 30 Nov. - 05 Dec. 2020

Source :- Observed track of cyclone burevi storm

Overview of the Disaster

Cyclone Burevi, originating from the Bay of Bengal and the Indian Ocean, made consecutive landfalls—first in Sri Lanka on 2nd December 2020 and was forecasted to strike Tamil Nadu on 4th December, though the second landfall did not occur. Following Cyclone Nivar's devastation on 26th November, Burevi became the fifth cyclonic storm to impact peninsular India in 2020 and the third from the Bay of Bengal. Frequent cyclones, including Amphan, Nisarga, and Gati, were fueled by high sea surface temperatures (29–30°C), which sustain storm formations during peak seasons (October–December, April–June). Burevi, however, remained less severe due to its prolonged movement and dual landfall process.

The year 2020 was marked by the COVID-19 pandemic and multiple severe cyclones in coastal peninsular India. Cyclone Burevi, forming over the Bay of Bengal on 28th November, hit Sri Lanka on 2nd December and was expected to strike India on 4th December. Originating as a low-pressure area, it intensified into a deep depression on 1st December and a cyclonic storm later that day. Burevi was the 4th named storm in the 2020 North Indian Ocean list and the 3rd in the Bay of Bengal that year. The cyclone brought heavy rainfall and strong winds to Tamil Nadu, Puducherry, Kerala, and Maharashtra, with IMD warning of storm surges up to 3.2 feet in low-lying areas. (das, 2020)

Impact in India:

- **Casualties and Property Damage:** In Tamil Nadu, the cyclone led to the loss of seven lives (Scroll Staff, 2020). The accompanying heavy rainfall and strong winds caused damage to huts, houses, and buildings.

- **Rainfall and Flooding:** Several districts in southern Tamil Nadu and southern Kerala experienced heavy to very heavy rainfall, with some areas receiving extremely heavy rain (over 20 cm). This led to flooding in various regions, including the Chidambaram Nataraja Temple in Cuddalore district, which was inundated after receiving 340 mm of precipitation.
- **Agricultural Impact:** The heavy rain caused by Cyclone Burevi damaged crops in approximately 289,000 hectares across 18 districts in Tamil Nadu, affecting local agriculture.

Causes/Reason

Cyclone Burevi originated from a low-pressure area over the South Andaman Sea and adjacent regions of the southeast Bay of Bengal and Equatorial Indian Ocean on 28th November 2020. This system intensified into a depression on 30th November over the southeast Bay of Bengal and further developed into a cyclonic storm by the evening of 1st December 2020. The cyclone crossed the Sri Lankan coast near Trincomalee on 2nd December and subsequently entered the Gulf of Mannar, approaching the south Tamil Nadu coast near Pamban on 3rd December. It then weakened into a deep depression and remained stationary over the Gulf of Mannar, close to the Ramanathapuram district coast, for approximately 36 hours until 5th December 2020.

The development and intensification of Cyclone Burevi were influenced by several meteorological factors:

- **Sea Surface Temperature (SST):** Elevated SSTs in the Bay of Bengal provided the necessary heat and moisture, fueling the cyclone's formation and intensification.
- **Atmospheric Conditions:** Favorable atmospheric conditions, including low vertical wind shear and adequate moisture in the mid-troposphere, supported the cyclone's development.

Response

Meteorological Sector:

- **India Meteorological Department (IMD):** The IMD provided timely forecasts and warnings regarding Cyclone Burevi's trajectory and intensity. Press releases issued as early as 27th November 2020 highlighted the potential for extremely heavy rainfall over Tamil Nadu and Puducherry on 2nd and 3rd December. These advisories included warnings about heavy rainfall, strong winds, sea conditions, and guidance for fishermen.

Disaster Management Sector

- **National Disaster Management Authority (NDMA):** The NDMA disseminated information and alerts to the public through various channels. During Cyclone Burevi, over 7.63 million SMS alerts were sent in Tamil to residents of Tamil Nadu, providing critical information about the cyclone and safety measures.
- **National Disaster Response Force (NDRF):** The NDRF deployed multiple teams to the affected regions in Tamil Nadu and Kerala to assist with evacuations, search and rescue operations, and relief distribution. Their proactive deployment ensured timely assistance to communities in cyclone-affected areas.

State Governments

- **Tamil Nadu and Kerala:** State authorities established numerous relief centers and implemented precautionary measures to safeguard residents. In Thoothukudi district, for instance, 63 relief centers were set up, and 30,000 sandbags were prepared to prevent breaches in irrigation tanks. Additionally, public holidays were

declared in certain districts, and fishing activities were suspended to ensure public safety.

Recommendation

1. National Cyclone Risk Mitigation Project (NCRMP): Launched in 2011, NCRMP aims to minimize the vulnerability of coastal communities to cyclones and other hydro-meteorological hazards. The project focuses on:

- **Early Warning Dissemination Systems (EWDS):** Establishing robust communication networks to ensure timely dissemination of warnings to vulnerable populations.
- **Cyclone Risk Mitigation Infrastructure:** Constructing cyclone shelters, improving road connectivity for evacuations, and strengthening embankments to protect against storm surges.
- **Technical Assistance and Capacity Building:** Enhancing the capabilities of communities and institutions in disaster risk management.

These efforts are detailed in the NCRMP report by the National Disaster Management Authority (NDMA).

2. Four-Stage Cyclone Warning System: The India Meteorological Department (IMD) employs a structured warning protocol:

- **Pre-Cyclone Watch:** Issued 72 hours in advance, providing early alerts about potential cyclonic developments.
- **Cyclone Alert:** Issued 48 hours before the expected impact, offering updates on the cyclone's position and likely trajectory.
- **Cyclone Warning:** Issued 24 hours prior, detailing expected landfall areas and associated weather conditions.
- **Post-Landfall Outlook:** Issued 12 hours before landfall, focusing on anticipated impacts in inland areas.

This system ensures that authorities and the public receive timely and accurate information.

3. Community-Based Disaster Risk Reduction (CBDRR): Recognizing the importance of local involvement, NDMA has developed guidelines to empower communities:

- **Participatory Risk Assessment:** Engaging community members in identifying vulnerabilities and planning mitigation measures.
- **Capacity Building:** Training local populations in disaster preparedness, response, and recovery to foster resilience.

These guidelines aim to integrate community efforts into the broader disaster management framework.

4. Prime Minister's Ten-Point Agenda on Disaster Risk Reduction: This agenda emphasizes:

- **Risk Coverage:** Expanding insurance and social safety nets to protect vulnerable populations.
- **Early Warning Systems:** Investing in technology and infrastructure to improve forecasting and dissemination capabilities.
- **Resilient Infrastructure:** Promoting the construction of structures that can withstand cyclonic forces.

The agenda outlines a holistic approach to disaster risk management.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons Learned	Recommendations
Forecasting	Timely IMD alerts	Low risk perception	Communication matters	Improve risk communication
Preparedness	Preventive measures taken	Limited shelter readiness	Preparedness reduces casualties	Upgrade cyclone shelters
Rainfall Impact	Flooding and landslides	Drainage issues	Cyclones cause compound hazards	Integrate flood preparedness
Infrastructure	Power and road damage	Vulnerable assets	Infrastructure resilience matters	Climate-resilient infrastructure
Recovery	Quick restoration	Limited BBB	Recovery should reduce risk	Apply BBB principles

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Kerala Floods, 2020

Introduction

In 2020, India experienced significant flooding events across various regions, leading to substantial loss of life, displacement, and damage to infrastructure. The National Disaster Management Authority (NDMA) and respective State Disaster Management Authorities (SDMAs) played crucial roles in managing these disasters.

Overview of the Disaster

The monsoon season of 2020 brought above-average rainfall to several parts of India, resulting in widespread flooding. States such as Assam, Bihar, Kerala, and Karnataka were notably affected. The Brahmaputra River in Assam overflowed, inundating numerous districts, while Bihar faced severe floods due to the swelling of the Gandak and Kosi rivers. In Kerala and Karnataka, heavy rains led to landslides and flash floods, exacerbating the situation. Between June 1 and August 18, 2020, all 14 districts of Kerala were affected by heavy rainfall and subsequent flooding. On August 7, 2020, four districts—Idukki, Wayanad, Malappuram, and Kottayam—experienced particularly severe flooding. A major landslide occurred in Idukki district on August 6, resulting in significant casualties.

Impact

- **Casualties and Displacement:** The floods and landslides led to around 60 deaths and affected nearly 2–3 lakh people, with thousands displaced and shifted to relief camps, particularly in districts like Idukki, Malappuram, and Wayanad.
- **Property and Infrastructure Damage:** Several houses were damaged or destroyed due to landslides and flooding. Roads, bridges, and public utilities suffered significant damage, disrupting connectivity in hilly and flood-prone regions. Agricultural lands, especially plantations and paddy fields, were also heavily impacted.
- **Economic Losses:** The total economic loss was estimated at around ₹5,000 crore, affecting agriculture, housing, and infrastructure sectors.

Possible Causes/Reasons

- **Heavy Monsoon Rainfall:** Intense and continuous southwest monsoon rainfall caused rivers to overflow and triggered landslides.
- **Hilly Terrain and Landslides:** Fragile slopes and steep terrain in districts like Idukki and Wayanad increased vulnerability.
- **Land Use Changes:** Deforestation, quarrying, and unplanned construction reduced slope stability and natural water absorption.

Response

- **Evacuation and Relief Operations:** The Kerala government, along with NDRF and SDRF, carried out evacuation and rescue operations and established relief camps.
- **Community Participation:** Local communities, fishermen, and volunteers played a crucial role in rescue and

relief efforts.

- Restoration Measures: Efforts were made to quickly restore roads, electricity, water supply, and essential services.

Issues/Challenges/Concerns

- Landslide Early Warning: Limited early warning systems for landslides increased risks in vulnerable areas.
- Infrastructure Vulnerability: Damage to roads and houses highlighted the need for resilient construction practices.
- Community Preparedness: Lack of awareness and preparedness at the local level affected timely response and evacuation.

Recommendations/Preventive Measures

To mitigate future flood risks, the following measures are recommended:

- Strengthening Early Warning Systems: Enhance the accuracy and dissemination of flood forecasts to ensure timely alerts to vulnerable populations.
- Infrastructure Development: Invest in flood-resistant infrastructure and improve drainage systems in urban areas.
- Afforestation and Sustainable Land Use: Promote afforestation and implement sustainable land-use practices to enhance natural water absorption.
- Community Training and Awareness: Conduct regular training programs and awareness campaigns to prepare communities for flood response and evacuation procedures.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons Learned	Recommendations
Rainfall Warning	Heavy rainfall alerts issued	Warning-fatigue	Risk communication must be nuanced	Improve impact-based forecasting
Dam Operations	Reservoir releases made	Coordination gaps	Integrated dam management needed	Strengthen reservoir SOPs
Landslides	Multiple landslides triggered	Weak slope monitoring	Floods & landslides are linked	Integrate multi-hazard planning
Evacuation	Evacuations undertaken	COVID-related challenges	Evacuation planning must be inclusive	Pandemic-resilient evacuation plans
Recovery	Reconstruction ongoing	Rebuilding in risk zones	Recovery must reduce exposure	Relocate from high-risk areas

References

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- 2 State Disaster Management Authority (SDMA) Publications
- 3 Central Water Commission (CWC) Flood Bulletins
- 4 India Meteorological Department (IMD) Weather Forecasts
- 5 Ministry of Home Affairs, Government of India: Situation Report as on 18th August 2020
- 6 Asian Disaster Reduction Center (ADRC) Reports

Assam Gas and Oil Leak, 2020

Introduction

In May 2020, Assam experienced a significant environmental disaster due to a blowout at Oil India Limited's (OIL) Baghjan Oilfield in Tinsukia district. This incident led to extensive ecological damage, displacement of local communities, and raised concerns about industrial safety and regulatory compliance.

Overview of the Disaster

On May 27, 2020, a blowout occurred at Well No. 5 in the Baghjan Oilfield, resulting in an uncontrolled release of natural gas. The situation escalated when the well caught fire on June 9, 2020, leading to extensive damage to the surrounding environment and necessitating the evacuation of nearby residents. The well was successfully "killed" on November 15, 2020, after 173 days, using a technique called snubbing. Subsequently, Well No. 5 was abandoned on December 3, 2020.

Impact

The blowout and subsequent fire had severe repercussions:

- **Environmental Damage:** The incident caused significant harm to the nearby Dibru-Saikhowa National Park and the Maguri-Motapung Wetland, both ecologically sensitive areas. Reports indicated contamination of water bodies and adverse effects on local wildlife habitats.
- **Human Displacement:** Approximately 11,000 residents from nearby villages were evacuated and housed in relief camps due to the hazardous conditions. The disaster also resulted in the tragic loss of three lives, including two firefighters and an OIL engineer.

Possible Causes/Reasons

Investigations into the incident revealed several contributing factors:

- **Regulatory Non-compliance:** The National Green Tribunal (NGT) found that OIL had commenced drilling operations without obtaining the necessary environmental clearances, violating multiple environmental laws.
- **Safety Protocol Lapses:** Reports indicated failures in adhering to standard operating procedures and safety protocols during drilling operations, which may have precipitated the blowout.

Response

In the aftermath of the disaster, several measures were undertaken:

- **Immediate Actions:** OIL, in collaboration with local authorities and international experts, initiated efforts to control the blowout and extinguish the fire. Despite challenges, the well was successfully sealed in November 2020.
- **Regulatory Interventions:** The NGT mandated OIL to deposit ₹25 crore as an initial compensation for the environmental and public health damages. An eight-member committee, led by former Gauhati High Court judge Justice B.P. Katakey, was established to investigate the incident comprehensively.

Issues/Challenges/Concerns

The incident highlighted several critical issues:

- **Environmental Degradation:** The proximity of drilling activities to ecologically sensitive zones like national parks and wetlands raised concerns about the long-term ecological impact.
- **Regulatory Oversight:** The lack of requisite environmental clearances and adherence to safety protocols underscored deficiencies in regulatory enforcement and corporate accountability.
- **Community Impact:** The displacement of local communities and the loss of livelihoods due to environmental contamination emphasized the need for robust disaster management and compensation mechanisms.

Recommendations/Preventive Measures

To prevent similar incidents in the future, the following measures are recommended:

- **Strict Regulatory Compliance:** Ensure that all industrial operations, especially those near sensitive ecosystems, obtain necessary environmental clearances and adhere to stringent safety standards.
- **Enhanced Monitoring and Enforcement:** Strengthen the capacity of environmental oversight bodies to monitor compliance and enforce regulations effectively.
- **Community Engagement:** Involve local communities in decision-making processes related to industrial activities and ensure transparent communication regarding potential risks.
- **Emergency Preparedness:** Develop and regularly update emergency response plans, conduct safety drills, and ensure readiness to address potential industrial disasters promptly.

Lessons Learned

The 2020 Assam gas and oil leak at the Baghjan oilfield highlighted crucial lessons in industrial safety and environmental governance. It underscored the importance of strict compliance with safety protocols and environmental clearances, as lapses in regulatory adherence and internal procedures contributed to the blowout and prolonged leak that severely impacted local communities and sensitive ecosystems like the Dibru-Saikhowa National Park and Maguri-Motapung Wetland. The disaster emphasized the need for robust emergency preparedness, timely response coordination, and transparent risk assessment to protect lives, livelihoods, and biodiversity in areas near oil and gas operations. It also demonstrated the long-term ecological and socio-economic costs of inadequate oversight in energy extraction activities.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons Learned	Recommendations
Industrial Safety	Blowout lasted several months	Poor safety oversight	Prevention is critical	Strict safety audits
Environmental Impact	Severe wetland damage	Weak environmental safeguards	Environmental risks are disaster risks	Strengthen environmental compliance
Emergency Response	Evacuations conducted	Delayed containment	Rapid containment saves lives	Strengthen oilfield emergency capacity
Livelihood Impact	Fishing and farming affected	Delayed compensation	Livelihood restoration vital	Long-term livelihood support
Governance	Judicial oversight initiated	Reactive governance	Proactive regulation needed	Independent safety regulation

Liquor Poison, 2020

Introduction

In late July 2020, Punjab, India, faced a tragic incident of mass alcohol poisoning, resulting in numerous fatalities across the districts of Amritsar, Gurdaspur, and Tarn Taran. The consumption of illegally produced toxic liquor led to this devastating event, prompting a comprehensive response from state authorities.

Overview of the Disaster

The incident began on July 29, 2020, with the first reported deaths in Amritsar's Muchhal and Tangra villages. Over the following days, the death toll increased significantly, affecting multiple districts. The victims had consumed spurious liquor, which was later found to contain toxic substances. The rapid spread of fatalities highlighted the extensive distribution network of the illicit alcohol.

Impact

The immediate impact was the tragic loss of 105 lives (Al Jazeera, 2020, August 3), with families across several districts mourning the sudden deaths of their loved ones. Beyond the fatalities, the incident exposed significant gaps in the regulation and monitoring of alcohol production and distribution within the state. The proliferation of illegal liquor manufacturing units posed severe health risks to the public and undermined legal enterprises.

Possible Causes/Reasons

Preliminary investigations suggested that the spurious liquor contained methanol, a highly toxic substance when ingested. The production and distribution of this illicit alcohol were traced back to unauthorized manufacturing units operating covertly within the state. The ease of access to raw materials and the clandestine nature of these operations allowed such hazardous products to circulate widely before detection.

Response

In response to the crisis, Punjab Chief Minister Amarinder Singh ordered a magisterial inquiry to investigate the circumstances leading to the mass poisoning. The Divisional Commissioner of Jalandhar was tasked with conducting the inquiry, coordinating with senior police officials to uncover the source of the spurious liquor and identify those responsible. Law enforcement agencies conducted extensive raids across the affected districts, resulting in multiple arrests and the seizure of large quantities of illicit alcohol. Additionally, several excise and police officials were suspended for negligence, reflecting the administration's commitment to accountability.

Issues/Challenges/Concerns

The incident underscored several critical issues:

- **Regulatory Oversight:** The existence of illegal manufacturing units pointed to lapses in regulatory enforcement and surveillance.
- **Public Health Risks:** The consumption of unregulated alcohol posed severe health hazards, including the risk of mass poisoning.
- **Corruption and Negligence:** The suspension of officials suggested potential corruption and negligence within regulatory and law enforcement bodies, hindering effective control over illicit activities.

Recommendations/Preventive Measures

To prevent similar tragedies in the future, the following measures are recommended:

- **Strengthened Enforcement:** Enhance the monitoring and regulation of alcohol production and distribution channels to detect and dismantle illegal operations promptly.
- **Community Awareness:** Implement public awareness campaigns to educate communities about the dangers of consuming unregulated alcohol and encourage reporting of suspicious activities.
- **Accountability Mechanisms:** Establish stringent accountability protocols for officials in excise and law enforcement departments to deter negligence and corruption.
- **Policy Reforms:** Review and reform existing policies related to alcohol licensing and distribution to close loopholes that enable the proliferation of illicit liquor.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons Learned	Recommendations
Public Health	High fatalities	Weak surveillance	Poisoning is a public health disaster	Strengthen surveillance
Regulation	Illicit liquor circulation	Enforcement gaps	Regulation failure causes disasters	Strengthen enforcement
Medical Response	Delayed treatment	Limited toxicology readiness	Early treatment saves lives	Upgrade district hospitals
Awareness	Low public awareness	Risk communication gaps	Awareness prevents poisoning	Community awareness campaigns
Governance	Post-event crackdowns	Reactive approach	Prevention over punishment	Continuous monitoring

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Visakhapatnam Gas Leak, 2020

Introduction

Visakhapatnam, often called “The Jewel of the East Coast,” is a coastal and port city in Andhra Pradesh, nestled between the Eastern Ghats and the Bay of Bengal. It serves as the administrative headquarters of Visakhapatnam District and is home to the Eastern Naval Command of the Indian Navy.

The city, spanning 550 km², is Andhra Pradesh’s largest and a major industrial hub. Historically, it was named after the god Vishakha and was once part of the Kalinga Kingdom under Ashoka’s rule. Over time, it was governed by the Andhra Kings, Pallavas, Cholas, Gangas, and later the Vijayanagar Empire.

Renowned for its tourism, Visakhapatnam offers everything from serene lakes and beaches to scenic hills, caves, and valleys, showcasing India’s rich culture and heritage.

Background

A gas leak is the unintentional release of gas from pipelines, appliances, or cylinders due to damage or faulty connections. It poses serious risks, including fire, explosions, and health hazards like dizziness or asphyxiation. Common signs include a strong rotten egg smell, hissing sounds, or dead plants near pipelines. If a leak is suspected, avoid sparks, ventilate the area, turn off the gas supply, and evacuate before calling emergency services.

The Visakhapatnam gas leak, also known as the LG Polymers Gas Leak, occurred on May 7, 2020, at a chemical plant in RR Venkatapuram, Visakhapatnam, Andhra Pradesh. The leak involved styrene gas, a hazardous chemical, leading to severe health and environmental consequences.

In the early hours of May 7, toxic styrene gas leaked from the LG Polymers plant, spreading over a 3 km radius. The leak exposed thousands of residents to harmful fumes, causing panic and an immediate evacuation of nearby areas.

Impact

- Thirteen individuals lost their lives, and over 1,000 residents experienced symptoms such as breathing difficulties, nausea, and eye irritation.
- The exposure led to acute symptoms such as respiratory distress, mucous membrane irritation, and neurological manifestations. Long-term health consequences remain a concern, necessitating ongoing medical surveillance.
- The styrene vapor adversely affected local flora and fauna, contaminating water bodies and soil in the vicinity. The ecological impact includes potential bioaccumulation and disruption of local ecosystems.
- The disaster prompted the evacuation of approximately 200-250 families, disrupted local businesses, and imposed substantial economic burdens due to healthcare costs and environmental remediation efforts.

Possible Causes

Preliminary investigations suggest that a malfunction in the cooling system of the styrene storage tanks led to an increase in temperature, causing the liquid styrene to vaporize and leak. Additionally, reports indicate that LG

Polymers had been operating without the necessary environmental clearances for its expansions between 2006 and 2018, potentially contributing to safety oversights

- The National Green Tribunal (NGT) identified operational negligence as a primary cause, citing lapses in following standard safety norms, including the absence of onsite and offsite emergency plans and failure to conduct regular mock drills.
- There was insufficient maintenance of the styrene storage units, leading to the malfunction of the refrigeration system, which is critical for maintaining the stability of styrene monomer.
- The storage facilities were not designed for long-term storage of styrene, and the material was kept beyond the recommended duration without adequate safety measures.

Response Measures

The response to the incident involved multiple actions:

- Authorities evacuated residents within a 5-kilometer radius to minimize exposure.
- Over 300 individuals were hospitalized, and medical teams were mobilized to provide necessary treatment to those affected.
- Experts from the National Disaster Management Authority (NDMA) and other institutions were deployed to assess the situation and recommend remedial measures.
- The Andhra Pradesh government announced an ex-gratia payment of ₹1 crore to the families of the deceased and allocated funds for the injured.

Issues

Several challenges were identified in the aftermath:

- The incident highlighted significant lapses in safety protocols and emergency preparedness at the plant.
- The plant had been operating without the necessary environmental clearances, raising concerns about regulatory oversight and enforcement.
- The disaster eroded public trust in industrial safety and the effectiveness of regulatory bodies in ensuring compliance.

Recommendations

To prevent similar incidents in the future, the following measures were recommended:

- Conduct comprehensive safety audits of industrial units, particularly those handling hazardous materials, to ensure compliance with safety norms.
- Develop and regularly update onsite and offsite emergency plans, including conducting mock drills every six months.
- Ensure that all industrial units obtain and renew necessary environmental clearances and adhere strictly to the stipulated guidelines.
- Implement community awareness programs to educate residents about potential industrial hazards and emergency response procedures.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons Learned	Recommendations
Chemical Safety	Styrene gas leaked from LG Polymers	Poor storage safety	Industrial negligence causes disasters	Enforce chemical safety norms
Early Detection	Leak detected after exposure	No early warning system	Sensors save lives	Install continuous gas monitoring
Land Use	Plant near residential areas	Poor land-use planning	Buffer zones critical	Enforce industrial zoning
Emergency Response	Rapid evacuation & medical response	Initial confusion	Preparedness reduces casualties	On-site emergency plans
Governance	Regulatory review post-incident	Weak oversight	Proactive regulation needed	Strengthen chemical safety authority

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Covid -19 Pandemic, 2020-2022

The COVID-19 pandemic (2020–2021) represents one of the most significant health emergencies in recent history, profoundly impacting public health systems, governance structures and socio-economic conditions across India. The first wave of covid -19 in India in 2020 led to nationwide containment measures, including lockdown, significantly affecting mobility, livelihoods, and economic activity. The subsequent waves placed unprecedented stress on the healthcare infrastructure with long-lasting impact beyond 2022. India adopted a comprehensive strategy for testing, tracking, treatment and vaccination with strengthening health systems through dedicated emergency response.

India launched the world's largest COVID-19 vaccination drive on 16 January 2021, achieving rapid scale-up through digital platforms and coordinated institutional mechanisms. This period underscored the importance of integrated disaster management, public health preparedness, and technology-enabled response systems.

A comprehensive account of policy measures, operational responses and key observations documented in the Ministry of Home Affairs documentation, which serves as a key reference for understanding COVID-19 management. In this regard, the comprehensive document on MHA's Role in Covid-19 Management is available at https://nidm.gov.in/PDF/pubs/MHA_COVID-19.pdf.

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DISASTER YEAR 2021

Cyclone Tauktae, May 2021

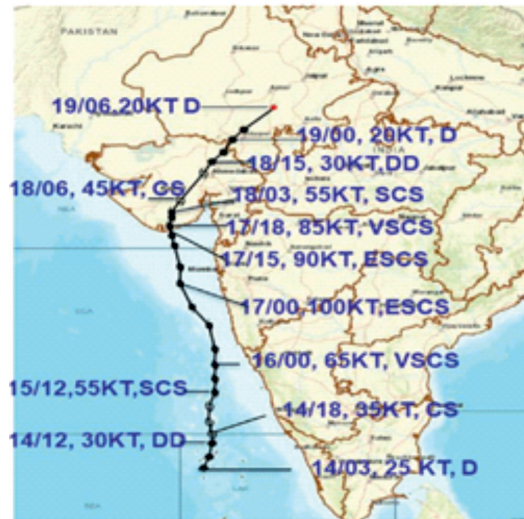


Fig - 37 : Observed track of Extremely Severe Cyclonic Storm Tauktae (14- 19 May 2021)

Source :- India Meteorological Department

A powerful tropical cyclone named Tauktae (which means Gecko, a highly vocal lizard in Burmese) struck the Indian state of Gujarat on May 17, 2021. The Visible Infrared Imaging Radiometer Suite (VIIRS) on the NASA-NOAA Suomi NPP satellite acquired this natural-color image of the storm a few hours before it made landfall between Porbandar and Mahuva. Cyclone Tauktae, an extremely severe cyclonic storm, struck the western coast of India in May 2021, causing significant damage across multiple states. This report provides a comprehensive overview of the disaster, its impact, underlying causes, response efforts, challenges faced, and recommendations for future preparedness.

Even before making landfall, Tauktae caused a trail of destruction in Kerala, Karnataka, Goa, and Maharashtra as it brushed India's northwest coast over the weekend. According to news reports, the storm contributed to the deaths of at least 12 people, destroyed hundreds of homes, and caused power outages and traffic jams. More than 150,000 people evacuated Gujarat in anticipation of Tauktae's arrival.

Introduction

Cyclone Tauktae originated in the Arabian Sea and intensified rapidly, making landfall on the Gujarat coast on May 17, 2021. It was one of the most powerful cyclones to affect the region in recent years, impacting states along the western coastline, including Kerala, Karnataka, Goa, Maharashtra, and Gujarat. The cyclone's trajectory and intensity posed significant challenges to disaster management authorities and affected populations.

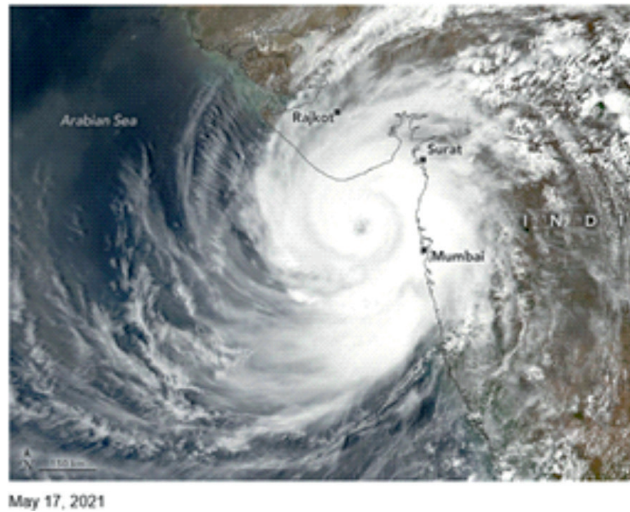


Fig - 38 : Major extreme weather events occurred during 2021

Sources :- <https://earthobservatory.nasa.gov/images/148325/cyclone-tauktae-strikes-india>

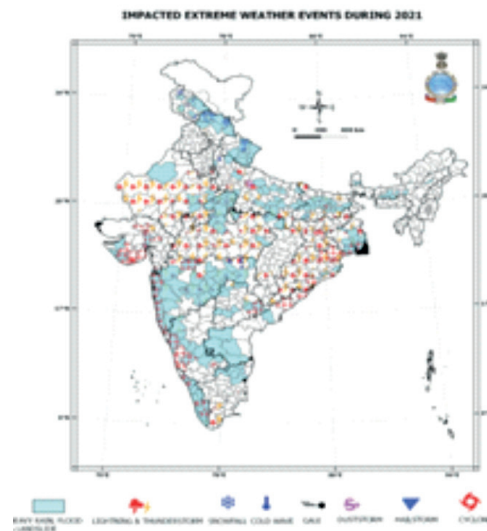


Fig - 39 : Major extreme weather events occurred during 2021

Sources :- https://www.imdpune.gov.in/cmpg/Product/Annual_Climate_Summary/annual_summary_2021.pdf

Overview of the Disaster

The India Meteorological Department (IMD) first identified a low-pressure area over the southeast Arabian Sea on May 13, 2021. This system intensified into Cyclone Tauktae, moving northward parallel to the western coast of India. The cyclone reached its peak intensity with maximum sustained wind speeds of 180-190 km/h, gusting to 210 km/h, over the east-central Arabian Sea on May 17, 2021. Tauktae made landfall in Gujarat's Saurashtra region, bringing heavy rainfall, strong winds, and storm surges.

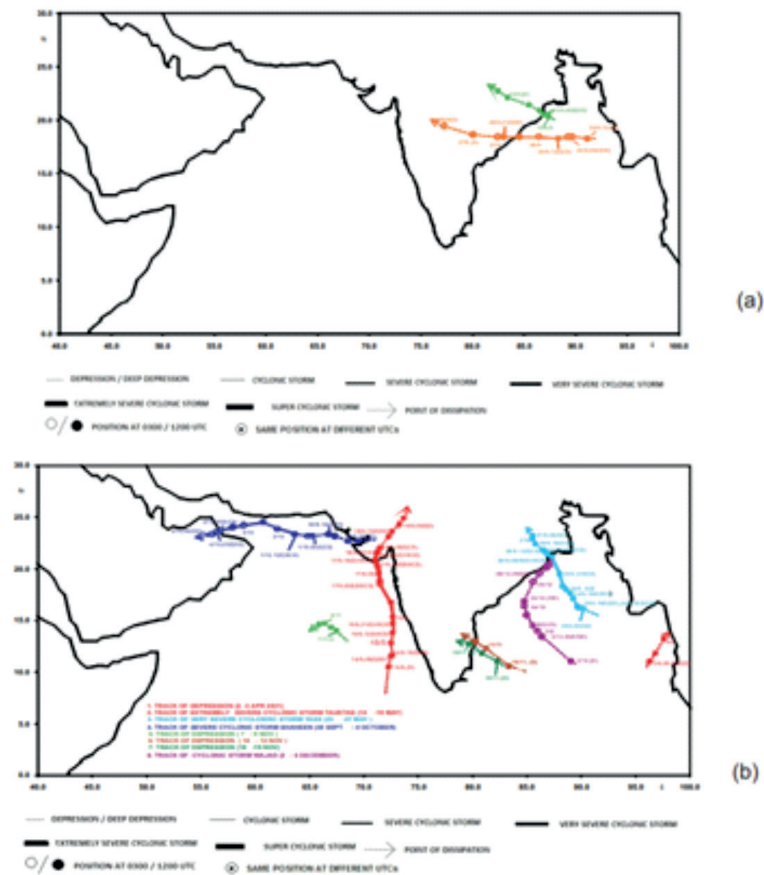


Fig - 40 : (a) and (b) respectively show track of these systems formed during the monsoon season and other seasons in the year 2021. Frequency of depressions and cyclonic storms formed over the north Indian Ocean and Land (1951-2021) during the monsoon and post monsoon is shown in Fig.14 (a) and 14(b) respectively Tracks of depressions and cyclonic storms formed during 2021 (a) Monsoon season (b) Other seasons https://www.imdpune.gov.in/cmpg/Product/Annual_Climate_Summary/annual_summary_2021.pdf

Consequences of Cyclone Tauktae

The states of Kerala, Karnataka, Goa, Maharashtra and Gujarat experienced severe consequences due to Tauktae cyclone.

Kerala

Cyclone Tauktae, while not making direct landfall in Kerala, had significant impacts on the state. According to the Kerala State Disaster Management Authority, the cyclone resulted in 11 fatalities, with causes including falling trees, electric posts, lightning, drowning, and electric shocks. Additionally, 22 individuals sustained serious injuries requiring hospitalization. The cyclone also caused damage to over 100 houses, leading to the displacement of several hundred people who were evacuated to relief camps. The National Disaster Response Force (NDRF) was deployed to assist in rescue and relief operations. These events underscore the importance of effective disaster preparedness and response mechanisms in mitigating the impacts of such natural calamities.

Rainfall received in different districts As the cyclone moved parallel to the west coast, it caused heavy to extremely heavy rainfall activity, strong winds, and tidal waves to affect Kerala on 14th -15th May 2021 (as recorded on 15th -16th May 2021).

Karnataka

Cyclone Tauktae significantly impacted Karnataka, particularly its coastal regions. According to the Karnataka State Disaster Management Authority, the cyclone affected over 70 villages across seven districts, resulting in the deaths of four individuals. The cyclone caused damage to at least 112 houses and uprooted numerous trees, leading to disruptions in transportation and power supply. The state effectively managed the adverse impacts through meticulous planning and preparedness measures.

Goa

Cyclone Tauktae significantly impacted Goa, resulting in the loss of two lives and causing substantial damage to infrastructure. The cyclone led to widespread power outages, with approximately 70% of the state experiencing disruptions due to fallen trees and electric poles. Over 1,000 trees were uprooted, and around 200 houses suffered damage. The state received 1,443 emergency calls during the cyclone, highlighting the extensive distress caused. The Government of Goa estimated the total damages at ₹146 crore (approximately USD 20 million).

Gujarat

Cyclone Tauktae, an extremely severe cyclonic storm, made landfall on the Saurashtra coast of Gujarat between Diu and Una on May 17, 2021, bringing with it devastating consequences. The cyclone resulted in the loss of 67 lives in the state and caused significant damage to infrastructure and agriculture. Approximately 55,384 homes were damaged, and over 2,400 villages experienced power supply failures due to the uprooting of more than 1,000 electric poles. The agricultural sector suffered substantial losses, with an estimated 30 lakh tonnes of salt being lost. In response to the extensive damage, the Central Government released an additional financial assistance of ₹1,000 crore to Gujarat from the National Disaster Response Fund for relief and rehabilitation efforts.

Impact

Cyclone Tauktae caused widespread damage across several states:

- **Kerala:** Heavy rainfall led to flash floods and waterlogging, damaging over a hundred homes and causing significant agricultural losses estimated at ₹828 crore (US\$113 million).
- **Karnataka:** The coastal regions experienced high winds and heavy rain, affecting over 70 villages in seven districts. At least 112 homes were damaged, and 139 electricity poles were uprooted.
- **Goa:** The state faced power outages, with approximately 70% of the area losing electricity. Around 200 homes were damaged, and numerous roads were blocked by fallen trees.
- **Maharashtra:** Mumbai recorded its wettest day in May, with gusty winds reaching up to 114 km/h, leading to waterlogging and disruption of services.



Fig - 41 : Videos of huge tidal waves lashing the Gateway of Mumbai area went viral on social media platforms where people also shared images of the trail of destruction left by the cyclonic storm at some of the prominent monuments here

Source :- PTI Photo



Fig - 42 : Mumbai: Mangled remains of vehicles after a tree collapsed on them, uprooted by strong winds induced by Cyclone 'Tauktae' in Mumbai.

Source :- PTI Photo



Fig - 43 : Along with the rain, Mumbai could witness gusty winds with speed reaching up to 80-90 kmph, the Brihanmumbai Municipal Corporation said quoting the India Meteorological Department (IMD) forecast issued at 7 am.

Source :- Reuters Photo

- **Gujarat:** The cyclone's landfall caused extensive damage, with preliminary estimates pegging losses at ₹10,000 crore. Infrastructure, agriculture, and housing sectors were severely affected. Overall, Tauktae resulted in significant human casualties, displacement, and economic losses across the affected states.
-



Fig - 44 : NDRF personnel clear a fallen tree from a road as they carry out restoration works following the landfall process of Cyclone Tauktae, in Gujarat.

Source :- PTI Photo



Fig - 45 : Gir Somnath: Fishermen check their damaged boat at a shore of the Arabian Sea, after Cyclone 'Tauktae' made landfall, near Una Town in Gir Somnath district.

Source :- PTI Photo



Fig - 46 : Cyclone Tauktae crossed the Gujarat coast as an "extremely severe cyclonic storm" and gradually weakened.

Source :- <https://www.financialexpress.com/photos/business-gallery/2252554/cyclone-tauktae-becomes-cyclonic-storm-to-intensify-into-a-very-severe-cyclonic-storm/3/>

Possible Causes/Reasons

Several factors contributed to the formation and intensification of Cyclone Tauktae:

- **Sea Surface Temperatures (SSTs):** Elevated SSTs in the Arabian Sea provided the necessary energy for the cyclone's rapid intensification.
- **Atmospheric Conditions:** Favorable atmospheric conditions, including low vertical wind shear and high moisture content, facilitated the cyclone's development.
- **Climate Change:** While individual weather events cannot be solely attributed to climate change, the increasing frequency of intense cyclones in the Arabian Sea may be linked to broader climatic shifts.

Preparedness Measures:

- **Early Warning Systems:** The India Meteorological Department (IMD) issued timely advisories, providing forecasts and warnings to coastal states, enabling them to prepare effectively.
- **Evacuation Plans:** State Disaster Management Authorities (SDMAs) activated evacuation plans, relocating vulnerable populations from coastal and low-lying areas to safer locations. **Deployment of NDRF Teams:** The National Disaster Response Force (NDRF) mobilized teams across affected states, including Kerala, Maharashtra, Gujarat, Karnataka, and Goa, to assist in rescue and relief operations.
- **Public Awareness Campaigns:** Authorities conducted awareness programs, disseminating information on safety measures and cyclone preparedness to the public.

Response Actions:

- **Rescue Operations:** NDRF teams, along with local authorities, conducted search and rescue operations, evacuating thousands from affected areas.
- **Provision of Relief Materials:** Relief camps were established, and essential supplies such as food, water, medical aid, and temporary shelters were provided to displaced individuals. **Restoration of Services:** Efforts were made to restore electricity, clear debris from roads, and repair infrastructure to facilitate normalcy.
- **Coordination among Agencies:** Central and state agencies coordinated their efforts, ensuring a unified response to the disaster.

These measures highlight the proactive approach adopted by Indian authorities in managing Cyclone Tauktae, emphasizing the importance of preparedness, timely response, and inter-agency coordination in disaster management.

Response

The response to Cyclone Tauktae involved coordinated efforts from various agencies:

- **Evacuations:** Over 200,000 people were evacuated from vulnerable areas in Gujarat alone.
- **Disaster Response Forces:** The National Disaster Response Force (NDRF) deployed multiple teams across affected states for rescue and relief operations.
- **Medical Preparedness:** Given the concurrent COVID-19 pandemic, special arrangements were made to ensure the safety of patients, including the relocation of COVID-19 patients to safer facilities.
- **Restoration Efforts:** Post-cyclone, efforts were undertaken to restore power, clear roads, and provide essential supplies to affected populations.
- **NDRF Teams Deployed:** Dt. 17/05/2021

Here is a table summarizing the deployment of NDRF teams during Cyclone Tauktae based on the provided data:

Table 3 - Deployment of NDRF teams during Cyclone Tauktae

State/UT	NDRF Teams Deployed	Additional Teams on Standby
Gujarat	44	22
Maharashtra	10	-
Kerala	9	-
Tamil Nadu	8	-
Karnataka	3	-
Daman & Diu	3	-
Dadra & Nagar Haveli	1	-
Goa	1	-
Total Deployed Teams	69	-
Total Reserve Teams	-	22

This table effectively presents the distribution of NDRF teams deployed across various states and UTs during Cyclone Tauktae, along with the reserve teams kept on standby for any contingencies.

Issues/Challenges/Concerns

Several challenges were encountered during the disaster:

- **COVID-19 Pandemic:** The ongoing pandemic complicated evacuation and relief efforts, necessitating additional precautions to prevent virus transmission.
- **Infrastructure Damage:** Widespread damage to infrastructure hindered timely delivery of aid and restoration of services.
- **Communication Disruptions:** Power outages and network disruptions affected communication, complicating coordination among response teams.

Recommendations/Prevention Measures

To enhance preparedness for future cyclones, the following measures are recommended:

- **Strengthening Early Warning Systems:** Enhance the accuracy and dissemination of early warnings to ensure timely evacuations.
- **Infrastructure Resilience:** Invest in building resilient infrastructure capable of withstanding extreme weather events.
- **Community Awareness:** Conduct regular awareness programs to educate communities on cyclone preparedness and response.
- **Integrated Disaster Management:** Develop comprehensive disaster management plans that account for concurrent challenges, such as pandemics.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Early Warning & Forecasting	IMD provided accurate and timely cyclone forecasts	Risk perception low in western coast	Early warning saves lives when acted upon	Strengthen impact-based risk communication
Evacuation & Preparedness	Preventive evacuations conducted across coastal states	Shelter availability constrained due to COVID-19	Evacuation planning must be multi-hazard	Upgrade cyclone shelters with health safeguards
Marine & Fisheries Safety	Advance warnings issued to fishermen	Some vessels remained at sea	Last-mile dissemination critical	Strengthen community-based marine warning systems
Infrastructure Resilience	Widespread damage to power and telecom	Vulnerable coastal infrastructure	Infrastructure resilience reduces losses	Climate-resilient power and telecom networks
Inter-State Coordination	Coordinated response across Gujarat, Maharashtra, Goa, Kerala	Logistics challenges	Regional coordination enhances efficiency	Strengthen regional disaster response hubs
Recovery & Reconstruction	Rapid restoration of services	Limited application of BBB	Recovery must reduce future risk	Enforce Build Back Better principles
Climate Change Linkages	Rapid intensification observed	Climate influence underestimated	Cyclones are becoming more intense	Integrate climate risk into coastal planning

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Maharashtra Floods, 2021

Maharashtra is largely vulnerable to floods. It may be noted that there are many man-made reasons for the occurrence of floods. Analyzing the floods in Maharashtra, one observes that most floods in Maharashtra are flash floods due to nallah-overflows and poor drainage systems. Very few floods, like the one in Konkan in 1983, are due to heavy rains in the region. In July 2021, Maharashtra faced one of its worst flood disasters due to unprecedented rainfall, affecting multiple districts such as Raigad, Ratnagiri, Sindhudurg, Satara, Sangli, and Kolhapur. The disaster resulted in significant loss of life, large-scale displacement, and extensive damage to infrastructure, agriculture, and livelihoods. Poor urban planning, deforestation, and unregulated construction in flood-prone areas further aggravated the impact. The 2021 floods highlighted the urgent need for improved disaster management, climate resilience strategies, and sustainable urban planning to mitigate future flood risks in the state.

The Maharashtra flood: An Overview

Maharashtra witnessed one of its worst flood disasters in July 2021, triggered by unprecedented heavy rainfall across multiple regions. The extreme weather led to severe flooding and landslides, particularly affecting the western districts, including Raigad, Ratnagiri, Sindhudurg, Satara, Sangli, and Kolhapur. The intensity of rainfall, combined with overflowing rivers and poor urban planning, resulted in widespread destruction, making it a significant calamity in the state's disaster history.

The floodwaters claimed the lives of approximately 251 people, while over 375,000 individuals were displaced from their homes. Sangli and Kolhapur were the worst-affected districts, with mass evacuations of 206,000 and 150,000 people, respectively. The floods also devastated agriculture and livestock, leading to the loss of 28,700 poultry animals and around 300 other livestock, significantly impacting the livelihoods of local farmers. An estimated 200,000 hectares of crops were damaged, affecting food supply chains and rural economies.

Infrastructure damage was widespread, with around 800 bridges submerged, cutting off access to several villages. The drinking water supply of 700 villages was severely disrupted, leaving thousands without access to clean water. Furthermore, 14,700 electric transformers sustained damage, impacting nearly 950,000 electricity consumers. However, by the end of July 2021, power supply was partially restored for 650,000 affected consumers after extensive repairs.

The financial impact of the disaster was estimated at ₹4,000 crore (approximately US\$539 million), covering losses in public infrastructure, agriculture, and private property. In response to the crisis, the National Disaster Response Force (NDRF) deployed 34 teams across the state for rescue and relief operations. Additionally, on 27 July 2021, the Central Government announced ₹700 crore in financial assistance for rehabilitation and rebuilding efforts in Maharashtra.

The 2021 Maharashtra floods underscored the growing risks of extreme weather events due to climate change and unplanned urban expansion. This disaster highlighted the urgent need for improved flood management strategies, enhanced early warning systems, and sustainable urban development to mitigate future calamities.

Impact:

- **Loss of Life:** As of July 27, 2021, the death toll had risen to 192, with many individuals reported missing.
- **Displacement:** Over 100,000 people were displaced, seeking refuge in relief camps set up by the government and various organizations.
- **Infrastructure Damage:** Approximately 9,700 houses and 45 buildings suffered damage in Maharashtra's

Mahad during the July floods.

- Agricultural Losses: The floods destroyed crops over thousands of hectares, severely impacting the livelihoods of farmers.

Table 4 : Key Statistics of Maharashtra Flood 2021

Category	Impact
Total Deaths	192 (as of July 27, 2021)
Displaced People	100,000+ (across affected districts)
Houses Damaged	9,700 houses in Mahad and other affected areas
Damaged Infrastructure	45 buildings, several bridges, and roads
Crops Destroyed	Thousands of hectares of agricultural land affected
Rescue Operations	Over 1,000 people rescued by NDRF and SDRF

These efforts highlight the scale of the response and ongoing needs for enhanced disaster management planning in flood-prone areas.



Fig - 47 : Flood water rose 13 ft in Mahadev, 80,000 sans power as towers fell, Mumbai

Source :- <https://timesofindia.indiatimes.com/city/mumbai/mumbai-flood-water-rose-13ft-in-mahad-80k-sans-power-as-towers-fell/articleshow/84694070.cms>, https://www.nrsc.gov.in/sites/default/files/pdf/DMSP/FloodAffectedAreaAtlas_Digital.pdf

Consequences of the Maharashtra floods

The 2021 Maharashtra floods had significant consequences across various sectors. According to the Maharashtra State Disaster Management Plan 2023, the floods in 2021, along with those in 2019, 2020, and 2022, resulted in a cumulative loss of 1,246 lives. The National Disaster Management Authority's Annual Report 2021-22 highlights that 12% of India's land is prone to floods and river erosion, underscoring the vulnerability of regions like Maharashtra to such natural disasters. For a comprehensive understanding of the flood-affected areas in Maharashtra, the "Flood Affected Area Atlas of India" provides detailed insights that one district in Maharashtra has a flood-affected area between 50,000 to 100,000 hectares, two districts between 25,000 to 50,000 hectares, and four districts between 12,500 to 25,000 hectares. These reports from the State and National Disaster Management Authorities offer a detailed overview of the impact and consequences of the 2021 Maharashtra floods.

Possible Causes

The 2021 Maharashtra floods were primarily caused by heavy rainfall, leading to river overflows and subsequent flooding in various districts. The Maharashtra State Disaster Management Plan 2023 highlights that recent floods, including those in 2021, have been exacerbated by flash floods resulting from nallah (drain) overflows and inadequate drainage systems. In specific districts, such as Palghar, floods were caused by the overflowing of rivers due to excessive rainfall in their catchment areas and the excessive discharge of water from dams. Additionally, the National Disaster Management Authority's guidelines on urban flooding indicate that urbanization leads to developed catchments, which, in the event of heavy or high-intensity rainfall, can result in significant urban flooding. In summary, the 2021 Maharashtra floods were caused by a combination of heavy rainfall, river overflows, inadequate drainage systems, and the challenges posed by urbanization.

Role of Government of India

In response to the 2021 Maharashtra floods, the Government of India, through the National Disaster Management Authority (NDMA), played a pivotal role in coordinating relief and rehabilitation efforts. The NDMA's Annual Report 2021-22 outlines the comprehensive measures undertaken to manage such disasters, emphasizing the importance of preparedness, mitigation, and effective response strategies.

The NDMA, in collaboration with the State Disaster Management Authorities (SDMAs), facilitated the implementation of disaster management plans, ensuring that various government agencies were equipped to handle the crisis. This included the deployment of the National Disaster Response Force (NDRF) to assist in search and rescue operations, provision of essential supplies, and support in evacuation processes. Furthermore, the NDMA's guidelines on urban flooding highlight the challenges posed by rapid urbanization, which can exacerbate flood risks due to inadequate drainage systems. These guidelines advocate for the development of robust urban planning and infrastructure to mitigate the impact of such disasters.

The Government of India's proactive approach, through the NDMA, underscores its commitment to strengthening disaster resilience and ensuring a coordinated response to natural calamities like the 2021 Maharashtra floods.

Role of the State Government

Immediate Relief Measures:

1. **Rescue Operations:** The SDMA coordinated with the National Disaster Response Force (NDRF) to conduct rescue operations, evacuating affected individuals from inundated areas.
2. **Provision of Essentials:** The government facilitated the distribution of food, clean drinking water, and medical supplies to the affected populations.

3. **Deployment of National Disaster Response Force (NDRF):** The government facilitated the rapid deployment of NDRF teams stationed at Talegaon, Pune, to the affected areas. These teams played a crucial role in search and rescue operations, providing immediate relief to those impacted by the floods.
4. **Implementation of the State Disaster Management Plan (SDMP):** The Maharashtra State Disaster Management Plan 2023 outlines the state's approach to disaster preparedness and response. During the 2021 floods, the government activated protocols from the SDMP, coordinating efforts across various departments to ensure a unified and efficient response.
5. **Coordination with District Authorities:** The state government worked closely with District Disaster Management Authorities (DDMAs) to assess local needs, distribute resources, and manage evacuation and relief operations. This collaboration ensured that assistance was tailored to the specific requirements of each affected district.
6. **Public Communication and Warnings:** Utilizing various communication channels, the government issued timely warnings and updates to the public regarding rising water levels, evacuation orders, and safety precautions. This proactive communication strategy was vital in minimizing casualties and ensuring public safety.
7. **Post-Disaster Rehabilitation and Infrastructure Repair:** Following the immediate response, the state government initiated efforts to repair damaged infrastructure, restore essential services, and provide financial assistance to affected individuals and businesses to facilitate recovery and rehabilitation. These actions underscore the Maharashtra State Government's commitment to disaster management and its proactive approach to mitigating the impacts of natural calamities.

Roles of Social Media:

1. **Information Dissemination:** Social media platforms were instrumental in providing timely updates on weather conditions, flood warnings, and evacuation procedures, ensuring that residents received critical information promptly.
2. **Coordination of Rescue Operations:** Through social media, authorities and rescue teams were able to coordinate efforts, share locations of stranded individuals, and request assistance, enhancing the efficiency of rescue missions.
3. **Resource Mobilization:** Social media facilitated crowdfunding and the collection of donations, enabling the provision of essential supplies such as food, water, and medical aid to affected communities.
4. **Public Awareness and Preparedness:** The Maharashtra State Disaster Management Plan 2023 underscores the role of media, including social media, in generating public awareness and sensitizing communities about disaster preparedness and response. The National Disaster Management Authority (NDMA) also recognizes the transformative impact of social media in disaster management, noting its role in building local capacity and leveraging community initiatives. In summary, social media served as a vital tool during the 2021 Maharashtra floods, enhancing communication, coordination, and resource mobilization, thereby significantly contributing to the overall disaster management efforts.

Lessons Learned

1. **Enhanced Flood Forecasting and Early Warning Systems:** The floods revealed the necessity for more accurate and timely flood forecasting to enable early evacuations and preparedness. Improving these systems can significantly reduce loss of life and property.
2. **Strengthening Infrastructure Resilience:** The damage to infrastructure during the floods highlighted the

importance of constructing and maintaining flood-resistant structures, especially in flood-prone areas.

3. **Community Awareness and Preparedness:** There is a need to increase community engagement in disaster preparedness programs to ensure effective response during emergencies. The Maharashtra State Disaster Management Plan 2023 emphasizes the role of public awareness in disaster risk reduction.
4. **Improved Drainage Systems:** The floods underscored the importance of developing and maintaining efficient drainage systems to prevent urban flooding, particularly in cities like Mumbai. The National Disaster Management Authority's guidelines on urban flooding stress the need for effective drainage infrastructure.
5. **Effective Coordination among Agencies:** The floods highlighted the need for better coordination among various agencies involved in disaster response to ensure timely and efficient relief operations. Implementing these lessons is crucial for enhancing disaster resilience and minimizing the impact of future floods in Maharashtra.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Rainfall Forecasting	IMD issued extreme rainfall alerts	Localised cloudburst risks not communicated	Impact-based forecasts needed	Strengthen district-level rainfall warning systems
Dam & Reservoir Management	Emergency water releases undertaken	Poor coordination and communication	Integrated reservoir management essential	Establish basin-level reservoir SOPs
Landslides	Multiple landslides triggered in Konkan	Weak slope monitoring	Floods and landslides are linked hazards	Expand landslide early warning systems
Rural Vulnerability	Villages severely affected	Limited evacuation preparedness	Rural preparedness saves lives	Community-based disaster preparedness
Search & Rescue	NDRF/SDRF deployed rapidly	Access constraints in hilly terrain	Pre-positioning improves response	Pre-monsoon deployment of SAR teams
Infrastructure	Roads and bridges washed away	Poor siting and design	Infrastructure siting drives risk	Hazard-informed infrastructure planning
Recovery	Compensation announced	Delays in disbursement	Timely recovery reduces distress	Streamline DBT-based compensation
Climate Change Linkages	Increased frequency of extreme rainfall	Climate risks not mainstreamed	Flood risk is climate-amplified	Integrate climate projections in planning

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- 3 https://ndma.gov.in/sites/default/files/PDF/FHA/Flood_Affected_Area_Atlas_of_India.pdf
- 4 [https://maharashtra.gov.in/Site/upload/WhatsNew/SDMP-2015%20\(1\).pdf](https://maharashtra.gov.in/Site/upload/WhatsNew/SDMP-2015%20(1).pdf)
- 5 Maharashtra Flood 2021 - Sphere India
- 6 State Disaster Management Plan 2023

Uttarakhand Landslide, 2021

Introduction

On February 7, 2021, a catastrophic event unfolded in Uttarakhand's Chamoli district when a massive rock and ice avalanche from the Ronti peak triggered a devastating flash flood. This disaster primarily affected the Rishiganga and Dhauliganga rivers, leading to significant loss of life and property.

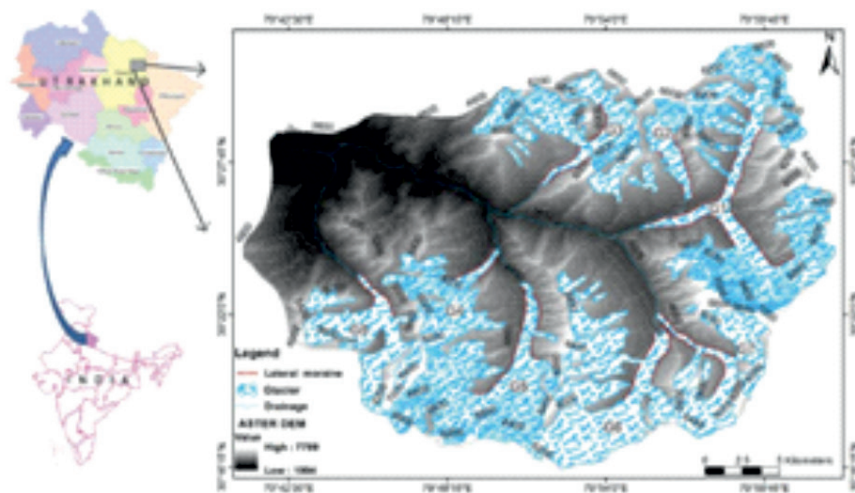


Fig - 48 : Topographic setting of the area in the background image of ASTER DEM, [red dash line indicating the lateral moraines of the glaciers in the Rishiganga catchment. G1- Uttari Nanda Devi Glacier, G2- Changbang Glacier, G3- Ramni

Source :- https://ndma.gov.in/sites/default/files/PDF/Reports/Detailed_report_UK_Disaster.pdf

Location

The 2021 Uttarakhand glacier disaster originated from a rockfall and debris flow in the Raunthi Glacier, impacting the Dhauliganga-Rishiganga river catchments in Chamoli district, Uttarakhand. The highest peak in the region is Nanda Devi (7,816m), with other significant peaks including Lata (3,848m), Bugyalpati (5,188m), Trishul (7,043m), and Raunthi (6,063m).

The Dhauliganga and Rishiganga rivers are the main waterways in the area. The Raunthi Gadhera stream, which originates from the Raunthi Glacier, flows into the Rishiganga River as a left-bank tributary.

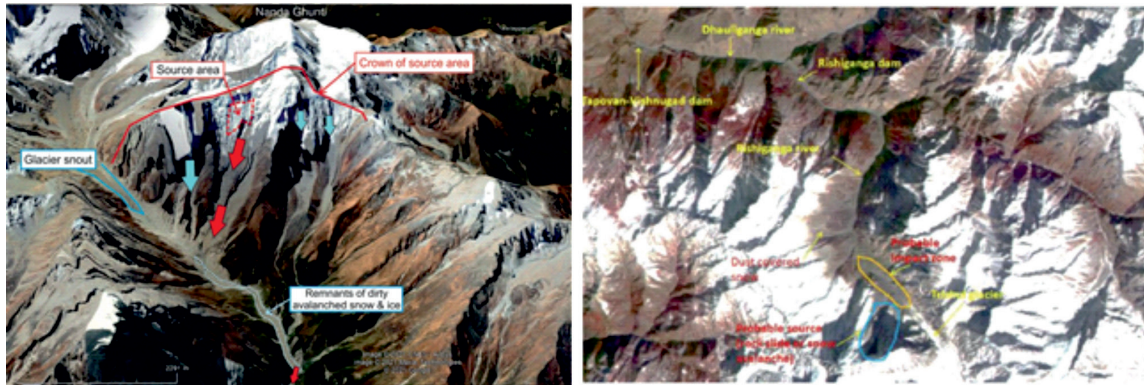


Fig - 49 : Location of rock slide displaced glacieret zone and affected catchment of Raunthi Gadhera, Rishiganga and Dhauliganga valley.

Source: https://ndma.gov.in/sites/default/files/PDF/Reports/Detailed_report_UK_Disaster.pdf

Source :- <https://www.reynolds-international.co.uk/news/chamoli-disaster-uttarakhand-northern-india-7th-february-2021/>

Overview of the Disaster

The avalanche released approximately 27 million cubic meters of material, comprising 80% rock and 20% ice. This mass descended over a 3.2 km elevation drop, the ice melted, intensifying the flood's impact. The sudden surge of water and debris caused extensive damage to infrastructure, including the Tapovan Vishnugad Hydropower Plant and the Rishiganga Hydroelectric Project.

Impact

The disaster resulted in over 200 fatalities and numerous injuries. Several villages were evacuated, and key infrastructure was destroyed. The environmental impact was also significant, with the flood altering river courses and affecting local ecosystems.

The incident led to adverse consequences in the form of damages and losses to the economy, infrastructure, and society. The impact included damages and losses to power projects, bridges, houses, infrastructure, and environment as given in Table 5.

Table 5 : Damages and losses to power projects, bridges, houses, infrastructure, and environment

S.No.	Parameters	Data
1.	Damages to projects	Rishiganga Hydro Project (13.2MW) & NTPC Hydro Power project (520MW)
2.	Damage of Roads (Access routes) and bridges	BRO Motor bridge on NH-7 at Raini washed away. 5 suspension bridges washed away.
3.	Number of affected villages	13 villages (Paing, Murranda, Jugju, Juwagwad, Raini Chak Lata, Raini Chak Subhai, Bhangule, Gahar, Tapovan, Ringi, Subhai including Tok) due to damage of utility supply lines [Electricity and water]
4.	Human Lives lost	~204 died / missing (Bodies recovered: 80; Missing: 124)
5.	Animal & Livestock lost	Dead Animals -03 (02 Goat, 01 Cow) Missing Animals – 186 (02 Cow, 04 Mule, 180 Goat)
6.	Damage to Buildings	1 Temple & 1 pucca House at Raini Chak Lata
7.	Psycho-social impact	Fear and panic amongst affected families. Trauma particularly for those families who lost their earning members. The affected families also lost their sources of regular income.
8.	Volume of Debris Dammed Lake	0.219MCM of lake water (Impending Risk)



Fig - 50 : Before and after images of the Rishiganga HEP

Source :- https://ndma.gov.in/sites/default/files/PDF/Reports/Detailed_report_UK_Disaster.pdf



Fig - 51 : Remnants of damage BRO motor bridge withbailey bridge constructed by BRO for vehicular movement on Joshimath – Malari road after the event

Source: https://ndma.gov.in/sites/default/files/PDF/Reports/Detalied_report_UK_Disaster.pdf



Fig - 52 : House which was affected. Villagers rescued three girls who were stuck inside the house

Source: https://ndma.gov.in/sites/default/files/PDF/Reports/Detalied_report_UK_Disaster.pdf



Fig - 53 : Outside of the intake Adit tunnel with HFL of 1801 m with submerged inside of the HRT intake adit

Source :- https://ndma.gov.in/sites/default/files/PDF/Reports/Detalied_report_UK_Disaster.pdf

Possible Causes

Initial speculations suggested a glacial lake outburst flood; however, further investigations identified a massive rock and ice avalanche as the primary cause. Factors contributing to this event include climate change-induced glacial retreat and permafrost degradation, which destabilize mountain slopes, increasing the likelihood of such disasters.

Response by Agencies

- **NDRF and SDRF:** Teams from NDRF and SDRF were promptly deployed to the affected areas. They conducted search and rescue missions, provided medical assistance, and facilitated evacuations.



Fig - 54 : Rescue and relief operations are in full progress in Chamoli district of Uttarakhand where a glacier burst, led to the massive flood, and caused large-scale devastation. The glacier burst triggered massive flooding of the Dhauliganga river near the Rishiganga Power Project at Raini village in the Tapovan area of the district on Sunday.

Source: <https://x.com/satyaprad1/status/1358625355704135680/photo/1>

- **Indian Army:** The Army played a crucial role in rescue operations, particularly in evacuating individuals trapped in flood-affected regions. They also assisted in restoring connectivity by rebuilding damaged bridges and roads.



Fig - 55 : Rescue operation underway after a glacier broke off in Uttarakhand's Chamoli district

Source: <https://www.ndtv.com/india-news/as-uttarakhand-glacier-break-triggers-floods-massive-rescue-ops-on-2365056>

Challenges Faced

- **Accessibility:** The rugged terrain and debris-blocked routes hindered the movement of rescue teams and equipment.
- **Communication:** Damage to communication infrastructure led to difficulties in coordinating between various agencies and affected communities.
- **Weather Conditions:** Adverse weather further complicated rescue efforts, posing risks to both survivors and responders.

Recommendations and Preventive Measures

1. **Infrastructure Assessment:** Regular monitoring and maintenance of infrastructure in vulnerable areas to ensure resilience against natural disasters.
2. **Early Warning Systems:** Enhancement of early warning mechanisms to provide timely alerts to communities at risk.
3. **Community Training:** Conducting disaster preparedness programs to educate local populations on emergency response protocols.
4. **Environmental Regulations:** Implementing stricter regulations on construction activities in ecologically sensitive zones to prevent exacerbation of natural hazards.

Lesson Learnt

India's Prime Minister, Shri Narendra Modi, emphasized the importance of learning from disasters in his ten-point agenda for disaster risk reduction and resilience, presented at the 7th Asian Ministerial Conference on Disaster Risk Reduction (AMCDRR) in 2016. In Point 9, he highlighted that "the opportunity to learn from a disaster must not be wasted" and expressed concern that "after every disaster, lessons are documented but rarely implemented."

Following this guidance, the joint study team of the National Disaster Management Authority (NDMA) ensured a focused approach on both learning from the disaster and applying those lessons. The key takeaways from the Chamoli, Uttarakhand disaster have been systematically documented in the following sections.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Hazard Monitoring	No real-time monitoring of hanging glaciers	Absence of cryosphere early warning	High-altitude hazards need monitoring	Establish cryosphere monitoring systems
Early Warning	No warning issued prior to event	Sudden onset limited response time	Zero-warning disasters require preparedness	Install automated alarm systems downstream
Infrastructure Siting	Hydropower projects located in narrow valleys	High exposure of critical infrastructure	Siting decisions amplify losses	Reassess hydropower siting in Himalayas
Environmental Sensitivity	Fragile Himalayan ecosystem	Cumulative impacts overlooked	Environmental fragility increases disaster risk	Enforce cumulative impact assessments
Emergency Response	Rapid deployment of Army, ITBP, NDRF	Access challenges due to terrain	Specialized mountain SAR essential	Strengthen mountain rescue capacities
Worker Safety	Large number of workers affected	Limited occupational safety planning	Worker safety is DRR	Enforce strict safety protocols
Communication	Communication lines disrupted	Lack of redundancy	Communication failure delays rescue	Satellite-based emergency communication
Governance & Policy	Post-disaster reviews initiated	Reactive governance	Prevention must precede development	Integrate DRR into Himalayan development
Climate Change Linkages	Possible climate-related triggers	Climate influence not fully factored	Climate change alters cryosphere risks	Mainstream climate risk into planning
Recovery & Reconstruction	Reconstruction initiated	Risk of rebuilding in unsafe zones	Build Back Better is essential	Relocate and redesign infrastructure

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DISASTER YEAR 2022

Vaishno Devi Temple Stampede, 2022

Introduction

Stampedes occur frequently at crowded places in India. People have been trampled to death at religious meetings, mass processions, electoral rallies, and even concerts. According to estimates from the National Crime Records Bureau, about 2,000 people died in stampedes in India between 2000 and 2013. According to a 2013 study published in the International Journal of Disaster Risk Reduction (IJDRR), 79% of stampedes in India have occurred at religious gatherings and pilgrimages. Recurring stampede incidents in India highlight the need for effective crowd management in the country.

The Vaishno Devi Temple, situated in Katra, Jammu and Kashmir, is one of India's most revered Hindu pilgrimage sites, attracting millions of devotees annually. This sacred shrine attracts pilgrims year-round, with numbers swelling significantly during festive seasons and the New Year period. The influx of devotees during these peak times often leads to overcrowding, posing substantial challenges to crowd management and safety protocols.

On the first day of the New Year, a stampede unfolded at the Mata Vaishno Devi shrine in Jammu and Kashmir, causing many people to have a traumatic experience. The event occurred on Saturday between 2.30 and 2.45 a.m., along a relatively tight route at gate number 3 outside the sanctum sanctorum. This is the spot where pilgrims routinely assemble around the clock after trekking roughly thirteen kilometers from the Katra base camp.

Preliminary investigations suggested that an argument between two groups of pilgrims escalated, causing panic and a sudden rush among the crowd. This, combined with the large number of devotees exceeding the shrine's capacity, led to the fatal stampede.

Impact

In the early hours of January 1, 2022, the temple witnessed a tragic stampede resulting in the loss of 12 lives. Fifteen or sixteen injured were undergoing treatment at the Mata Vaishno Devi Narayana Super Speciality Hospital and the condition of two of them was stated to be critical. A day after the stampede at the Mata Vaishno Devi hill shrine, authorities reinforced security precautions and announced an array of measures to minimise congestion at the temple complex as pilgrims continued to arrive.

Soon after the incident, local residents, pilgrims and members of the Baridar Sangharsh Samiti staged a massive protest at the Katra bus stand, demanding a probe by the Central Bureau of Investigation and framing of charges against the shrine administration under Section 302 (murder) of the Indian Penal Code.



Fig - 56 : Vaishno Devi Stampede

Source :- Times of India

Possible Causes/ Reasons

- As per Jammu and Kashmir Police, Preliminary information from the scene suggests there was an altercation among some young boys, and within seconds, there was a stampede situation.
- The stampede was triggered by a heavy rush of devotees who had come to pay their obeisance to mark the beginning of the New Year.
- One group going in the opposite direction wanted to take a u-turn to re-enter the shrine, and that led to the scuffle, which further resulted into a stampede.
- There was a lack of supervision as well.

Response

- The government launched an investigation by setting up a high-level inquiry into the stampede, which was headed by the Principal Secretary (Home) with ADGP, Jammu and Divisional Commissioner, Jammu as members.
- Prime Minister Narendra Modi and Lieutenant Governor Manoj Sinha announced ex gratia of a total of Rs 12 lakh to the next of kin of those who lost their lives in the stampede.
- PM Modi also announced ex-gratia of Rs 2 lakh each to the kin of the victims and said Rs 50,000 would be given to the injured. The relief amount was released from the Prime Minister's National Relief Fund (PMNRF).

Issues/ Challenges/ Concerns

The stampede at the Vaishno Devi Temple highlighted several critical issues and challenges:

- **Overcrowding:** Eyewitnesses reported that the bhawan (shrine area) was overcrowded, contributing to the stampede.

- **Mismanagement Allegations:** Survivors and eyewitnesses accused the authorities of inadequate crowd control and poor management. Some claimed that despite being aware of the potential rush, officials allowed unrestricted entry, leading to chaos.
- **Inadequate Infrastructure:** The pathways and areas near the sanctum sanctorum were reportedly narrow, making it difficult to manage large crowds and contributing to the severity of the incident.
- **Delayed Emergency Response:** Some survivors alleged that there was a lack of immediate assistance following the stampede, with help arriving hours after the incident.
- **Communication Gaps:** There were reports of confusion and lack of clear communication among pilgrims during the incident, exacerbating the situation.

Recommendations/ Preventive Measures

- As per LG, Manoj Sinha, directions were issued for physical and systematic improvements wherever required after critical examination, augmentation of infrastructure, online booking to be made 100 percent.
- Authorities have initiated steps to decongest the entire track leading to the shrine, ensuring smoother movement and reducing bottlenecks that can lead to overcrowding.
- The implementation of Radio Frequency Identification (RFID) tracking systems has been proposed to monitor and manage crowd flow effectively. This technology aids in real-time tracking of pilgrim movement, enhancing safety measures.
- **Infrastructure Enhancements:** The Shri Mata Vaishno Devi Shrine Board has considered constructing a suspension bridge or skywalk to manage queues better and identifying open spaces near the Bhawan and in Katra to accommodate large crowds. Additionally, exploring options for connecting the shrine with Katra through a ropeway for the aged and infirm has been discussed.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Crowd Management	Sudden surge of pilgrims at a narrow passage near the sanctum	Inadequate real-time crowd density control	Crowd surges can escalate rapidly into disasters	Implement real-time crowd density monitoring and access control
Early Warning & Anticipation	Crowd build-up was visible prior to the incident	No trigger-based preventive action	Early signs must prompt immediate intervention	Define crowd threshold limits with automatic restrictions
Infrastructure Design	Narrow passage created a bottleneck	Structural constraints not mitigated	Bottlenecks are high-risk zones	Redesign pathways to eliminate choke points
Access Regulation	Multiple entry points converged simultaneously	Weak regulation of entry timings	Unregulated access increases risk	Introduce staggered entry and time-slot based access
Policing & Security Deployment	Security personnel present	Limited crowd flow control expertise	Presence alone does not ensure safety	Train security staff in crowd dynamics and flow management
Communication Systems	Limited public address and warning mechanisms	Delayed communication to pilgrims	Communication failure increases panic	Strengthen PA systems and visual signage
Emergency Response	Immediate response by local authorities	Congestion delayed medical access	Accessibility is critical during emergencies	Maintain clear emergency corridors at all times
Medical Preparedness	On-site medical facilities available	Inadequate capacity for sudden mass casualties	Mass gatherings need surge medical capacity	Deploy mobile medical units during peak periods
Community & Volunteer Role	Volunteers assisted post-incident	No formal role defined	Trained volunteers can save lives	Formalise volunteer engagement and training
Governance & Oversight	Inquiry ordered post-incident	Reactive safety audits	Prevention must precede events	Conduct mandatory pre-event safety audits
Preparedness & Planning	SOPs existed for pilgrimage management	SOPs not stress-tested for peak crowd loads	Planning must consider worst-case scenarios	Conduct crowd surge simulations and mock drills
Data & Technology	Manual crowd assessment relied upon	Lack of real-time analytics	Technology improves situational awareness	Deploy AI-enabled CCTV and crowd analytics

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Public Information	Pilgrims unaware of congestion severity	No real-time advisory dissemination	Informed pilgrims make safer decisions	Issue live crowd advisories via apps and displays
Relief & Compensation	Ex-gratia assistance announced promptly	Long-term trauma support limited	Recovery includes psychosocial care	Integrate counselling and follow-up support
Governance & Policy	Review of pilgrimage management initiated	Crowd safety not institutionalised nationwide	Mass gatherings are disaster risks	Develop national guidelines for crowd safety
Disaster Typology	Classified as a stampede incident	Crowd disasters underrepresented in DRR	Human-induced disasters need equal focus	Integrate crowd disasters into DRR planning

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Surat Gas Leak, 2022

Introduction

Gas leaks in India have been a significant concern due to their potential to cause widespread harm to human health, the environment, and property. These incidents range from minor leaks with limited impact to catastrophic disasters resulting in substantial loss of life and long-term environmental damage. In the past years, India has witnessed several gas leak incidents:

Surat is the hub of Industrial Plants in India. There are over 41,300 small and medium industries functioning in the district. Some of the main industries are textiles, chemicals, dying & printing, diamond processing, Zari (silver) making, and; engineering and related activities (including manufacturing machines & equipment).

On January 6, 2022, a tragic occurrence unfolded in the Sachin GIDC industrial region of Surat, Gujarat, where a toxic gas leak killed six people and hospitalized 22 more. The disaster was caused by the unauthorized discharge of chemical waste into a natural drain, which resulted in the release of hazardous vapours that predominantly harmed workers resting at a neighbouring textile mill.

Around 4:25 a.m. IST, a tanker driver illegally discharged chemical waste into a drain, resulting in the release of toxic gas. The driver departed the site shortly following the incident. The workmen, who were sleeping nearby, breathed the toxic fumes, resulting in immediate death and significant health consequences for others. Emergency responders responded quickly, securing the tanker and evacuating the area to minimize more damage.

The chemical was identified as sodium hydrosulphite, a material that, if handled incorrectly, can emit harmful gasses. The unauthorized dumping of this chemical into the drain caused a reaction that emitted poisonous vapours into the surroundings.



Fig - 57 : Photo of the Tanker

Source :- Green Tribunal

Impact

The gas leak resulted in the immediate deaths of six individuals, with 23 others requiring hospitalization due to exposure, 7 of them got critical and were in ventilator. Two stray dogs in the area also succumbed to the toxic fumes. The affected individuals were transported to New Civil Hospital in Surat for treatment.

Possible Causes

- **Illegal Chemical Dumping:** The immediate cause was the unauthorized disposal of hazardous chemicals into a natural drain. This practice is highly dangerous, as it can lead to chemical reactions that produce toxic gases.
- **Lack of Regulatory Oversight:** The incident highlighted deficiencies in monitoring and enforcement by regulatory bodies. The National Green Tribunal (NGT) noted the failure of the Gujarat Pollution Control Board (GPCB) to prevent such illegal activities, indicating systemic issues in environmental governance.



Fig - 58 : People affected by the gas being treated in the New Civil Hospital, Surat

Source :- Times of India

Response

- When the gas leak was discovered, emergency services such as the Surat Fire and Emergency Services (SFES) and police were summoned to the location right away. Their quick efforts included removing victims and safeguarding the area to prevent additional harm. The police arrested four key persons from Ankleshwar, Vadodara.
- The National Green Tribunal (NGT) ordered a nine-member committee to conduct a thorough examination. The committee's conclusions revealed severe flaws in hazardous waste management and emphasized the need for strict regulatory control to prevent similar incidents in the future.

PROFILES OF THE ACCUSED

Ashishkumar Gupta: He is one of the three directors of Vadodara-based Sangam Enviro Private Limited and as per company details it is involved in legal, accounting, book-keeping, and other businesses. He has studied up to Class VIII and operates Shweta Transport, a transport business in Ranoli, Vadodara.

Premasagar Gupta: A class VII dropout and resident of Sachin Pardi, Gupta has been living in the city for the past 15 years. He owns two trucks and has been operating Baba Mahendranath Road lines, a transport business, for five years now. He has criminal history and was booked under Gujarat Prohibition Act in 2009 and for gambling in 2016.

Jayprakash Tomar: A BCom dropout from M S University in Vadodara. Tomar is working in the loans department of Unity Small Finance Bank at Ankleshwar.

Vishal alias Chotu Yadav: A class X pass out, Yadav runs his auto garage Shree Sai bodybuilder in Ankleshwar GIDC area.

ACCUSED IS A REPEAT OFFENDER OF DUMPING: According to the police, the accused have confessed to involvement in disposal of chemical waste from different companies. Cops are investigating from which units the chemical had been collected and where it was disposed of.

ALERT TANKER DRIVER REFUSED JOB: Investigation revealed that the tanker driver who collected the chemical from the company in Taloja of Maharashtra refused to dump the hazardous chemical in the open when he was told to do so by the key accused. The driver was earlier told that the chemical was supposed to be delivered in a cement company. Later, the accused arranged for another tanker in Ankleshwar where chemicals were transferred to another tanker which was driven by Surendra Singh, police said.

Fig - 59 : Newspaper clipping of the profiles of the accused

Source :- Times of India

Preventive Measures

The Surat gas leak episode highlighted major gaps in environmental regulation enforcement, particularly when it came to industrial waste disposal. In response, authorities have been advised to strengthen monitoring and enforcement tools to guarantee that hazardous waste disposal protocols are followed. The NGT's engagement, as well as subsequent directives, attempt to tighten regulatory frameworks and avoid such industrial tragedies from occurring in the future.

Recommendations

- Strengthening Regulatory Frameworks:** There is a pressing need to enhance the monitoring and enforcement of hazardous waste disposal regulations. Implementing stricter penalties for violations and ensuring regular inspections can deter illegal activities.

- **Improving Emergency Preparedness:** Establishing robust emergency response protocols, including regular drills and community awareness programs, can mitigate the impact of such incidents. Equipping local hospitals with necessary resources to handle chemical exposure cases is also crucial.
- **Promoting Safe Waste Management Practices:** Industries must adopt best practices for waste management, including proper treatment and disposal of hazardous materials. Encouraging the use of technology for real-time monitoring of waste disposal can prevent illegal dumping.
- **Community Engagement and Awareness:** Educating communities residing near industrial areas about potential risks and safety measures can enhance preparedness and reduce casualties in the event of accidents

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Industrial Safety	Toxic gas leaked from industrial unit	Poor safety compliance	Prevention is critical	Enforce strict industrial safety audits
Early Detection	Leak detected after public exposure	Lack of gas sensors	Early detection saves lives	Install continuous gas monitoring systems
Emergency Response	Fire services responded promptly	Limited hazmat preparedness	Specialized response needed	Strengthen HAZMAT response units
Public Warning	Residents evacuated post-exposure	No real-time alert	Public alerts are vital	Implement siren & mobile alerts
Governance	Inquiry ordered post-incident	Reactive oversight	Proactive regulation needed	Regular third-party safety audits

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Cyclone Asani, 2022

Introduction

Cyclones are one of the natural hazards that impact India practically every year, resulting in significant loss of life and property. Cyclone Asani was the first cyclonic storm of the season over the Bay of Bengal (BoB) named by Sri Lanka. In Sinhalese, Asani denotes wrath. Following timeline presents the progress of the cyclonic activity:

- **May 6, 2022:** A low-pressure area formed over the South Andaman Sea and adjoining Southeast Bay of Bengal.
- **May 7:** The system intensified into a depression by late morning and further into a deep depression by evening.
- **May 8:** It strengthened into Cyclonic Storm Asani early morning and escalated to a severe cyclonic storm by evening.
- **May 9-10:** Asani reached peak intensity with maximum sustained winds of 100-110 km/h, gusting to 120 km/h, maintaining this strength for approximately 30 hours.
- **May 11:** The storm weakened to a cyclonic storm in the early morning and further to a deep depression by evening. It made landfall along the Andhra Pradesh coast between Machilipatnam and Narsapur during the evening, with wind speeds of 55-65 km/h, gusting to 75 km/h.
- **May 12:** Asani continued to weaken, becoming a well-marked low-pressure area over coastal Andhra Pradesh by morning.

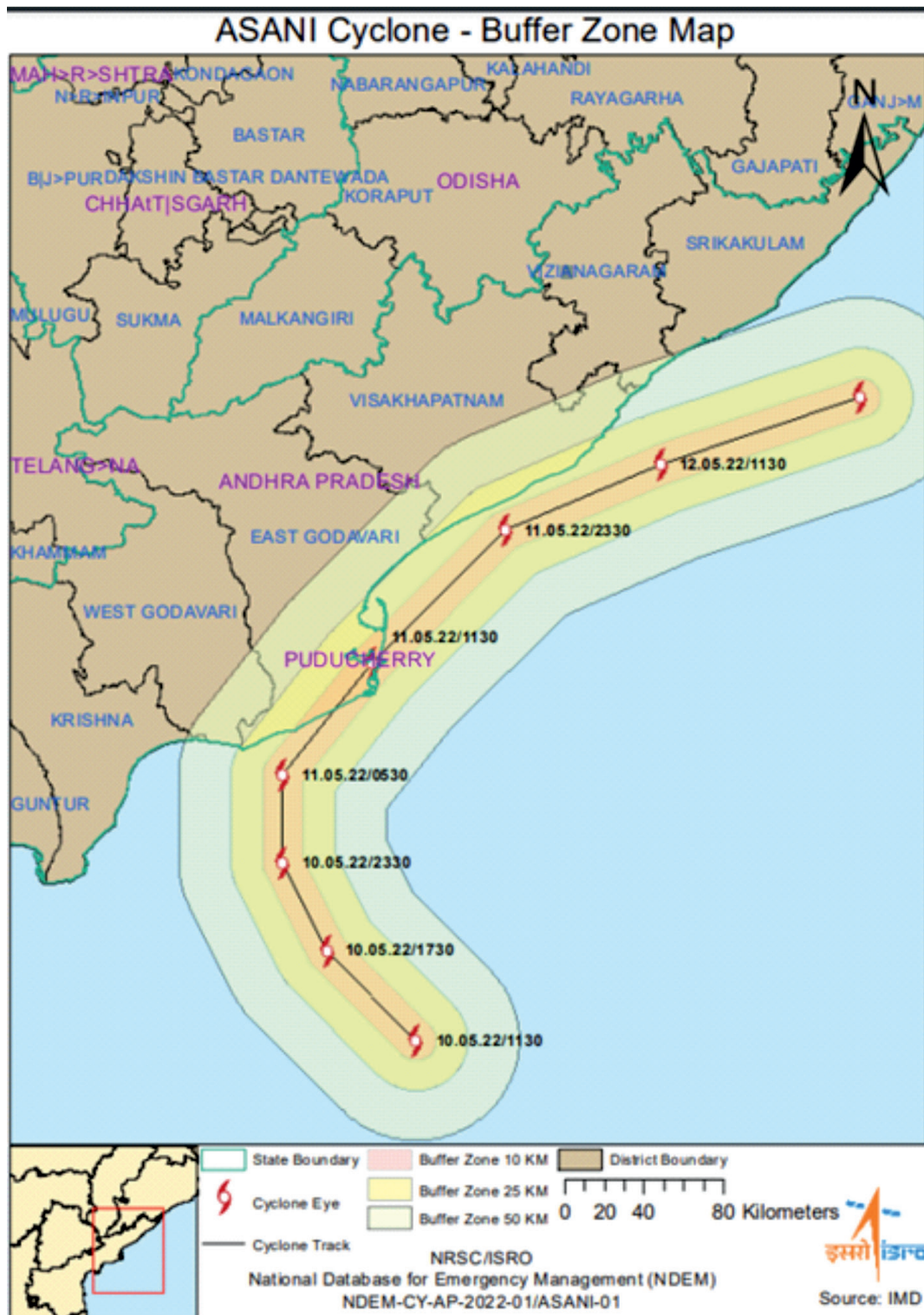


Fig - 60 : Cyclone : Buffer Zone Map

Source :- NDEM, ISRO, NRSC

Table 6 : Forecast track and intensity of Cyclone Asani

DATE/TIME(UTC)	POSITION (LAT. ON/ LONG. °E)	MAXIMUM SUSTAINED SURFACE WIND SPEED (KMPH)	CATEGORY OF CYCLONIC DISTURBANCE
08.05.22/0600	11.6/88.7	80-90 GUSTING TO 100	CYCLONIC STORM
08.05.22/1200	12.2/88.2	90-100 GUSTING 110	SEVERE CYCLONIC STORM
08.05.22/1800	13.1/87.7	95-105 GUSTING 115	SEVERE CYCLONIC STORM
09.05.22/0000	14.1/87.3	105-115 GUSTING TO 125	SEVERE CYCLONIC STORM
09.05.22/0600	14.9/86.8	105-115 GUSTING TO 125	SEVERE CYCLONIC STORM
09.05.22/1800	15.9/86.1	105-115 GUSTING TO 125	SEVERE CYCLONIC STORM
10.05.22/0600	16.8/85.6	95-105 GUSTING TO 115	SEVERE CYCLONIC STORM
10.05.22/1800	17.6/85.3	90-100 GUSTING TO 110	SEVERE CYCLONIC STORM
11.05.22/0600	18.2/85.4	80-90 GUSTING TO 100	CYCLONIC STORM
11.05.22/1800	18.6/85.7	70-80 GUSTING TO 90	CYCLONIC STORM
12.05.22/0600	19.1/86.2	60-70 GUSTING TO 80	CYCLONIC STORM
12.05.22/1200	19.3/86.6	50-60 GUSTING TO 70	DEEP DEPRESSION

Source :- Regional Specialised Meteorological Centre-Tropical Cyclones, New Delhi Special Tropical Weather Outlook, IMD

Impact

Throughout its course, Asani impacted regions including the Andaman and Nicobar Islands, Andhra Pradesh, Tamil Nadu, Karnataka, and Odisha, causing damage and resulting in three fatalities.

Impact on Andhra Pradesh:

- **Wind Speeds:** Along the Andhra Pradesh coast, maximum sustained wind speeds were estimated at around 30 knots (50-60 km/h). On May 11, the IMD station in Machilipatnam recorded a peak wind speed of 30 knots (55 km/h).
- **Rainfall:** Several districts in Andhra Pradesh, Yanam, Rayalaseema, and Odisha received rainfall exceeding 7 cm on May 11 and 12.

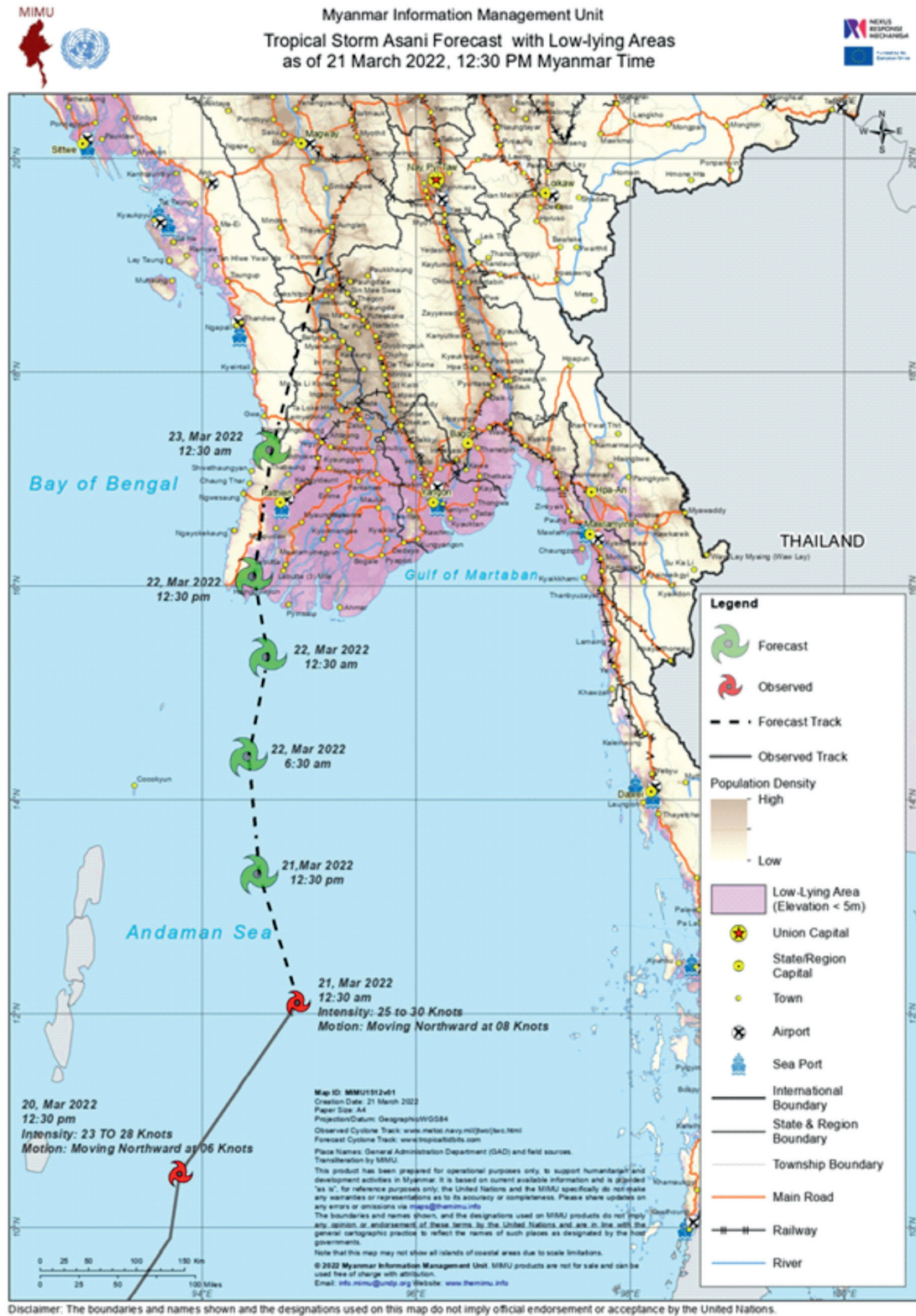


Fig - 61 : Tropical Storm Asani Forecast

Source :- Myanmar Information Management Unit

Wider Regional Effects:

- **Temperature Drop:** The cyclone-induced cloud cover extended over the entire southern peninsula, blocking intense summer sunlight. This cooling effect was significant enough to lower daytime temperatures in Bengaluru to 24.3°C on May 11, making it the coldest May Day in the city since 2000.

Casualties and Damage:

- **Fatalities:** The cyclone resulted in three fatalities in Andhra Pradesh. 07 districts and 53 villages were affected. 16 houses were damaged and 02 animal deaths were reported.
- **Property Damage:** The storm caused substantial damage to crops and infrastructure in the affected regions. In Andhra Pradesh, the damage was estimated at Rs 12.12 crore. 8325.99 hectare of Agriculture crop and 285.49 hectare Horticulture area affected.

Environmental Impact

- Rainfall under the influence of cyclonic storm Asani affected both agriculture and horticulture crops on about 30,000 hectares in Andhra Pradesh.
- Based on a preliminary assessment, paddy suffered the worst in 30,225 hectares followed by maize in 6,095 hectares, black gram in 3,882 hectares, groundnut in 875 hectares, sesamum in 589 hectares, sunflower in 200 hectares, bengal gram in 150 hectares while blackgram, bajra, cotton, sugarcane, ragi etc suffered the impact of rain.



Fig - 62 : Trees uprooted during cyclone Asani

Source :- Deccan Chronicle

Possible Causes/ Reasons

Cyclone Asani, which formed over the Bay of Bengal in May 2022, was influenced by several meteorological factors:

- **Madden-Julian Oscillation (MJO):** A strong pulse of the MJO, a large-scale atmospheric disturbance, prevailed in the region during the first week of May. This contributed to the development of cyclonic

conditions over the southern Andaman Sea.

- **Equatorial Rossby Wave (ERW):** The presence of an ERW, a type of atmospheric wave, further enhanced the cyclonic activity in the area.
- **Westerly Wind Burst:** On May 4, a westerly wind burst occurred, leading to the formation of twin cyclones on either side of the Indian Ocean. The southern hemisphere counterpart was Tropical Cyclone Karim, while the northern hemisphere counterpart was Cyclone Asani.
- **Sea Surface Temperatures:** The Bay of Bengal's sea surface temperatures were above 26.5°C, providing the necessary heat and moisture to fuel the cyclone's development.

Response

In response to Cyclone Asani, the Indian Coast Guard (ICG) deployed four ships and two aircraft along the coasts of West Bengal, Andhra Pradesh, and Odisha. Additionally, 19 ICG Disaster Response Teams, equipped with lifeboats, were placed on standby to assist in rescue and relief operations. One team was actively deployed in Andhra Pradesh, while the others were deinducted as the situation stabilized.

The Guntur Diocese Social Service & Welfare Society (GDSS&WS), in collaboration with its members in coastal areas, took proactive measures to alert communities and facilitate evacuations from low-lying regions. Diocesan NGOs in the affected areas assessed the needs of the impacted populations, focusing on providing relief related to water and food. Reports indicated that the Yanadi community—a semi-nomadic tribe residing along water bodies—was among the most affected. Many of their palm leaf huts were damaged due to high winds. These coordinated efforts by the ICG and local organizations were crucial in mitigating the impact of Cyclone Asani and providing essential support to the affected communities.

Issues/ Challenges/ Concerns

1. Infrastructure Vulnerability:

- The cyclone caused disruptions in power and communication lines, leading to traffic congestion and localized flooding in low-lying areas.

2. Humanitarian Impact:

- The cyclone resulted in fatalities and displaced communities, highlighting the need for effective disaster response and relief operations.

3. Economic Losses:

- Agricultural damage was significant, with crops over approximately 30,000 hectares affected, leading to economic losses for farmers.

4. Environmental Concerns:

- The cyclone's heavy rainfall and strong winds led to soil erosion and habitat destruction, impacting local ecosystems.

Recommendations/ Preventive Measures

- Conduct regular community outreach to educate the public on interpreting and responding to cyclone warnings.
- Implement training for local communities on disaster response, including first aid and evacuation procedures.

- Encourage households to maintain emergency kits containing essential supplies such as water, non-perishable food, flashlights, and first aid materials.
- Enforce stringent building codes to ensure structures can withstand cyclonic winds and flooding.
- Identify and prepare cyclone shelters equipped with necessary amenities to accommodate displaced populations.
- Establish clear evacuation routes and ensure the availability of transportation for vulnerable groups.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps	Lessons Learned	Recommendations
Forecasting	IMD accurately tracked cyclone	Risk perception low	Accurate forecasts save lives	Improve risk communication
Evacuation	Preventive evacuations conducted	Shelter fatigue	Preparedness reduces casualties	Improve shelter amenities
Coastal Infrastructure	Limited casualties	Power & housing damage	Resilient infrastructure matters	Expand cyclone-resilient housing
Fisheries	Boats secured in advance	Livelihood loss	Livelihood protection essential	Introduce risk insurance
Recovery	Rapid service restoration	Limited BBB	Recovery must reduce risk	Enforce BBB principles

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Hapur Chemical Plant Explosion, 2022

Introduction

On June 5, 2022, between 2:30 and 3:00 pm, a fire broke out in an illegal fireworks production factory in Hapur. The unit was located at Plot No. F-128 in MG Road Industrial Area of Uttar Pradesh State Industrial Development Corporation (UPSIDC) site in Hapur's Dhaulana area, Distt. Hapur, Uttar Pradesh. Both polluting and non-polluting industries are served by the aforementioned area.

The factory, Ruhi Industries, was engaged in the illegal manufacture of fireworks, despite its license permitting the production of electronic equipment. The explosion was so powerful that it caused roofs to be blown off the factory and the houses nearby, with the sound traveling up to 10 kilometers away. The factory was owned by Dilshad of Meerut and had been leased to Wasim of Hapur.



Fig - 63 : Multiple fire tenders present at spot in Hapur, Uttar Pradesh, where a huge explosion happened

Source :- Hindustan Times

The event raises important concerns about industrial safety, facility maintenance, and emergency response processes. The explosion not only claimed the lives of 12 individuals, but it also sparked questions about chemical plant safety regulations and the need of competent risk management in preventing such tragedies.

Impact

The impact of the explosion was so intense that the roofs of some of the factories located in the vicinity were damaged. It took three hours for the fire tenders to douse the blaze in the factory. On the day of the incident, 12

casualties were reported, and 13 labourers were seriously injured. There were around 30 people in the factory at the time of the blast. Eight labourers died on the spot, while two succumbed during treatment at a Meerut hospital. One labourer died at a Ghaziabad hospital.



Fig - 64 : Investigation underway after an explosion inside a factory in Uttar Pradesh's Hapur

Source :- Hindustan Times

Response

Upon receiving reports of the explosion, local authorities, including fire brigade teams and medical personnel, promptly arrived at the scene to conduct rescue operations and provide medical assistance to the injured. Senior officials, including the Inspector General of Meerut Zone and the District Magistrate, visited the site to assess the situation and oversee relief efforts.

Causes

- **Illegal Manufacturing Activities:** The factory was licensed to produce electronic equipment but was found to be illegally manufacturing toy gun pellets using gunpowder. This unauthorized activity significantly increased the risk of explosions.
- **Inadequate Safety Measures:** The presence of gunpowder in the factory indicates a lack of proper safety protocols and risk assessments, especially when handling highly volatile materials. This oversight likely contributed to the explosion.
- **Regulatory Lapses:** Despite the factory's license permitting the manufacture of electronic equipment, it was engaged in the production of firecrackers illegally. This suggests a failure in regulatory oversight and enforcement, allowing the factory to operate outside the scope of its authorized activities.

Issues

- The explosion's impact on the surrounding environment, including potential contamination from chemicals, posed significant challenges for local authorities. The blast caused widespread panic, with reports of roofs being blown off houses and sounds heard up to 10 km away, affecting the local community's safety and well-being.
- Health Risks: Acute and long-term exposure to toxic chemicals affecting public and responders.
- Environmental Damage: Pollution of air, water, and soil, and managing hazardous waste.
- Infrastructure Disruption: Damage to roads, bridges, and communication lines, affecting rescue and recovery.
- Psychosocial Impact: Trauma on affected communities and loss of public trust.

Recommendations

- Enforce Licensing Compliance: Regular inspections to ensure factories operate within their licensed activities.
- Conduct Safety Audits: Routine evaluations to identify and mitigate potential hazards.
- Provide Employee Training: Comprehensive instruction on handling hazardous materials and emergency procedures.
- Raise Community Awareness: Educate local communities on industrial risks and emergency responses.
- Protect Whistleblowers: Encourage reporting of safety violations without fear of retaliation.
- Enhance Emergency Preparedness: Develop and regularly update emergency response plans, including drills.
- Ensure Legal Accountability: Implement strict consequences for safety regulation violations.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons	Recommendations
Chemical Safety	Explosion killed workers	Poor compliance	Safety lapses cause disasters	Enforce chemical safety norms
Worker Protection	Contract workers affected	Weak labour oversight	Worker safety is DRR	Strengthen labour inspections
Emergency Planning	Ad-hoc response	No on-site emergency plan	Preparedness saves lives	Mandatory on-site emergency plans
Medical Response	Local hospitals overloaded	Limited trauma care	Industrial areas need preparedness	Upgrade district hospitals
Governance	Inquiry ordered	Reactive enforcement	Prevention over prosecution	Regular inspections

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Manipur Landslides, 2022

Introduction

Landslides in India are one of the major hydro-geological hazards affecting large parts of landmass of the country. The Northeastern Region of India consisting of the states of Assam, Arunachal Pradesh, Nagaland, Meghalaya, Manipur, Mizoram & Tripura experiences several landslide hazards specially during monsoon season.

North Eastern Regional node for Disaster Risk Reduction (NER-DRR), NESAC prepared a landslide inventory that are triggered by 2022 monsoonal rainfall. A total of 145 landslide incidents have been documented in the different states of NER. 41 casualties are reported out of which 10 are from Arunachal Pradesh, 11 from Assam, 8 from Manipur and 12 from Meghalaya.



Fig - 65 : Landslide Locations 2022, NER, India

Source :- NEDRR, NESAC,GOI

A massive landslide occurred on the intervening night of 29th - 30th June 2022 in Manipur. Excessive rainfall was experienced during May' 2022 (375.60mm) and June' 2022 (329.9 mm) which was approximately 60% higher than the normal earlier recorded rainfall. at Makhuam village, located in the Tupul District of Manipur, Northeast (NE) India, in two coherent episodes of failure. . The first failure occurred around 12.30 am, and the second followed at about 6 am.

The landslide area was near a local fault (Dalang Fault, ~2 km away) in the Tupul District of Manipur, India. The southernmost extension of two major faults of NE India, namely, the Kopili Fault and the Churachandpur Fault, also lies very close to the site. These two faults are seismically active and play an intrinsic role in characterizing the tectonic configuration of NE India. Besides, the region falls under Zone V of the seismic hazard map of India (Baruah, 2023).



Fig - 66 : Newspaper clipping depicting location of Tupul Landslide

Source :- The Hindu

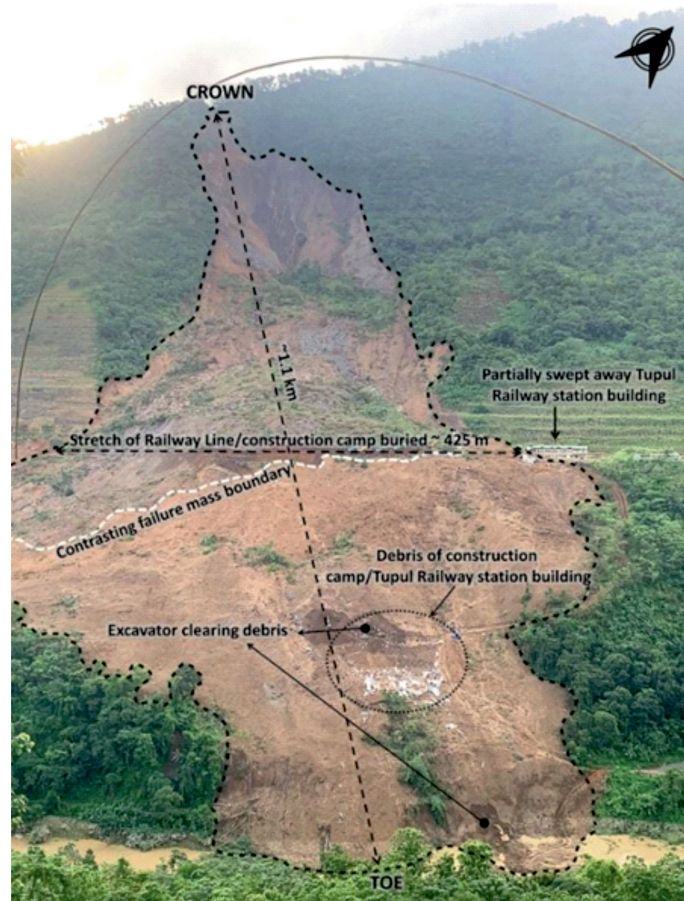


Fig - 67 : Annotated image of the 30 June 2022 Tupul, Manipur landslide in India

Source :- Springer

Impact

The construction worker camp of the ongoing Jiribam–Imphal new railway line project, along with a significant portion of the under-construction Tupul railway station building, was engulfed by the landslide.

This has been considered to be one of the worst-ever landslide to hit the Indian state of Manipur affected at least 79 people, of which 18 sustained injuries and 61 died. 56 bodies were recovered, and five remained missing when the joint search operation was called off after 20 days of the extensive searching. Nearly half of the deceased persons belonged to Indian army troops assigned to guard the building site, and the others were railway officials, construction workers, and local residents (Sahana,2022).



Fig - 68 : A railway station affected by the landslide

Source :- International Journal for Multidisciplinary Research

Causes of Landslide

- According to a preliminary study by the Geological Survey of India's (GSI) Imphal office, the landslide was caused by an "extensive slope cut for the construction of the railway station, presence of break in slope in the upslope area, affluence convergence of water and unprotected slope cut for long duration (from 2014 onwards).
- The report stated that the area where the landslide occurred is a 'highly susceptible zone', according to the National Landslide Susceptibility Mapping (NLSM) of 2019.
- The other causes were listed as: debris dumps limiting the normal water flow of Ijei river; unconsolidated materials dumped and used for temporary construction sites; improper hillside drainage along the slope cut region. The site is 350 metres north of Ijei fault, making it a geologically weak zone.
- Sabyasachi De, Chief Public Relations Officer (CPRO) of NFR, said, "A report prepared by Manipur University specifically states that incessant rainfall this year, which is 400% more than the earlier recorded rainfall in the last decade, was the triggering factor behind the landslide."

Response

- The Government of Manipur promptly mobilized both the National Disaster Response Force (NDRF) and the State Disaster Response Force (SDRF) to lead rescue operations. Over 250 personnel, including soldiers, rescuers, and police officers, were deployed to the site. Heavy machinery such as bulldozers and excavators was utilized to search for victims, and efforts were made to clear debris blocking the Ijei River to prevent potential flooding.
- By July 4, 2022, 46 bodies had been recovered, and 18 individuals were rescued and transported to hospitals for treatment. Despite challenging weather conditions and the risk of additional landslides, the search for the remaining missing persons continued.



Fig - 69 : Joint rescue operation after landslide incident at Noney, Manipur

Source :- NDRF



Fig - 70 : Joint rescue operation after landslide incident at Noney, Manipur

Source :- NDRF

- The Government of Manipur, led by Chief Minister N. Biren Singh, announced ex gratia payments of ₹5 lakh to the families of the deceased and ₹50,000 to those injured. Additionally, the Northeast Frontier Railways, Noney district administration, and Makhuam village authority signed a memorandum of understanding to conduct a joint survey assessing the damage and to discuss preventive measures for future projects.

Issues/ Challenges/ Concerns

- **Accessibility Issues:** The remote location and rough terrain hindered the swift movement of rescue teams and machinery.
- **Adverse Weather Conditions:** Continuous rainfall increased the risk of additional landslides, posing threats to both survivors and rescuers.
- **Communication Gaps:** The disaster disrupted communication networks, complicating coordination among various agencies involved in the rescue efforts.
- **Limited Resources:** The scale of the disaster overwhelmed local resources, necessitating assistance from national agencies and the military.

Recommendations

- Conduct comprehensive geological studies to identify landslide-prone areas before initiating any construction projects, particularly in hilly terrain
- Implement appropriate slope stabilization measures such as retaining walls, drainage systems, and rock bolting to prevent future landslides
- Educate local communities about landslide risks, evacuation procedures, and reporting mechanisms.
- Partner with universities and research institutions to develop effective landslide mitigation strategies and conduct detailed analysis of the affected areas.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons	Recommendations
Rainfall Warning	Heavy rain alerts issued	No slope-specific warning	Landslides need targeted alerts	Landslide early warning systems
Land Use	Settlements on unstable slopes	Weak zoning	Land-use drives risk	Enforce hazard zonation
Infrastructure	Roads repeatedly damaged	Poor slope protection	Engineering solutions needed	Improve slope stabilization
Response	SDRF/NDRF deployed	Remote access issues	Pre-positioning essential	Pre-monsoon deployment
Climate	Intense rainfall events	Climate underestimated	Climate amplifies landslides	Integrate climate risk

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Amarnath Flash Floods, 2022

Introduction

This case study focusses on Amarnath Flash Floods, 2022. The Amarnath Flash Floods of 2022 stand as a stark reminder of the vulnerability of ecologically sensitive regions to extreme weather events. The floods struck without warning, overwhelming the narrow valley and leaving little time for evacuation or response.

Anantnag District of Jammu & Kashmir is famous for the Amarnathji cave situated at Mount Amarnath whose altitude is about 5,486m above sea level. The world-famous shrine of Amarnathji is situated about 48 Kms. from Pahalgam and attracts devotees from all over India. It is located in the upper reaches of District Anantnag at an altitude of about 13,000 ft. from the sea level. The Amarnath Yatra is a pilgrimage to the Amarnath Cave in the South Kashmir Himalayas. It takes place annually during the summer months of June–August. The Amarnath area in the Northern Hemisphere has a moderate climate, which is largely defined by its geographic location with the towering Karakoram range in the north, Pir Panjal range in the south and west, and Zaskar range in the east. (Sain et al., 2022)



Fig - 71 : Photo of Amarnath Cave

Source :- Heavy Rainfall-triggered Flash Floods around the Amarnath Holy Cave

(Kalachand Sain, Manish Mehta and Vinit Kumar), Research Gate*

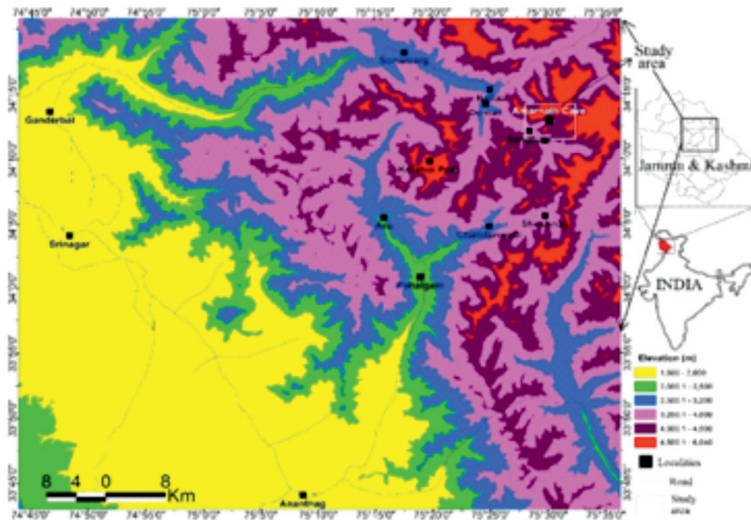


Fig - 72 : Digital elevation model (DEM) showing location of the study area

Source :- Analysing the Incidences of Cloudburst near Shri Amarnath Ji Holy Cave area, District Anantnag, Jammu and Kashmir (Imran Khan, Harish Bahuguna), Research Gate

Overview of Disaster

Heavy rains caused flash floods at 5:30 p.m. on July 8, 2022, causing extensive damage around the Amarnath holy cave, which is located at 3900 meters above sea level along the Amravati Nala river. It was an unusual event considering the fact that Amarnath is located in the semi-arid Trans-Himalaya, where the total precipitation during the period of May to October is less than 300 mm.



Fig - 73 : Approximate Location of Flooding and Landslip

Source :- The Hindu

The Automatic Weather Station (AWS) below the holy Amarnath cave recorded 75 mm of rainfall between 4:30 pm and 7:30 pm of 8 July 2022. The recorded hourly rainfall was 31 mm between 4:30 pm and 5:30 pm, 25 mm from 5:30 pm to 6:30 pm and 19 mm from 6:30 pm to 7:30 pm, which was far less than the categories of cloudburst. (Sain et al., 2022)

As per the criteria of the Indian Meteorological Department (IMD), 100 mm or more rainfall per hour is termed as a cloudburst. Based on the analysis of satellite imagery, the IMD suggested that the heavy rain at Amarnath area was highly localized. This indicated that an intense convective cloud cluster was developed over the valley in the morning of 8 July.



Fig - 74 : Destruction At Amarnath due to Floods

Source :- DNA, India

Impact

The flash flood triggered by a cloudburst near the holy cave shrine of Amarnath in Jammu and Kashmir swept away pilgrims, killing 16 and leaving at least 35 others injured. Gushing waters rolling down the mountainside due to the incessant rain damaged 25 tents, swept away scores of people near the Baltal base camp in central Kashmir's Ganderbal area and three community kitchens where pilgrims were served food.

Response

Teams from Indo-Tibetan Border Police, National and State Disaster Response Forces, Border Security Force, Indian Army and Air Force among others were deployed to the site to help with rescues and evacuations. Helicopters started rescue operations early on 09 July. At least 15,000 pilgrims, who were stranded near the Amarnath holy cave in Jammu and Kashmir due to a flash flood triggered by a cloudburst, were shifted to the lower base camp of Panjtarni.



Fig - 75 : Search and rescue operations after the floods Amarnath, Jammu and Kashmir, India, July 2022.

Source :- Floodlist.com



Fig - 76 : Indian army soldiers carry an injured of flash floods near Amarnath cave for treatment, at Baltal, 105 kilometers northeast of Srinagar, Jammu and Kashmir, on July 09 2022.

Source :- The Hindu

Deployment of NDRF, Army, Air Force, BSF, CRPF and ITBP:-

- Three teams of the National Disaster Response Force (NDRF) were deployed at the incident site to carry out search and rescue operations. These teams successfully rescued three pilgrims alive and recovered three bodies.
- One company each from the Indo-Tibetan Border Police (ITBP), Border Security Force (BSF), and Central Reserve Police Force (CRPF) assisted the state administration in the ongoing rescue and relief efforts.

- A total of 10 Army teams from Sangam and Brarimarg, comprising 90 personnel, including officers and Junior Commissioned Officers (JCOs), actively participated in rescue operations at the holy cave. These teams recovered five bodies and rescued five pilgrims.
- The Army also provided medical assistance at the cave, with a medical team stationed on-site. The Commander of 3 Sector Rashtriya Rifles (RR) was flown to the site by helicopter to oversee rescue operations. Additionally, two medical teams—one each from Panjtarni and Kalimata—were dispatched to the holy cave for support.
- Two Advanced Light Helicopters (ALH) from the Indian Air Force (IAF) were mobilized to evacuate casualties from the holy cave. However, landing attempts at the cave were unsuccessful. The helicopters were placed on standby at Nilgrar to transport casualties from Panjtarni once they reached there.
- Two dog squads, one each from Pattan and Sharifabad, were airlifted to the site to aid in search operations.

Causes

- **Localized Cloudburst:** A sudden, intense cloudburst near the Amarnath Cave Shrine led to a rapid accumulation of water, mud, and debris.
- **Fragile Ecological Conditions:** The region's delicate environment, including deforestation and unregulated construction, exacerbated the impact of the heavy rainfall.

Issues/Challenges

The Amarnath Flash Floods of 2022 presented several significant challenges:

- **Loss of Life and Displacement:** The flash floods resulted in at least 16 fatalities, with over 40 individuals reported missing.
- **Rescue and Relief Operations:** The suddenness of the disaster posed challenges for rescue teams, leading to delays in reaching affected areas and providing timely assistance.
- **Infrastructure Damage:** The floods caused extensive damage to infrastructure, including roads and communication lines, hindering relief efforts and access to the affected regions.

Recommendations

Pilgrims planning to undertake the Amarnath Yatra are advised to stay updated with the latest weather forecasts and adhere to guidelines issued by authorities. It's essential to remain vigilant and prepared for sudden weather changes in the region.

By staying informed and following the safety measures, pilgrims can contribute to a safer pilgrimage experience.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons	Recommendations
Early Warning	Rainfall alerts issued	No cloudburst warning	Micro-level warnings needed	Install localized EWS
Pilgrimage Management	Large gathering present	Carrying capacity ignored	Crowd = disaster risk	Enforce carrying capacity
Camp Location	Tents washed away	Located on flood path	Site planning critical	Relocate camps to safe zones
Response	Army/NDRF rescued pilgrims	Terrain constraints	Pre-positioning saves lives	Pre-deploy SAR teams
Climate	Extreme rainfall	Climate ignored	Cloudbursts increasing	Climate-informed planning

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Uttarakhand Avalanche, 2022

Introduction

Avalanches are one of the most dangerous natural disasters in mountainous areas, caused by the rapid sliding of snow, ice, and debris down slopes. This phenomenon can be caused by a variety of circumstances, including intense sunshine, human activity, vibrations, steep gradients, variable temperatures, or snow layer instability.

On October 4, 2022, an avalanche was triggered approximately 6 km uphill of the Kedarnath temple from the peaks of the companion glacier that flows parallel to Chorabari Glacier. A team of 41 climbers from the Nehru Institute of Mountaineering (NIM) was conducting an advanced mountaineering course on Draupadi Ka Danda II, a peak in the Garhwal Himalaya region of Uttarakhand. The group, comprising 34 trainees and 7 instructors, was descending from the summit when they were struck by this avalanche at approximately 8:45 a.m.

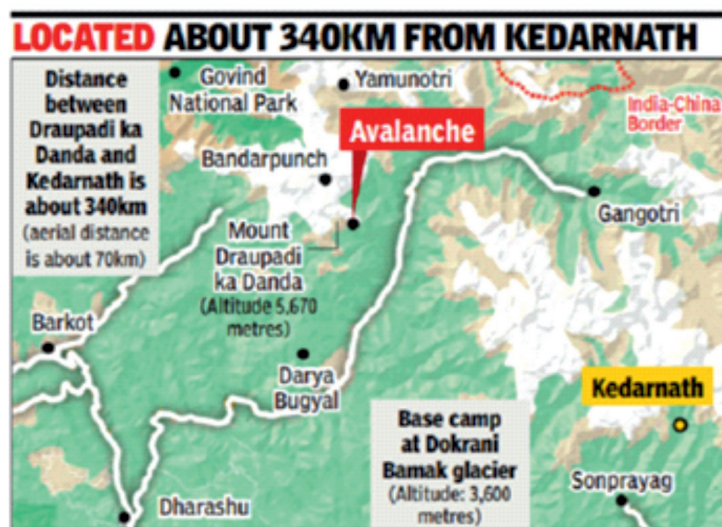


Fig - 77 : Location of Uttarakhand Avalanche

Source :- Times of India



Fig - 78 : Mount Draupadi-ka-Danda-2, the site of avalanche disaster in Bhatwari tehsil of Uttarkashi district

Source :- Indian Express

This incident not only highlights the unpredictable nature of avalanches but also underscores the importance of rigorous safety protocols and preparedness in mountaineering expeditions. In the aftermath, the mountaineering community and relevant authorities have been prompted to re-evaluate training methodologies, early warning systems, and emergency response mechanisms to mitigate such risks in the future.

Impact

The avalanche resulted in the deaths of 26 individuals, with 24 being trainees and 2 instructors.

Response

- **Immediate Rescue Operations:** The Indian Air Force (IAF), along with the State Disaster Response Force (SDRF), National Disaster Response Force (NDRF), Indo-Tibetan Border Police (ITBP), and the Indian Army, initiated rapid rescue missions to locate and assist the trapped mountaineers.
- **Weather Monitoring:** Meteorological departments closely monitored weather conditions to provide timely updates, aiding in the planning of rescue operations and ensuring the safety of personnel involved.
- **Support for Victims' Families:** The state government announced compensation packages for the families of the deceased and injured, offering financial assistance and support during their recovery.

Causes

- Prior to the incident, the region experienced unusually high levels of rainfall and snowfall. This excessive precipitation increased the snow load on the slopes, making them more susceptible to avalanches(NDMA)
- The area around Draupadi Ka Danda II is known for its glacial terrain. While specific glacial activity was not directly linked to this incident, such environments inherently carry avalanche risks due to the presence of snow and ice.

- The steep slopes and unpredictable weather patterns in the Garhwal Himalaya region contribute to avalanche risks.

Challenges

- **Treacherous Terrain:** The high-altitude areas where avalanches occur are characterized by steep slopes and deep crevasses, making access difficult for rescue teams.
- **Communication Barriers:** Remote locations often suffer from poor communication infrastructure. In the aftermath of avalanches, establishing reliable communication becomes challenging, hindering coordination among rescue teams.
- **Unpredictable Weather:** Rapidly changing weather conditions can exacerbate the situation, making rescue operations perilous. Authorities have mounted efforts to retrieve bodies from exposed mountain faces, risking bad weather and treacherous terrain.

Recommendations

- **Slope Modification:** Implement benching at various elevations along steep snowdrift channels north of the temple to reduce slope angles and slow snow and debris movement.
- **Structural Barriers:** Construct concrete wedges mid-slope in avalanche-prone chutes to divert descending snow and ice, minimizing potential damage.
- **Momentum Reduction Mounds:** Build mounds to arrest and break the momentum of decelerating avalanche masses, bringing moving ice to rest quickly and protecting downstream structures.
- **Construction Prohibition:** Enforce a complete ban on building in unstable areas, such as scree fans and active debris slopes, to prevent altering the angle of repose of loose materials, which could exacerbate avalanche risks.
- **Public Awareness:** Launch media campaigns to educate the public about natural snow accumulation processes in glacial environments, preventing the spread of rumors and misinformation.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons	Recommendations
Avalanche Forecasting	Weather warnings issued	No avalanche alert	Hazard-specific warnings needed	Expand avalanche forecasting
Workforce Safety	Workers trapped	Limited protective protocols	Occupational safety critical	Enforce high-altitude safety SOPs
Rescue	Army/ITBP rescued workers	Difficult terrain	Specialized capacity vital	Strengthen mountain SAR units
Infrastructure	Project in avalanche zone	Risk underestimated	Siting decisions matter	Reassess project locations
Climate	Snow instability	Climate overlooked	Climate alters cryosphere risk	Integrate climate data

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Morbi Bridge Collapse, 2022

Introduction

India's bridge infrastructure has faced significant challenges, with approximately 2,000 bridge failures reported between 1977 and 2017. The average age of these failed bridges was 34.5 years, notably shorter than their expected design life, indicating systemic issues in maintenance and durability.

Morbi, located in the Saurashtra region of Gujarat, India, boasts a rich history and cultural heritage. One of the town's prominent attractions was the Machchhu River suspension bridge, sometimes called Jhulto Pul or "suspension bridge." Built during British administration in the 1880s, the bridge served as a crucial connection for the local community by connecting Darbargadh Palace with Nazarbag Palace. In consequence of its limited design, the bridge could only accommodate 15 passengers at first. The bridge measured 1.25 meters wide by 230 meters long. However, with an enhanced capacity of 125 people, it was reopened on October 26, 2022, after undergoing improvements over time.

Tragically, the bridge collapsed on October 30, 2022, with more than 500 passengers on board. According to a forensic assessment, the bridge's structural integrity was compromised by corroded cables, fractured anchors, and loose bolts. Investigations also showed that the bridge had been reopened without the required safety certifications. There were nine people that worked for the private company that maintained the bridge. All were arrested and charged under various sections of the Indian Penal Code, including culpable homicide not amounting to murder



Fig - 79 : Morbi Bridge Collapse

Source :- BBC

Impact

The Morbi Bridge collapse on October 30, 2022, had profound and far-reaching impacts on the local community, the state of Gujarat, and the nation as a whole.

Humanitarian Impact

The immediate outcome was the terrible loss of at least 135 people, including many women and children. Nine persons were critically hurt and admitted to the hospital. This tragic catastrophe devastated many families and created significant trauma among survivors and bystanders.

Economic Impact

Morbi's economy, that had been mainly depending on the ceramic and wall clock sectors, suffered major disruption. The collapse of the bridge, a famous tourist destination, resulted in a reduction in tourists, harming local businesses and livelihoods. The incident also spurred a re-evaluation of infrastructure safety, which could result in higher maintenance and upgrading expenses across the region.

Political and Social Impact

The event caused considerable public outcry and raised questions about infrastructure maintaining and safety standards. Accusations of corruption and carelessness surfaced, prompting investigations and arrests. The incident fuelled debates about the need for more laws and control in infrastructure projects to avoid similar calamities in the future.

Legal and Regulatory Impact

In the aftermath, authorities arrested nine individuals associated with the private company responsible for the bridge's maintenance, charging them under various sections of the Indian Penal Code, including culpable homicide not amounting to murder. This legal action underscored the serious consequences of neglecting public safety and highlighted the importance of accountability in infrastructure management.

Possible Causes/ Reasons

A preliminary report submitted by the Special Investigation Team (SIT) appointed by the Gujarat government has revealed that the collapse of a suspension bridge was caused by several major faults.

- **Corrosion of Structural Components:** The bridge's main cables, each comprising seven strands of seven steel wires (totaling 49 wires), exhibited significant corrosion. The SIT report noted that 22 out of these 49 wires were corroded, indicating that these wires may have already broken before the incident.
- **Altered Load-Bearing Capacity:** During recent repairs, old suspenders (steel rods connecting the cable to the deck) were welded to new ones. This modification changed the behavior of the suspenders, potentially compromising the bridge's load-bearing capacity. The SIT emphasized that in such bridges, single rod suspenders should be used to bear the load.
- **Lack of Structural Testing:** Before reopening the bridge, no comprehensive load testing or structural analysis was conducted. This oversight failed to identify critical issues, such as the corroded wires and altered suspenders, which could have been detected through proper testing.
- **Inflexible Deck Structure:** The replacement of individual wooden planks with an aluminium deck contributed

to the collapse. The aluminum panels were fixed without any gaps, reducing the deck's flexibility and increasing its overall weight. This rigidity and added weight may have compromised the bridge's structural integrity.

Response

In the aftermath of the Morbi bridge collapse on October 30, 2022, the following actions were undertaken:

Rescue Operations:

- **Deployment of Emergency Services:** Five teams from the National Disaster Response Force (NDRF) were among the first responders, swiftly reaching the site. Subsequently, personnel from the Army, Navy, and Air Force joined the efforts. Rescue operations were conducted using boats, with the Indian Coast Guard deploying three teams equipped with divers, equipment, and boats. Additionally, the municipal corporation and fire brigade departments provided rescue boats and life jackets, while over 25 ambulances from various sources, including the Army, were stationed at the location. Seven deep divers from the Navy, equipped with lighting for underwater operations, were also deployed.

Compensation and Assistance:

- **State Government Compensation:** The Gujarat state government announced a compensation of ₹4 lakh for the families of each deceased victim and ₹50,000 for the injured.
- **Prime Minister's Relief Fund:** Prime Minister Narendra Modi declared ex-gratia of ₹2 lakh from the Prime Minister's National Relief Fund for the next of kin of each deceased and ₹50,000 for each injured individual.



Fig - 80 : Rescue Operations After Morbi Bridge Collapse

Source :- Twitter



Fig - 81 : Recue Operations After Morbi Bridge Collapse

Source : - Twitter



Fig - 82 : Recue Operations After Morbi Bridge Collapse

Source :- Twitter

Issues/ Challenges/ Concerns

The collapse of the Morbi bridge highlighted several critical issues and challenges:

1. Inadequate Safety Standards and Maintenance:

- **Lack of Official Inventory:** India lacks an official inventory of pedestrian footbridges, complicating maintenance and safety oversight.
- **Insufficient Standards:** Among the 256 standards published by the Indian Roads Congress, only one addresses the “Design of Small Bridges and Culverts,” leaving a gap in comprehensive safety guidelines.

2. Regulatory and Oversight Failures:

- **Premature Reopening:** The bridge was reopened without the necessary safety certifications from local authorities, bypassing required safety audits
- **Lack of Structural Testing:** No comprehensive load testing or structural analysis was conducted before reopening, missing critical issues that could have been identified.

3. Structural Integrity Concerns:

- **Corrosion and Wear:** Main suspension cables exhibited significant corrosion, with 22 out of 49 wires corroded, indicating potential pre-existing weaknesses.

Recommendations

For India to begin future-proofing its bridges, a methodical yet doable three-step plan must be implemented at the very beginning.

- **Establish a Comprehensive Footbridge Inventory:** Compile detailed records for each footbridge, including construction date, materials used, structural design, and usage frequency. This information should be maintained in a centralized asset register at the state or district level.
- **Implement Regular Inspection Protocols:** Develop and enforce standardized procedures for the routine inspection and monitoring of footbridge conditions. This proactive approach will facilitate the early detection and remediation of potential structural issues.
- **Develop Adaptive Safety Standards for High-Usage Events:** Formulate national structural safety guidelines that account for exceptional circumstances, such as festivals or public gatherings, ensuring that footbridges can safely accommodate temporary surges in pedestrian traffic.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons	Recommendations
Structural Safety	Suspension bridge collapsed	Poor maintenance	Maintenance saves lives	Mandatory structural audits
Crowd Load	Overcrowding observed	Load limits ignored	Crowd control critical	Enforce capacity limits
Governance	Bridge reopened post-renovation	Weak certification	Safety certification vital	Independent safety clearance
Emergency Response	Swift local response	Limited preparedness	Preparedness reduces fatalities	Emergency planning
Policy	Inquiry initiated	Reactive regulation	Infrastructure safety reform	National safety standards

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Mundka Fire, 2022

Introduction

According to the National Crime Records Bureau (NCRB), fire incidents and related hazards result in approximately 25,000 fatalities annually in India. Women constitute nearly 66% of these casualties. Fire-related fatalities account for approximately 6% of all deaths attributed to natural or human-induced causes in the country.

A fire incident occurred on May 13, 2022, in a four-story commercial building near Mundka metro station in Delhi. The fire reportedly started around 4:40 PM on the first floor, which was occupied by Cofe Impex Pvt Ltd, a company manufacturing CCTV cameras and Wi-Fi routers.

When the explosion propagated, the individuals within the building were scattered out across multiple floors. On the first floor the employees were working at the offices of the CCTV and Wifi router assembly unit. Most people were on the second floor attending the motivational speaker's session. Others on the third floor were working at the assembly units (Singh and Bhandari, 2022). Survivors explain the situation that there were no windows in the hall on the second floor. Glass panels that covered the building on all sides were bolted, leaving just one exit from the inferno- a lone staircase. But that route was also blocked by the blaze. Officers at the site claimed because of the smoke, many workers in the building jumped out of the windows to survive (Disaster & Development, Vol. 11, Issue 02, July to December 2022).



Fig - 83 : Fire at four-story commercial building

Source :- Amarujala



Fig - 84 : Photo of the Building

Source :- Amarujala

Impact

Nearly 120 people became trapped in the fire, and 27 died from burn injuries, including 21 women, while 40 were injured. Many of the deceased were young women, some as young as 18, who were the primary breadwinners for their families.

Possible Causes/ Reasons

As per Delhi Chapter of Working Peoples' Charter (WPC), has termed the fire incident a "monumental criminal negligence of workers' safety by employers in connivance with the administration".

- According to the WPC, the four-story building was used for industrial purposes, which was forbidden in the area, and the unit was functioning without a valid factory license. It violated all labor rules and safety requirements since it was in a congested area, lacked adequate fire safety measures, and lacked a No Objection Certificate from the fire department.
- Preliminary investigations suggested that the fire originated from a short circuit on the first floor of the four-storey building. The presence of plastic materials on this floor facilitated the rapid spread of the fire, leading to massive smoke accumulation and hindering escape efforts.
- Reports indicated that the fire service arrived at the scene over an hour and a half after the incident was reported, delaying rescue operations. In contrast, a crane driver managed to rescue over 50 people trapped in the blaze, highlighting the critical role of timely emergency responses.

Response

- Eyewitness accounts and reports indicate that the response time of emergency services was delayed. Notably, a crane operator available near the site played a crucial role in rescuing over 50 individuals by assisting them in escaping the burning building before the fire services arrived.
- In order to rescue those who were trapped, the fire department deployed cranes while police officials broke

the windows of the building to help the people. Following a six-hour long firefighting operation, the blaze was brought under control.

- Police, fire department and NDRF teams were involved in the rescue work.
- In the wake of the tragedy, Delhi Police registered a case of culpable homicide and criminal conspiracy. Two brothers, owners of Cofe Impex Pvt Ltd, were arrested in connection with the incident.

Issues/ Challenges

- **Non-Compliance with Fire Safety Regulations:** The building lacked clearance from the fire department and was not equipped with essential fire safety measures such as fire extinguishers, hose reels, or fire detectors.
- **Inadequate Emergency Response:** Reports indicated that fire services arrived at the scene over an hour and a half after the fire had started, delaying rescue operations and exacerbating the situation.
- **Worker Safety and Rights Violations:** Investigations revealed that the factory employed a predominantly female workforce, many of whom were below 30 years of age. These workers were subjected to unsafe working conditions, including the absence of fire safety measures and inadequate emergency protocols.
- **Building Infrastructure Issues:** The building's design and infrastructure lacked essential safety features, such as multiple exits and fire-resistant materials, which are crucial for preventing the rapid spread of fire and ensuring safe evacuation.

Recommendations

Strengthen Fire Safety Regulations:

- Implement rigorous fire safety standards across industrial buildings.
- Ensure regular inspections and the mandatory installation of fire safety equipment.

Enhance Emergency Response Systems:

- Improve response times of emergency services.
- Conduct regular fire drills and preparedness training to reduce casualties.

Protect Workers' Rights:

- Ensure workers are officially registered and receive proper safety training.
- Provide adequate compensation and support to the families of victims to address socio-economic impacts.

Improve Building Infrastructure:

- Incorporate fire-resistant materials in building designs.
- Design buildings with multiple exits and clearly marked evacuation routes to ensure swift and safe evacuations during emergencies.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons	Recommendations
Fire Safety	Massive fire in commercial building	No fire clearance	Compliance is non-negotiable	Enforce fire safety laws
Building Design	Single exit, no ventilation	Unsafe design	Design failures kill	Strict building code enforcement
Worker Safety	Workers trapped	No evacuation drills	Drills save lives	Mandatory fire drills
Emergency Response	Fire services mobilized	Access constraints	Access planning critical	Ensure emergency access
Governance	Sealing drives post-incident	Reactive action	Prevention over penalties	Regular inspections

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Assam Floods, 2022

Introduction

Northeast India has been experiencing an alarming increase in flood frequency and intensity in recent years. This trend is largely attributed to erratic and intensified monsoon rainfall patterns, which have led to severe flooding and landslides across the region.

In 2022, Assam faced three waves of floods affecting 35 districts, resulting in loss of human lives, livestock and large-scale damage to the dwelling houses, standing crops, infrastructure like roads, bridges, embankments, schools, etc. Each wave of flood is counted from the date of starting of flood till recession to normal situation.

- First wave of Flood: In the first wave of flood (6th April to 12th June 2022) 33 districts were affected in the State viz. Bajali, Baksa, Barpeta, Biswanath, Bongaigaon, Cachar, Charaideo, Darrang, Dhemaji, Dhubri, Dibrugarh, Dima-Hasao, Goalpara, Golaghat, Hailakandi, Hojai, Jorhat, Kamrup, Kamrup (M), Karbi Anglong West, Karimganj, Kokrajhar, Lakhimpur, Majuli, Morigaon, Nagaon, Nalbari, Sivasagar, Sonitpur, South Salmara, Tamulpur, Tinsukia, Udalguri
- Second wave of Flood: In the second wave (13th June to 16th September 2022) 34 districts were affected viz. Bajali, Baksa, Barpeta, Biswanath, Bongaigaon, Cachar, Charaideo, Chirang, Darrang, Dhemaji, Dhubri, Dibrugarh, Dima-Hasao, Goalpara, Golaghat, Hailakandi, Hojai, Jorhat, Kamrup, Kamrup (M), Karbi Anglong West, Karimganj, Kokrajhar, Lakhimpur, Majuli, Morigaon, Nagaon, Nalbari, Sivasagar, Sonitpur, South Salmara, Tamulpur, Tinsukia, Udalguri
- Third wave of Flood: In the second wave (7th October to 28th October 2022) 15 districts were affected viz. Darrang, Dhemaji, Dhubri, Dibrugarh, Golaghat, Jorhat, Karbi Anglong, Kokrajhar, Lakhimpur, Majuli, Morigaon, Nagaon, South Salmara, Tinsukia, Kamrup

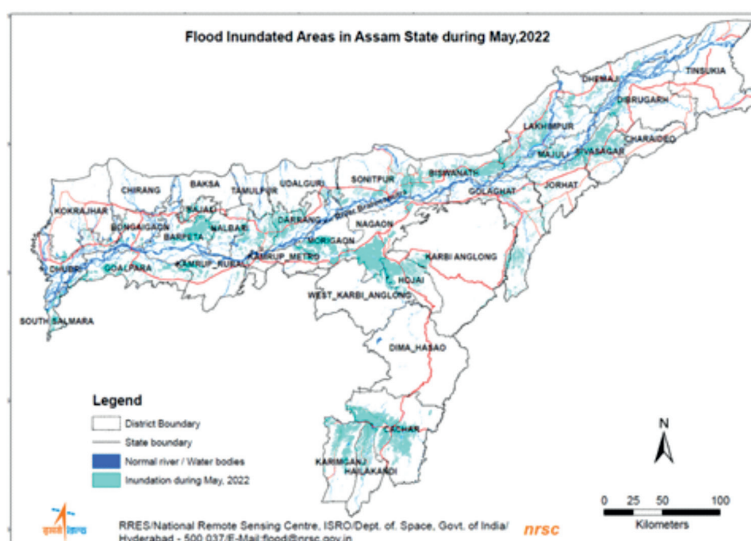


Fig - 85 : Flood Inundated Areas in Assam, May 2022

Source :- ISRO, NRSC

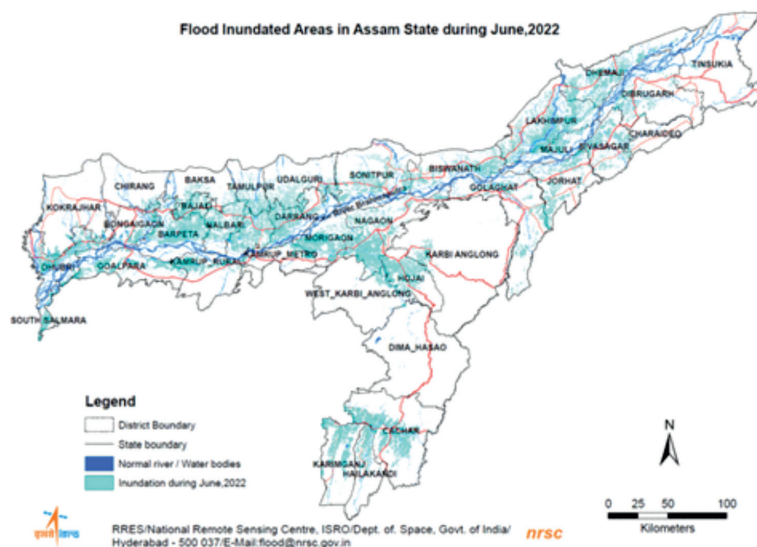


Fig - 86 : Flood Inundated Areas in Assam, June 2022

Source : ISRO, NRSC

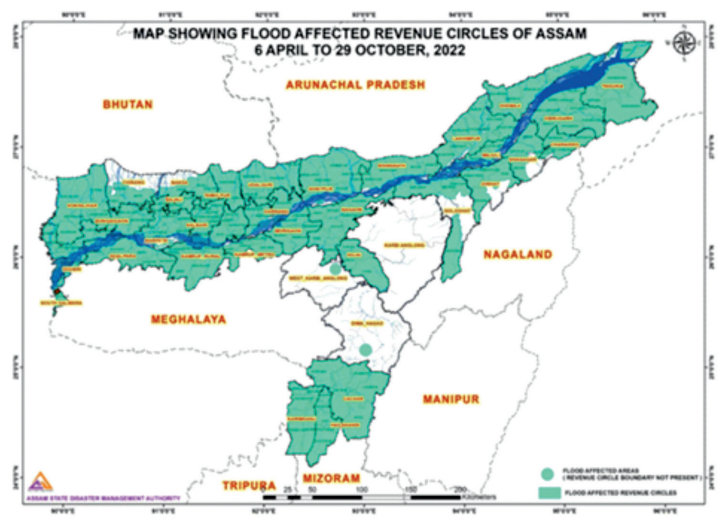


Fig - 87 : Flood Affected Revenue Circles of Assam

Source :- Assam Floods Memorandum, Govt. of Assam

Impact

In the Assam floods of 2022, 181 people lost their lives due to flooding and landslides across the state since the monsoon season began on April 6, 2022. Around 700 families in the area were affected by the flooding and lacking a supply of drinking water and dry rations. 96 Revenue Circles and 2,930 villages were impacted by flood incidents, including approximately 1.9 million people, over 100,000 of which took shelter in 373 relief camps.

As per ASDMA, during the 1st wave of floods (06-Apr-2022 to 12-Jun-2022), 33 districts were significantly affected, with 4,273 villages impacted. A total of 1,039,412 people were affected, and 33 lives were lost. During the 2nd wave of floods, A total of 34 districts were affected, with 9329 villages impacted. Approximately 8,770,186 people were affected, and 148 human lives were lost due to the flood. The 3rd wave impacted 15 districts and 514 villages, affecting a population of 84,713. However, there were no human lives lost during this wave.

Table 7 : Details of the three waves of floods in the year 2022

PERIOD	NO.OF DISTRICTS	NO.OF VILLAGES	POPULATION AFFECTED	HUMAN LIVES LOST IN FLOOD
1 st wave (06-Apr-2022 to 12-Jun-2022)	33	4273	1039412	33
2 nd wave (13-Jun-2022 to 16 Sept-2022)	34	9329	8770186	148
3 rd wave (7-Oct-2022 to 28-Oct-2022)	15	514	84713	0

Source : Assam Floods Memorandum, Govt. of Assam

Possible Causes/ Reasons

The state is traversed by an extensive network of rivers and tributaries, originating from steep upper catchment areas.

- **First Wave of Floods:** The first wave of flooding was triggered by intense rainfall in Assam and neighbouring states like Arunachal Pradesh and Meghalaya. From May 12th to May 18th, 2022, these regions experienced significantly above-normal rainfall, with deviations of 158% in Arunachal Pradesh, 663% in Meghalaya, and 327% in Assam. This excessive rainfall impacted around 10.39 lakh people. The situation began to stabilize after May 28th, 2022.
- **Second Wave of Floods:** The second wave was caused by renewed heavy rainfall in Arunachal Pradesh, Meghalaya, and Assam, leading to a sudden spike in the affected population, with 55.42 lakh people impacted on a single day, June 21st, 2022. Rainfall deviations during June 12th to June 18th, 2022, were 94% in Arunachal Pradesh, 329% in Meghalaya, and 235% in Assam.
- **Third Wave of Floods:** Another round of excessive rainfall occurred between October 8th and October 12th, 2022, with deviations of 356% in Arunachal Pradesh, 204% in Assam, and 82% in Meghalaya. This resulted in flooding across 14 districts during the third wave.

The cumulative population affected by the three waves of floods up to October 28th, 2022, reached 88.51 lakh. Additionally, the release of excess water from Bhutan's Kurichhu Dam contributed to flooding in the lower districts of Assam.

Response

- Agencies like the National Disaster Response Force (NDRF), State Disaster Response Force (SDRF), and local administrative authorities carried out extensive rescue operations in the affected regions. Through their efforts, 11,881 individuals were safely evacuated.
- The NDRF, SDRF, fire and emergency services, police, and trained Aapda Mitra volunteers from the Assam State Disaster Management Authority worked together to assist district authorities in evacuating people from flood-hit areas.
- During the heavy rainfall season, the Southwest Monsoon reached most parts of Northeast India. In response to a request from the Assam government, 27 NDRF teams were deployed across locations such as Guwahati, Cachar, Barpeta, Darrang, Tamulpur, Kamrup Rural, Jorhat, Bongaigaon, and Silchar. These teams worked swiftly in the most affected regions to restore normalcy. Their actions resulted in rescuing nine individuals, evacuating 22,410 people and 32 livestock, recovering 13 bodies, and providing pre-hospital treatment (PHT) to 17 individuals.
- The Union Government extended financial assistance of ₹648.48 crore to support Assam's relief and rehabilitation efforts.
- UNICEF mobilized teams in the worst-affected districts to provide urgent assessments and services. They focused on health, nutrition, water, sanitation, education, and child protection. Temporary toilets, water filtration systems, and child-friendly spaces were also established in relief centers to address immediate needs.
- The APPL Foundation distributed 1,636 kits containing essential items such as CGI sheets, water purifiers, cooking utensils, blankets, and reusable menstrual hygiene products to assist flood-affected families.
- Humanitarian Aid International (HAI) provided emergency relief kits to at least 3,000 families, prioritizing women-led households, marginal and landless farmers, and families with members with disabilities in districts with unmet needs.
- The North-East Affected Area Development Society (NEADS), an Assam-based organization supported by HAI, received funding of £60,000 from the Start Network to address the crisis. NEADS played a key role in delivering humanitarian aid to displaced and affected communities.



Fig - 88 : Rescue by 12th bn. NDRF at Biswanath & Sonitpur

Source :- Assam Floods Memorandum, Govt. of Assam



Fig - 89 : Relief Distribution at the flood affected areas of Assam

Source :- Assam Floods Memorandum, Govt. of Assam



Fig - 90 : Air Evacuation and Food Dropping at Dima, Hasao District, Assam.

Source :- Assam Floods Memorandum, Govt. of Assam

Issues

- **Recurrent Flooding:** Assam experienced three waves of flooding in 2022, affecting over 88 lakh people and straining relief efforts.
- **Loss of Lives and Livelihoods:** Over 180 people lost their lives, with widespread destruction of crops, livestock, and means of livelihood.
- **Infrastructure Damage:** Floodwaters caused severe damage to roads, bridges, homes, and communication systems.

- **Health and Sanitation Problems:** Disease outbreaks and poor sanitation created significant challenges in relief camps.
- **Environmental Effects:** Soil erosion, sediment buildup, and ecological damage worsened the situation.
- **Dam Water Release:** Release of excess water from Bhutan's Kurichhu Dam aggravated flooding in lower Assam.
- **Preparedness Issues:** Limited communication of flood warnings and lack of preparedness hampered timely evacuation efforts.

Recommendations

- Improve real-time flood forecasting and ensure timely dissemination of warnings to vulnerable communities through multiple communication channels.
- Implement sustainable riverbank protection measures, desilting of rivers, and afforestation to reduce soil erosion and sedimentation.
- Collaborate with neighbouring countries like Bhutan for better water release management and coordinated flood control measures.
- Train and empower local communities through capacity-building programs, such as Aapda Mitra, to improve preparedness and response.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons	Recommendations
Flood Warning	IMD/CWC forecasts	Weak dissemination	Last-mile communication vital	Community warning systems
Evacuation	Recurrent displacement	No permanent solutions	Chronic floods need long-term planning	Raised housing, relocation
Ecosystems	Wetland degradation	Weak protection	Nature buffers floods	Wetland restoration
Livelihoods	Agriculture losses	Delayed compensation	Quick recovery reduces poverty	DBT compensation
Climate	Frequent floods	Climate underestimated	Floods are climate-driven	Climate-informed planning

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Trikut Ropeway Incident, 2022

Introduction

Ropeways, while offering efficient transportation and scenic views, can pose significant risks if not properly maintained or operated. Mechanical failures, inadequate maintenance, or operator errors can lead to severe accidents, resulting in injuries or fatalities.

In India, there have been notable ropeway incidents underscoring these dangers. In April 2022, a tragic accident occurred at Trikut Hill in Jharkhand's Deoghar district, due to sudden technical snag, wire of ropeway came off and the cable cars plying on the ropeway lay hanged in mid-air. Trikut hill is situated at Trikut Basdiha in Mohanpur block of Deoghar district in Jharkhand state. There are three main peaks on the Trikut hill which is why it is called Trikutachal. Height of this hill is 2470 feet. Trikut Ropeway is India's highest vertical ropeway with the maximum lens angle of 43.7 degrees. Oneway length of ropeway is 766 meters (2512 feet).



Fig - 91 : A photo from the accident site where cable cars collided in Deoghar

Source :- India Today

The ropeway was inaugurated in 2009. Initially, the consultancy to build the ropeway was with RITES, a Government of India enterprise under the aegis of Indian Railways. However, later Damodar Ropeways and Infra Ltd. (DRIL) gained the contract and since then DRIL designed, built, operated, and maintained the ropeway and paid an annual license fee to the Jharkhand government.

Impact

About 76 passengers lay hanged in mid-air out of which about 17 passengers in cars which lay at low height managed to get down leaving 59 passengers (32 males and 27 females including 9 children) hanging at different heights.

Response

The response and stabilization of the incident took almost 48 hrs. In entire rescue operations, 56 passengers, comprising of 31 males and 25 females including 9 children, out of 59 were rescued while 3 of them lost their lives. The rescue operations were wound up after confirmatory check was carried out by the joint operations team comprising of Army, ITBP, NDRF and local administration.



Fig - 92 : An Indian Air Force helicopter was deployed for rescue and relief efforts following the collision of two cable cars on the Trikut Ropeway in Jharkhand's Deoghar district.

Source :- Economic Times

The Jharkhand government has blacklisted Damodar Ropeways and Infra Ltd (DRIL), the operator of the Trikut Hills cable car in Deoghar district, for a period of five years. Additionally, a fine exceeding ₹9 crore has been imposed on the company.

Response by various stakeholders:

- **State Government**
Following the incident, the State Government deployed a team, led by the Secretary of Disaster Management, to oversee rescue operations. A high-level committee, chaired by Principal Secretary A.K. Singh, was formed on April 19, 2022, with a two-month mandate to investigate the accident. Experts from RITES and ISM Dhanbad were engaged for technical assessments. The government announced ₹5 lakh ex-gratia per victim, while DRIL provided ₹25 lakh each. The Jharkhand High Court also initiated a suo-motu inquiry.
- **District Administration**
Upon receiving information, the Deputy Commissioner (DC) and officials reached the site, coordinating with state authorities and requisitioning the Army, Air Force, NDRF, and ITBP for rescue operations. The DC, supported by the District Disaster Management Officer (DDMO), ensured unified command under IRS principles. DDMO facilitated rescue logistics, provided essentials to stranded passengers, and coordinated with local volunteers. Passenger details were collected via public announcements to offer psychological

support and connect them with relatives.

- **Indian Army & Indian Air Force**

The Indian Air Force led a joint rescue operation under the Headquarters Integrated Defence Staff (HQ IDS), supported by the Army's 23 Infantry Division. Five helicopters (Mi-17 V5, ALH, Mi-17, and Cheetah) and mountaineering experts were deployed. Rescue operations were divided into ground (Indian Army, NDRF, ITBP) and air (IAF Garuds). A joint command post was set up with key officials. Seven passengers were rescued through belaying action, and medical aid posts were established. The IAF carried out 36 sorties, overcoming strong rotor downwash challenges.

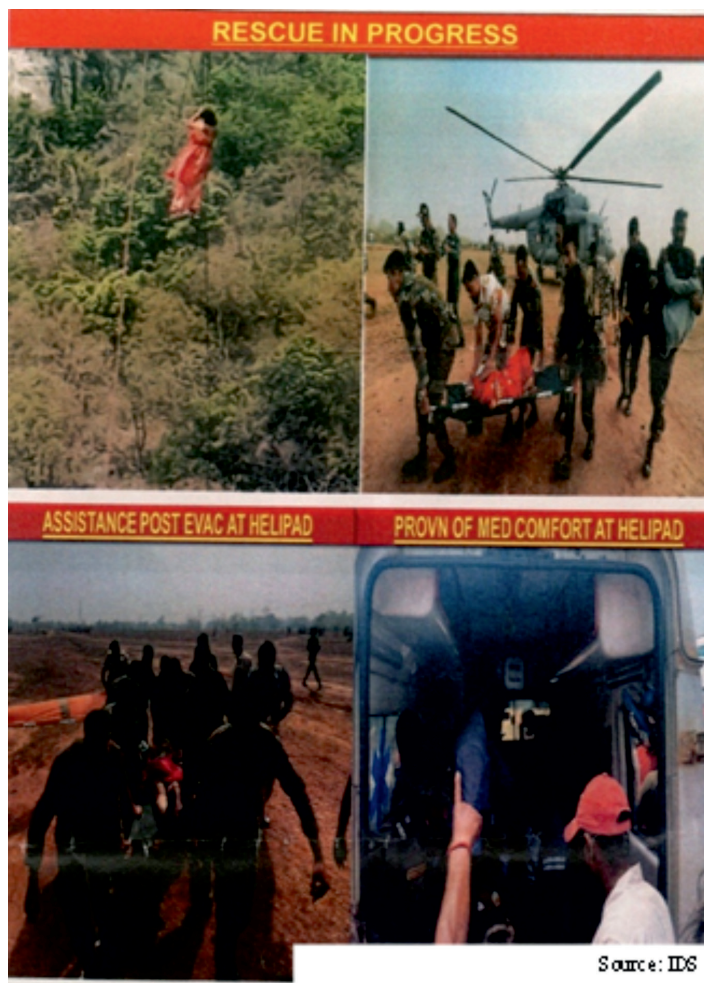


Fig - 93 : An Indian Air Force helicopter was deployed for rescue and relief efforts following the collision of two cable cars on the Trikut Ropeway in Jharkhand's Deoghar district.

Source :- Economic Times

- **Indo-Tibetan Border Police (ITBP)**

On orders from the 40th Battalion Commandant, the ITBP team reached the site and assisted in medical support, coordination, and aerial and ground rescues. Using drones, they provided food and water to stranded passengers. When initial heli-rescue attempts failed, ITBP improvised an anchor pulley and belay method, eventually evacuating all 56 passengers safely.

- **National Disaster Response Force (NDRF)**

NDRF's 9th Battalion, stationed at Deoghar, was immediately deployed. Due to challenging terrain, night rescues were not possible, but they maintained constant communication with passengers for psychological support. Additional teams from Patna and Ranchi, along with senior officers from Delhi, reinforced efforts. Food and water were supplied via maintenance trolleys. Through joint efforts of all agencies, all passengers were successfully evacuated.

Possible Causes

- **Mechanical Failure:** The primary cause was the failure or breaking of the return shaft during operation, leading to the displacement of the bull wheel and subsequent dislocation of the rope from the return bull wheel. This dislocation caused a cabin to lose its grip and fall to the ground.
- **Inadequate Maintenance:** The operating company, Damodar Ropeways and Infra Limited (DRIL), failed to adhere to preventive maintenance plans and schedules. Maintenance records were not in compliance with the required formats for daily and monthly upkeep of passenger ropeways.
- **Substandard Materials:** The grease used had a graphite flake content of 0.96%, significantly below the specified minimum of 6%. This deficiency increased friction between the shaft and bearings, potentially leading to enhanced stress and eventual failure of the shaft.

Challenges

- Limited experience in handling such rescues, as mid-air evacuations of this nature are extremely rare.
- The operation required highly specialized personnel equipped with advanced tools to safely conduct mid-air rescues.
- The low altitude of the stranded cable cars posed a significant risk to helicopters during the rescue process.
- The combination of rugged mountainous terrain and strong winds created obstacles for aerial rescue efforts.
- Limited access to the suspended cable cars made it difficult for rescue teams to reach the stranded passengers and deliver essential supplies.
- The challenging landscape rendered nighttime rescue operations unfeasible.
- The powerful rotor downwash from the Mi-17 helicopter caused instability in the winching rope, complicating the air rescue efforts.

Recommendations

- Regular maintenance of the ropeways and machines should be done, to avoid mechanical and other snags.
- DRIL must ensure the quality check on equipments and components of ropeway being procured from other agencies.
- Must prepare disaster management plan of the site in close consultation with district and local administration.
- A joint committee must be constituted for regular monitoring of activities being undertaken at ropeway site

including its maintenance

- Must organize regular mock drills of preparedness and response at ropeway site
- Rescue ropeway must be installed at the Trikut site.
- One team of SDRF personnel must be stationed at every such site.

Lessons Learned Matrix

Thematic Area	Observed Practice	Gaps	Lessons	Recommendations
Mechanical Safety	Ropeway stalled mid-air	Poor maintenance	Mechanical safety critical	Periodic technical audits
Emergency Rescue	Air rescue conducted	No ropeway rescue SOP	Preparedness saves lives	Ropeway-specific SOPs
Passenger Safety	Tourists stranded	No emergency communication	Communication essential	Install PA & alert systems
Governance	Facility operated by private agency	Weak oversight	Regulation must be strong	Strengthen regulatory framework
Tourism Safety	High tourist footfall	Safety secondary	Tourism safety = DRR	National adventure safety norms

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DISASTER YEAR 2023

Balasore Train Accident Odisha, 2023

Introduction

Odisha, formerly known as Orissa, is a state located on the eastern coast of India. The state is bounded by the Bay of Bengal on the east, West Bengal on the northeast, Jharkhand on the north, Chhattisgarh on the west, and Andhra Pradesh on the south. It has a population of over 4 crore (40 million) people, making it the 11th most populous state in India. The state can be broadly divided into four regions namely; Coastal Plains, Eastern Ghats, Central Plateau and Northern Plateau and Highlands.

Balasore is a coastal district in the northern part of Odisha, bordered by the Bay of Bengal in the east. The district lies between the latitude of 20° 35' N and 21° 1' N and the longitude of 86° 20' E and 87° 29' E. The district also has a few small hills and forests in its northern and western parts. It is known for its strategic location and historical significance. This area is known for its mineral resources. It has a tropical climate characterized by high humidity and hot temperatures throughout the year.

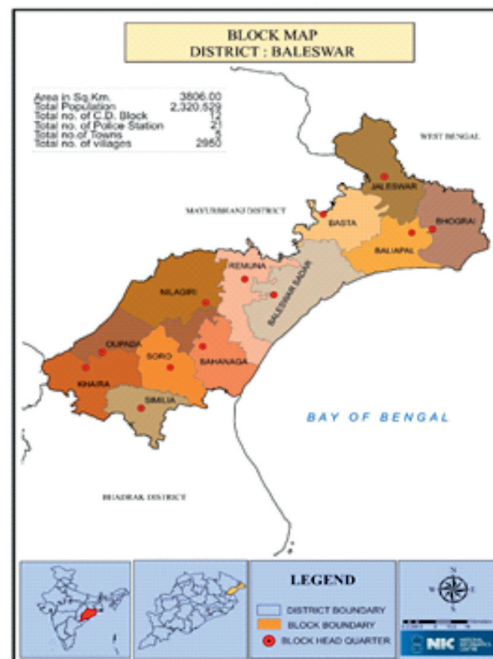


Fig - 94 : Balasore District Map

Source :- <https://gisodisha.nic.in/Block/BALESWAR.pdf>

Overview of the Odisha Train Accident

On the evening of June 2, 2023, tragedy struck at Bahanaga Bazaar Railway Station in Odisha's Balasore district when a horrific triple train collision claimed 288 lives and left over 1,175 injured. The accident involved the Coromandel Express, the Howrah-SMVT Bengaluru Superfast Express, and a stationary goods train, making it one of the deadliest railway disasters in India's history.

The disaster unfolded when the Coromandel Express, traveling at 120 km/h, mistakenly veered onto a loop line instead of the main track due to a suspected signal failure. It crashed into a stationary goods train with immense force, causing multiple coaches to derail violently. Some were thrown into the air, and tragically, a few of the derailed coaches struck the last two bogies of the passing Howrah-SMVT Bengaluru Express, which was traveling in the opposite direction. The entire sequence of events happened within minutes, leaving no time to react.

The scene was one of devastation—smoke, debris, and overturned compartments scattered across the tracks. Immediate rescue efforts were launched by local authorities, NDRF, ODRAF, and volunteers. Rail operations suffered heavily, with dozens of trains canceled or diverted.

Impact of the Odisha Train Accident

- Official figures confirmed 288 deaths, making it one of India's deadliest train accidents.
- Around 1,175 people suffered severe to minor injuries, including burns, fractures, head trauma, and electrocution.
- Many survivors experienced shock, distress, and post-traumatic stress disorder (PTSD) due to the tragic event. 17 coaches were completely destroyed, and several others were severely damaged.
- The railway tracks were extensively damaged, disrupting train services in the region.
- The signal malfunction was identified as a possible cause, emphasizing the need for technical upgrades.
- Over 58 trains were canceled, and 81 were diverted due to the track damage.
- Thousands of travelers faced inconvenience, leading to chaos at nearby railway stations.

Possible Causes

As per the information collected from the district collector of Balasore district, the accident occurred due to a technical (signal) fault, however, the real cause of the incident is yet to be ascertained by the concerned authorities.

Response to the Odisha Train Accident

- As soon as the triple train collision occurred at Bahanaga Bazaar Railway Station, local residents, police, and railway staff rushed to the site to help rescue passengers.
- The Odisha State Emergency Operations Centre was activated after news of the accident spread, mobilizing specialized rescue teams.
- Odisha Fire Services (24 teams, 250 personnel), ODRAF (2 teams), and NDRF (2 battalions, 350 personnel) were deployed, using gas cutters and inflatable light towers to reach trapped passengers.

- Over 250 ambulances, 80 doctors, and paramedics were dispatched, transporting injured survivors to hospitals in Balasore, Cuttack, and Bhubaneswar.
- By early morning, Army and Navy personnel joined the rescue operations, providing additional support in search efforts.
- A local government school was converted into a temporary morgue, and helpline numbers were set up for families to track missing passengers.
- The Odisha Chief Minister visited the site, ordering immediate assistance. Ex-gratia compensation was declared, including ₹10 lakh from Indian Railways and ₹5 lakh from the Odisha government for deceased victims.
- NGOs and volunteers distributed food and water to survivors and rescue workers, while identified victims' bodies were transported home, and unidentified ones shifted to Bhubaneswar.
- Cranes and heavy machinery were deployed to clear wreckage, while shuttle trains were arranged to help stranded passengers continue their journeys.
- High-level railway officials and the Railway Minister inspected the site, ordered a full investigation, and supervised round-the-clock track repairs. Train services resumed after the damaged lines were restored.

Major Issues and Challenges in the Odisha Train Accident

- **Management of Patients/Survivors:** One of the significant challenges faced during a disaster is the simultaneous management of patients/survivors and VIPs. It becomes crucial to prioritize the allocation of limited resources, such as medical personnel, equipment, and facilities. This can be a complex task as it involves making difficult decisions about who receives immediate medical attention and care, considering factors like severity of injuries, critical conditions, and urgency of treatment.
- **Lack of Coordination between Railway Agencies and State Agencies:** In situations where a disaster involves railway accidents or incidents, coordination between railway agencies and state agencies becomes essential. Effective communication and collaboration are required to ensure prompt rescue operations, medical assistance, transportation of injured individuals, and overall management of the situation. However, the lack of coordination and communication channels can hinder the response efforts, leading to delays and suboptimal outcomes.
- **Lack of Nursing Staff at Various Hospitals:** Adequate staffing, particularly nursing staff, is vital for providing timely and quality care to patients during a mass casualty incident. However, many hospitals may face a shortage of nursing personnel, which can strain the capacity to handle a sudden influx of patients. Insufficient staffing levels can result in delayed or compromised patient care, increased workload on existing staff, and overall challenges in managing the volume of patients effectively.
- **Identification of Dead Bodies:** In the aftermath of a disaster, the identification of deceased individuals becomes a critical task. This process requires coordination between different agencies, such as law enforcement, forensic experts, and medical personnel. However, it can be challenging to establish the identities of the deceased, especially if they are severely injured or disfigured. Lack of proper identification procedures or resources can prolong the process, causing distress to the families of the victims.
- **Decaying of Dead Bodies Due to Hot and Humid Climate:** In regions like Odisha with hot and humid climates,

the decomposition of dead bodies can occur at a faster rate, posing additional challenges in managing the aftermath of a disaster. High temperatures and humidity accelerate the decay process, making it crucial to have appropriate facilities and resources for the storage, handling, and identification of bodies. Failure to address this challenge promptly can lead to health risks, logistical difficulties, and emotional distress for families seeking closure.

- **Lack of Facilities to Cater to Mass Casualty Incidents:** Mass casualty incidents can overwhelm healthcare facilities, especially if they are not adequately prepared or lack the necessary resources. The sudden influx of a large number of patients can strain the available infrastructure, equipment, and supplies. Hospitals may face challenges in providing immediate and appropriate medical care, triaging patients effectively, and maintaining a well-functioning system to manage the influx. This highlights the importance of having dedicated facilities and disaster response plans in place to handle such incidents efficiently.

Recommendations

- Coordination between Indian Railways and District/State Administration must be strengthened.
- District Disaster Management Plans must be revised to include railway resources and accidents as disasters to initiate mitigation and preparedness activities.
- Robust and safe technological interventions in modes of transport.
- Capacity building of volunteers is also necessary
- IDRN may include resources available with Indian Railways as well.
- Management of carrying materials with hazardous goods through the district/habitat area.
- Facilitation of relatives of deceased and survivors.
- Strengthening of capacity building initiatives of Aapda Mitras and Civil Defence.
- Learning & Research about potential disasters which can be triggered due to the technological advancement

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Railway Safety Systems	Kavach (Train Collision Avoidance System) not operational on the affected route	Incomplete coverage of automatic protection systems	Safety systems are effective only when universally deployed	Accelerate nationwide implementation of Kavach across all high-density routes
Signalling & Interlocking	Electronic Interlocking failure led to wrong signal routing	Inadequate redundancy and fail-safe mechanisms	Signalling is a single point of failure in rail safety	Introduce multi-layered redundancy and independent signal verification

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Asset Maintenance	High traffic corridor with ageing infrastructure	Maintenance audits not fully risk-based	Preventive maintenance is critical in high-speed corridors	Shift to predictive, condition-based maintenance using sensors and AI
Human Factors	Heavy reliance on manual oversight in signalling operations	Fatigue, training gaps, and workload pressures	Human error must be anticipated in system design	Enhance simulation-based training and periodic competency certification
Emergency Response	Rapid mobilisation of Odisha Government, NDRF, SDRF, Railways, and local volunteers	Initial chaos due to scale of casualties	Preparedness and local capacity save lives	Institutionalise railway disaster response SOPs at district level
Medical Response	Swift triage and treatment at Balasore, Cuttack, and Bhubaneswar hospitals	Limited mass-casualty preparedness at peripheral facilities	Trauma preparedness must extend beyond major cities	Strengthen district hospitals for mass-casualty incidents
Community Participation	Local residents were first responders, providing rescue and blood donation	No formal integration of community responders	Communities are critical immediate responders	Train and formally integrate community volunteers into disaster plans
Communication & Information	Helplines and public information issued quickly	Initial misinformation and distress among families	Crisis communication must be coordinated and humane	Establish single-window disaster information systems
Relief & Compensation	Prompt ex-gratia announced by Central and State Governments	Long-term rehabilitation unclear initially	Relief must transition to structured rehabilitation	Develop standardized

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Cyclone Biparjoy, 2023

Introduction

Cyclone 'Biparjoy' (a Bengali word with literal meaning calamity or disaster) was a powerful tropical cyclone that formed over the east central Arabian Sea. It developed from a low pressure that formed over southeast Arabian Sea on 5th June 2023. It moved nearly northwards and intensified into an extremely severe cyclone with wind speed of about 170 kmph over the sea on 11th June 2023. From 14th June 2023, it moved gradually north-eastwards. The cyclone made landfall near Jakhau Port of Kachchh district between 2230 and 2330 hours IST on 15th June 2023 as a very severe cyclone with maximum sustained wind speed of 115-125 kmph after landfall. It had a long lifespan which lasted for 13 days 3 hours from 0530 hours of 6th June 2023 to 0830 hours of 19th June 2023.

Impact

Cyclone Biparjoy caused extensive damage across multiple sectors in Gujarat, with the total estimated loss amounting to ₹2,99,372.16 lakh. The tourism industry suffered significant setbacks due to strong winds, leading to an estimated loss of ₹377 lakh. The agricultural sector was severely impacted, with 3,53,688 hectares of farmland affected, resulting in production losses of ₹96,437 lakh and asset losses of ₹24,813 lakh. Key crops such as banana, papaya, mango, coconut, lemon, guava, sapota, pomegranate, date palm, vegetables, bajra, sesame, groundnut, moong, and cotton were damaged. The housing sector also faced destruction, with 951 huts and 7,219 dwellings affected, amounting to a loss of ₹1,386.65 lakh.

The industrial and mining sectors were not spared, with lignite mines at Mata no Madh and Umarsar in Kachchh sustaining damage, while bauxite mines recorded losses worth ₹9.5 lakh. The health sector suffered damages worth ₹66 lakh, affecting critical infrastructure such as district hospitals, community health centers, and primary health centers. The food and civil supplies sector incurred losses of ₹80.7 lakh due to damage to storage facilities. Despite these disruptions, pre-emptive actions by POWERGRID, GETCO, and PGVCL helped minimize power outages, ensuring quick restoration post-cyclone.

In terms of livestock protection, over 2 lakh animals were safely evacuated. The ports and transport sector suffered losses of ₹7,254.39 lakh, with private assets alone accounting for ₹4,900 lakh. The irrigation sector in Saurashtra and Kachchh sustained damages worth ₹208 lakh, while the urban development sector recorded total damages of ₹979.53 lakh. The government's proactive disaster management efforts ensured the safe evacuation of 1,43,053 people, preventing human casualties. Relief operations provided food, shelter, and medical aid through 2,405 safe shelters, including 38 cyclone shelters, 2,050 government schools, and 317 other facilities.

The response and recovery operations were well-coordinated through the Integrated Response System (IRS) and the State Emergency Operations Center (SEOC), which played a crucial role in managing the disaster. Efficient strategies in healthcare, power restoration, and infrastructure rebuilding facilitated swift recovery. The success of Gujarat's disaster preparedness was evident in achieving the Zero Casualty goal despite widespread economic losses.

Possible Causes/Reasons

- Gujarat's long coastline makes it prone to cyclones and storm surges.
- Favourable sea surface temperatures and atmospheric instability contributed to the cyclone's intensification.
- The pre-monsoon period often sees cyclone formations in the Arabian Sea.

- High population density and economic activities near the coast increase risks.
- On an average, about five to six tropical cyclones are formed in the Bay of Bengal and the Arabian Sea every year, of which two to three tropical cyclones may have the probability to be of severe intensity
- Oceanic Factors (Warm Sea Surface Temperatures & Moisture Supply)
The high sea surface temperatures (SSTs) in the Arabian Sea played a crucial role in the formation of Biparjoy. Ocean waters above 27°C provided the necessary heat and moisture, fuelling the cyclone's energy. Additionally, the Arabian Sea had abnormally high SSTs in June 2023, making it conducive for cyclogenesis. The warm water helped sustain deep convection, allowing the system to strengthen into a very severe cyclonic storm. Another contributing factor was the latent heat release due to continuous evaporation from the ocean surface. This increased the moisture content in the atmosphere, allowing the storm system to gain intensity over time. Since the Arabian Sea has become more cyclone-prone in recent years due to global warming, such conditions are becoming more frequent.
- Atmospheric Factors (Wind Shear, Pressure Variations & Monsoon Influence)
Biparjoy formed under low vertical wind shear conditions, meaning that the difference in wind speeds between the lower and upper atmosphere was minimal. This allowed the storm system to remain well-organized and intensify without being disrupted. Another key atmospheric factor was the low-pressure system that developed on June 5, 2023, and gradually deepened, leading to the formation of the cyclone. The cyclone's intensity increased as barometric pressure dropped, creating stronger winds and storm surges. Additionally, interaction with the monsoon trough influenced its track, leading to multiple directional changes during its lifespan. The presence of high-pressure systems in central India and the Arabian Peninsula further guided its movement, making it an unpredictable storm.
- Unique Cyclone Behaviour (Slow Movement & Recurving Track)
One of the defining features of Biparjoy was its slow translational speed, averaging 7.7 km/h, which was significantly lower than the usual 15 km/h for severe cyclones. This slow movement allowed it to gather more moisture and energy from the warm ocean, prolonging its lifespan and increasing its intensity. Additionally, Biparjoy underwent nine changes in direction, making it difficult to predict its exact path. These track changes were influenced by shifts in the subtropical high-pressure systems, as well as monsoonal interactions. The cyclone's erratic movement and extended duration increased the complexity of forecasting and disaster preparedness efforts.

Response Measures

- IMD provided real-time tracking and alerts.
- NDMA and Gujarat State Disaster Management Authority (GSDMA) conducted preparedness meetings.
- 1.43 lakh people relocated to cyclone shelters and schools.
- Special arrangements for pregnant women (828 safe deliveries recorded).
- Food, water, medical aid, and power backup ensured in shelters.
- Pre-positioning and deployment of trained personnel played a key role in efficient response, relief, and restoration.
- Emergency communication systems like HAM radio and satellite phones deployed.
- Community volunteers, SDRF, police, fire services, and local bodies formed the first three layers of response, while the Army, Navy, Air Force, and Indian Coast Guard remained on standby.
- The Department of Health and Family Welfare deployed doctors, paramedics, nurses, and ASHA workers

across medical centers, with additional support from the Indian Medical Association

- As soon as the cyclone passed away from the affected areas, the restoration activities for critical infrastructure and facilities were initiated by respective organizations as briefly described below.
- Relief assistance encompasses a range of coordinated actions and interventions aimed at providing immediate support and essential services to affected population. It involves various stakeholders, including government agencies, nongovernmental organizations (NGOs), and local volunteers working together to address the immediate needs have affected communities. By providing immediate assistance and supporting recovery, relief efforts contribute to building more resilient communities during disasters
- Power supply restored swiftly using pre-positioned teams.
- Ports and transport services were shut down in advance to prevent accidents.
- Survey and Visited by Union Minister of Home Affairs and Minister of Cooperation

Issues/Challenges/Concerns

- Managing inter-agency coordination effectively during the crisis.
- Restoration of power and transport networks.
- Economic Disruptions: Impact on fisheries, tourism, and industries.
- Public Awareness & Compliance: Ensuring people heed evacuation warnings.
- Resource Mobilization: Deployment of response teams and supplies under tight time constraints.

Recommendations/Preventive Measures

- Strengthening Infrastructure
- Enhancing Early Warning Systems:
- Community Engagement & Training and conduct regular mock drills
- Policy and Planning: Regular updates to NDMA guidelines on cyclone management.
- Public-Private Partnerships: tropical cyclones may have the probability to be of severe intensity

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Early Warning & Forecasting	Accurate long-range tracking by IMD; clear cyclone trajectory updates	Limited public understanding of uncertainty cones	Probabilistic forecasts need better interpretation at local level	Improve risk communication using simplified visual tools and local language advisories
Evacuation & Preparedness	Timely evacuation of ~1.8 lakh people in Gujarat	Shelter fatigue due to long warning lead time	Extended warning windows require sustained preparedness strategies	Develop phased evacuation and shelter rotation plans
Institutional Coordination	Effective Centre–State coordination; pre-positioning of NDRF	Over-dependence on central forces in remote areas	Decentralised response improves speed	Strengthen district and taluk-level response capacities
Infrastructure Resilience	Limited casualties due to improved coastal infrastructure	Kutcha houses and power infrastructure vulnerable	Coastal resilience investments reduce mortality	Accelerate cyclone-resilient housing and underground cabling
Livelihoods & Fisheries	Advance warnings helped secure boats and equipment	Inadequate livelihood compensation for fishers	Livelihood protection is critical for recovery	Introduce risk insurance and early livelihood restoration packages
Recovery & Reconstruction	Rapid restoration of roads and power	BBB principles inconsistently applied	Recovery is an opportunity to reduce future risk	Mandate Build Back Better (BBB) compliance

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- 4 NDMA guidelines on cyclone management

Himachal Pradesh Floods, 2023

Introduction

Due to the diverse topography of the Himachal Pradesh area, the flood problem in Himachal Pradesh is largely isolated in nature. The monsoon, apart from acting as the lifeline in the young, lofty, and fragile mountain belt of the Himalaya, becomes a potential cause for disturbing slope stability, inflicting heavy loss of life, and damaging Government, private, and public property. High monsoon rains in the areas of the Shiwalik and Lower and Mid Himalayan ranges cause extensive floods during the rainy season. In the upper reaches of the Beas and Satluj valleys, the main problems are flash floods and bank erosion because of the steep slopes of rivers and High River flows due to heavy rains. Often, flash floods caused by cloudbursts and temporary blockages of the river channels have also been observed. Extremely high-intensity rainfall events over a short period of time, or 'cloudbursts', as they may be called, are a natural phenomenon in the Himalaya and have been found to be a dominant factor in causing extensive damage in different parts of the State during the monsoon period every year.

Overview of the Disaster

During the monsoon period of 2023, the State witnessed three different spells of very high precipitation during 7-11 July 2023 (Ist spell), 11-14 August 2023 (IInd spell) and 21-23 August 2023 (IIIrd spell) causing widespread damage across the State. From July 7th to 11th, 2023, Himachal Pradesh experienced intense monsoon activity, resulting in widespread, heavy to extremely heavy rainfall across most of the state. Historically, during the monsoon season (June-September) from 1971-2020, the state averaged a rainfall of 734.4 mm. remarkably, in just four days, from July 7th to 11th, 2023, the state recorded 223 mm of rainfall, a staggering 436% above the typical amount of 41.6 mm for such a period. This surge in rainfall was unprecedented according to historical data. Every district in the state recorded excessive rainfall, with Kinnaur, Kullu, and Solan receiving the most. In particular, Kinnaur and Lahaul Spiti received 43% and 33%, respectively, of their average seasonal rainfall in these four days—a record high. A detailed district-by-district rainfall breakdown for this period is provided in a table below. The heavy rainfall caused significant damage, including overflowing rivers, road obstructions, landslides, flash floods, bridge damage, and total disruptions to electricity and communication. Furthermore, there were tragic losses of life. The state has also witnessed the second wave of rainfall, which has impacted the other districts, Hamirpur, Kangra, Una, Lahaul-Spiti, Sirmaur and Bilaspur.

The district wise precipitation received during the different spells is as under: -

Table 8 : Cumulative district wise rainfall (7th to 11th July 2023)

District	Actual(in mm)	Normal (in mm)	Departure (in %)
Bilaspur	335.9	44.5	655
Chamba	207.9	49.6	319
Hamirpur	258.7	49.2	426
Kangra	225.3	93.7	140
Kinnaur	107.6	11.2	861
Kullu	280.1	30.7	812

Lahaul and Spiti	124.8	21	494
Mandi	245.5	68.2	260
Shimla	268.9	35.4	660
Sirmaur	514	67.9	657
Solan	472.6	52	809
Una	265.3	49	441
Himachal Pradesh	223	41.6	436

Table 9 : Cumulative district wise rainfall (11th to 14th August 2023)

District	Actual(in mm)	Normal (in mm)	Departure (in %)
Bilaspur	235.1	56.5	316
Chamba	37.6	41.4	-9
Hamirpur	328.4	86.1	281
Kangra	309.9	98.3	215
Kinnaur	5.8	12	-52
Kullu	60.7	31.9	90
Lahaul and Spiti	3	15.5	-80
Mandi	365.2	70.8	416
Shimla	123.8	31.9	288
Sirmaur	93.6	66.3	41
Solan	194	54.1	259
Una	112.8	80.3	40
Himachal Pradesh	107.2	41.7	157

Table 10 : Cumulative district wise rainfall (21-23 August 2023)

Name	Actual(in mm)	Normal (in mm)	Departure (in %)
Himachal Pradesh	36.2	21.1	72
Bilaspur	155.2	21	639
Chamba	11.7	21.1	-45
Hamirpur	138.9	31.3	344
Kangra	85.6	55.3	55

Kinnaur	0	6.4	-100
Kullu	7	14.4	-51
Lahaul and Spiti	0	9.3	-100
Mandi	111	33.8	228
Shimla	38.6	18.6	107
Sirmaur	29.7	32.3	-8
Solan	124.3	22.5	452
Una	73.3	31.9	130
Subdivision Rainfall	36.2	21.1	72

The overall recovery needs for sectoral damage is estimated to ₹8667.66 Crore and DRR needs are estimated to ₹375 crore.

Impacts

- Lives loss more 30 people lost life in Kullu.
- Disaster has left a significant impact on the housing infrastructure, affecting a total of 24885 houses comprising pucca, semi-pucca, kutchha houses, huts, and cattle sheds. A total of 22,879 HHs have been directly affected by the disaster. There is a need for reconstruction of 3185 cattle sheds and 4948 houses and repair and retrofitting of 10986 houses and 5766 cattle sheds in line with BBB principles. There are 846 cases of land loss across the twelve affected districts. Landslide damages were sporadic and localised while flood damages were over large areas with buildings often situated in unsafe locations lacking compliance with safety norms. Shimla had more sporadic landslides, Kullu had more floods and Mandi/ Solan had both landslides and floods. Similar pattern has been observed in the second phase of the disaster in Bilaspur, Hamirpur, Kangra, etc.
- The total recovery estimate for the Social Sector was ₹2,944.29 crore.
- Education: Damage in the education sector was estimated at ₹369.14 crore, with a negligible loss of ₹0.25 crore, resulting in a combined damage and loss of ₹369.39 crore. The recovery estimate for education was ₹369.14 crore.
- The health sector incurred damage worth ₹182.55 crore.
- The tourism sector incurred damage worth ₹43.83 crore, along with a loss of ₹220.58 crore, leading to a combined damage and loss of ₹264.41 crore.
- Damage in the agriculture sector was estimated at ₹7.81 crore, with a substantial loss of ₹192.20 crore, leading to a combined damage and loss of ₹200.01 crore
- Damage in horticulture was estimated at ₹28.39 crore, with a significant loss of ₹260.81 crore, resulting in a combined damage and loss of ₹289.20 crore

Response to Disasters

- ₹71.50 crore released under SDRF/NDRF for relief and restoration.

- NDRF teams prepositioned in Mandi, Kullu, Kangra, and Rampur for search and rescue. Rescue operations were carried out by NDRF, Home Guards, and Kullu Police, successfully evacuating stranded individuals.
- Establishment of Relief Camps & Aid Distribution: 11 relief camps were set up across the districts: 7 in Kullu, 4 in Manali, and 1 in Sainj.
- Essential relief supplies (rations, blankets, cooking oil, spices, and first-aid kits) were distributed to affected populations. Air-dropping of relief materials was carried out in inaccessible areas via helicopters.
- Cash relief and essential items were sanctioned for people whose homes were washed away or badly damaged.
- The Indian Air Force (IAF) helicopters were mobilized to assist in rescue and supply distribution
- Organizations like CASA, Save the Children, Change Alliance, Sphere India, HAI, and others provided relief supplies, psychosocial support, and livelihood assistance.

Recommendation

- Priorities the stabilization of the slope through advanced engineering techniques. Geotechnical studies should be conducted to determine the most suitable stabilization methods, which might include retaining walls, soil reinforcement, drainage systems, and vegetation control.
- Implement flood-resilient construction practices for new houses and renovations, considering elevation, foundation, and flood-resistant materials.
- Needs a waste management system to prevent direct disposal of waste into the land.
- Needs awareness campaigns on flood risks, early warning systems, and emergency preparedness.
- Enforce regulations to restrict construction in flood-prone areas (along riverbanks).
- Invest in comprehensive flood management infrastructure, including river embankments, floodwalls, and drainage systems.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Rainfall Forecasting	IMD issued Red Alerts for extreme rainfall	Urban authorities underprepared for cloudbursts	Extreme rainfall is becoming the new normal	Integrate cloudburst risk into urban planning
Urban Flood Management	Emergency pumping and evacuations undertaken	Poor drainage and river encroachment	Structural measures alone are insufficient	Restore flood plains and urban wetlands
Landslide Risk	Search and rescue mobilised quickly	Lack of slope stability monitoring	Landslides are predictable with data	Expand landslide early warning systems
Infrastructure	Severe damage to roads, bridges, and hydropower projects	Infrastructure sited in high-risk zones	Development choices amplify disaster losses	Enforce hazard zoning in hill states
Governance	Crisis coordination improved over time	Reactive rather than anticipatory approach	Preparedness must precede monsoon	Mandatory pre-monsoon risk audits

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3. DDMA Kullu.

Delhi Flood, 2023

Introduction

Floods are a recurring disaster in India, affecting over 40 million hectares annually. They impact 7.5 million hectares, causing around 1,600 deaths and ₹1,805 crores in damages. NDMA notes that annual flood damage rose from ₹1,805 crores (pre-1996) to ₹4,745 crores (1996–2005) due to population growth, urbanization, economic activities in floodplains, and global warming.

According to the NCRB (National Crime Records Bureau), floods were a major cause of accidental deaths in India in 2021, with Bihar reporting the highest toll at 351 deaths. The state also saw a 6.4% rise in accidental deaths, from 14,474 in 2020 to 15,405 in 2021.

The WHO (World Health Organization) states that floods, the most frequent natural disaster, occur due to heavy rainfall, snowmelt, or storm surges. Between 1998 and 2017, they affected over 2 billion people worldwide, causing loss of life and damage to property and public health infrastructure.

In August 2018, Kerala experienced devastating floods, often referred to as the “disaster of the century.” The catastrophic flooding led to the loss of 483 lives and caused massive damage to infrastructure, agriculture, and the environment.

Overview of Disaster

In July 2023, Delhi experienced one of its worst floods in history due to relentless heavy rainfall and a dangerously swollen Yamuna River. The rain began in early July, with an unprecedented 153mm recorded in just 24 hours leading up to July 9—the highest single-day rainfall in the month in 40 years. This accounted for nearly 15% of the total rainfall expected in an entire monsoon season. As the downpour continued, the Yamuna River swelled to record levels, threatening densely populated areas of the capital. On July 12, the Central Water Commission issued a ‘red’ alert, its highest warning, which remained in place until July 16. By the morning of July 13, the river had risen beyond the danger mark at the Delhi Railway Bridge, surpassing a record set 45 years earlier in 1978. Even by July 18, the water levels were still above the danger threshold, though they had begun to recede. The flooding caused widespread devastation, submerging several parts of the city. More than 25,000 people had to be evacuated from inundated areas, as homes and infrastructure were severely affected. For many residents, it was a disaster they had never witnessed before, bringing life in the capital to a standstill.

Impact

- Key transportation networks, including Delhi Metro, rail services, and major roads, were disrupted, while heavy vehicles were banned to ease congestion.
- The floods increased the risk of vector-borne diseases, with authorities conducting fogging and medical interventions. Over 2,896 patients were treated in flood relief camps.
- Heavy siltation in the Yamuna and urban drains worsened waterlogging, requiring major de-silting and drainage improvements.
- Large areas faced power outages, especially in Vishwakarma Colony, Jaitpur, and affected regions, disrupting essential services.
- Agricultural lands, informal settlements, and businesses in low-lying areas suffered significant financial damages, affecting thousands of livelihoods.

- The disaster highlighted the urgent need for early warning systems, floodplain management, drainage improvements, and inter-agency coordination to prevent future crises.



Fig - 95 : Delhi Flood, 2023 & Flood evacuation in Ghaziabad, NCR Delhi, India, July 2023

Source :- NDRF Ghaziabad

Response

During the floods, more than 25,000 people from flood-prone areas had to leave their homes and move to safer places. To support them, the government set up 44 relief camps, mostly in schools, providing food, shelter, and basic facilities. The NDRF sprang into action, deploying 16 teams for rescue operations, while Delhi Fire Services worked tirelessly to evacuate stranded people, including 33 students trapped at an institute near ITO.

Medical teams were stationed in flood-hit areas with essential medicines and antivenom, while authorities carried out fogging and cleanliness drives to prevent the spread of diseases. Transport was also impacted—metro trains slowed down on bridges over the Yamuna, and heavy vehicles were kept out of the city to ease congestion. The flooding even forced the shutdown of three water treatment plants, leading to water rationing and urging residents to use water carefully.

Amidst all this, the Delhi Chief Minister held meetings to assess the situation and coordinate relief efforts. To reduce traffic and ensure public safety, private offices were encouraged to allow employees to work from home. These measures were put in place to manage the crisis effectively and help the city recover as quickly as possible.

Issues/ challenges/concerns

The Yamuna floods in Delhi in July 2023 exposed several critical challenges in managing urban flooding. The river surged to a record 208.66 meters, causing widespread devastation. Poor drainage and clogged sewers worsened waterlogging, while illegal encroachments on floodplains blocked the river's natural flow, making the situation even more severe. Essential services took a hit as water treatment plants and pumping stations were submerged, leading to shortages and disruptions.

A major challenge was the lack of coordination between agencies like the Delhi Jal Board, PWD, MCD, and NDRF, which slowed down response efforts. While IMD and CWC issued flood forecasts, limited lead time and gaps in real-time data made preparedness difficult. Evacuation efforts faced hurdles many residents were reluctant to leave, and there weren't enough boats initially to rescue stranded people. Roads, metro lines, and railways were heavily affected, leading to traffic chaos and economic losses.

Health risks also emerged as stagnant floodwaters became breeding grounds for diseases and contaminated drinking water. The disaster highlighted the urgent need for better flood management stronger infrastructure, clear coordination among agencies, and a long-term plan to reduce risks and build a more resilient city.

Recommendations

- **National Institute of Disaster Management (NIDM):**
 - Recommends setting up permanent pumping stations at all regulators.
 - These stations should be above the highest recorded flood level of 208.66 meters.
 - Aim: To manage water discharge effectively.
- **Green Tribunal (NGT):**
 - Stresses the importance of clearly demarcating the Yamuna floodplains in Delhi.
 - Emphasizes the removal of encroachments in these areas.
 - Recommends marking these areas properly on digital maps for better management.
- **Parliamentary Standing Committee on Water Resources:**
 - Suggests releasing at least 23 cubic meters per second (cumecs) of water from the Hathnikund Barrage during non-monsoon months.
 - Purpose: To maintain ecological flow and prevent excessive sedimentation.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
River Forecasting & Early Warning	CWC forecasts indicated rising Yamuna levels	Forecasts not translated into timely urban action	Forecasts must trigger predefined actions	Link river level thresholds with automatic response SOPs
Urban Flood Management	Emergency embankment strengthening and evacuations	Floodplains heavily encroached	Floodplain occupation magnifies disaster impact	Enforce floodplain zoning regulations strictly
Inter-State Coordination	Water releases coordinated with upstream states	Late information flow on sudden releases	River basin management is critical	Establish real-time inter-state data sharing mechanisms
Drainage Infrastructure	Emergency pumping deployed	Stormwater drains clogged and outdated	Poor drainage turns river floods into urban disasters	Modernise urban drainage with climate projections

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Critical Infrastructure	Flooding of power stations, WTPs, and transport corridors	Infrastructure located in flood-prone zones	Critical infrastructure siting is a risk multiplier	Conduct flood risk audits for all critical facilities
Evacuation & Relief	Timely evacuation of low-lying settlements	Temporary shelters lacked basic amenities	Evacuation planning must be humane and inclusive	Upgrade relief shelters with minimum service standards
Vulnerable Populations	Informal settlements most affected	Limited social protection coverage	Urban poor face disproportionate risk	Integrate DRR with urban social protection schemes
Governance & Preparedness	Crisis response improved over time	Preparedness was reactive	Urban floods require anticipatory planning	Mandatory pre-monsoon preparedness audits
Communication & Public Information	Frequent advisories issued	Conflicting messages from agencies	Single-window communication is essential	Designate a unified urban flood communication authority
Environmental Degradation	Loss of wetlands and flood buffers	Weak enforcement of environmental norms	Nature-based buffers reduce flood intensity	Restore wetlands and Yamuna floodplain ecosystems
Recovery & Rehabilitation	Rapid restoration of services	Limited focus on resilience	Recovery must reduce future flood risk	Apply Build Back Better in urban recovery
Climate Change Linkages	Extreme rainfall and high river flows observed	Climate risks not mainstreamed in city planning	Urban flooding is climate-driven	Integrate climate adaptation into Master Plans

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Sikkim Flash Floods, 2023

Introduction

Sikkim, the 22 state of the Indian Union is located in the foothills of the Eastern Himalayas and it has a mountainous terrain with elevations ranging from 280 meters to 8585 meters. About one third of the state is covered by forests. It has 28 peaks and more than 400 glaciers with similar number of high altitude glacial lakes. Due to its unique terrain and location, it is susceptible to multi hazards like earthquake, landslides, GLOF, lightning, thunder, hailstorms and so on. On the night of 3 October, 2023, a huge landmass slipped into the South Lhonak, located in the north western part of the state, which caused the lake to overflow. The water from the lake flowed into the Teesta River which caused the water level to rise beyond 15 feet. This led to surge in the flow of the river causing widespread damages to lives and properties at the downstream locations. This triggered a flash flood in the Teesta River Basin, severely affecting the districts of Mangan, Gangtok, Namchi, and Pakyong. The disaster resulted in the loss of 55 lives, affected approximately 80,000 people, and caused extensive damage to infrastructure, agriculture, tourism, and the environment

Impact

The devastating flood in Sikkim resulted in a significant human toll, with 55 lives lost and 74 people still missing. Over 7,000 residents were displaced, seeking shelter in 30 relief camps set up across the affected districts. The destruction extended to homes, with more than 2,000 houses severely damaged, leaving countless families without shelter. Critical infrastructure, including roads, bridges, water supply, and sanitation systems, suffered extensive damage, disrupting daily life and essential services.

Table 11 : District wise impact of disasters

District	Villages Affected	Family displaced	People Died	People displaced houses	No of damaged	No of relief camps opened	No of people missing
Mangan	50	588	4	2350	568	7	23
Pakyong	7	419	10+7	1677	635	10	27
Gangtok	19	477	16+15 (Indian Army)	1910	319	5	20
Namchi	24	272	3	1088	482	8	4
Sikkim	100	1756	55	7025	2004	30	74

The economic losses were equally staggering, with the tourism sector one of Sikkim's key industries—facing a revenue loss of ₹241.53 crore. Agriculture and horticulture, which provide livelihoods for many in the region, recorded damages worth ₹80.44 crore, while the animal husbandry and fisheries sectors faced losses amounting to ₹34.76 crore. The transportation network, essential for connectivity in the hilly state, suffered an estimated ₹205.4 crore in damages. Additionally, drinking water and sanitation infrastructure were severely impacted, with

losses amounting to ₹41.39 crore, affecting the availability of clean water and hygiene facilities.

Beyond the immediate economic and infrastructural damage, the disaster had a profound environmental impact. Large areas of forest cover were destroyed, threatening biodiversity and increasing the risk of landslides in an already fragile ecosystem. The aftermath of the flood has left Sikkim facing not just a humanitarian crisis but also long-term challenges in rebuilding its communities, restoring livelihoods, and ensuring environmental sustainability.

Causes

The devastating flood in Sikkim on October 3-4, 2023, was caused by a combination of natural and human-made factors. The main trigger was a Glacial Lake Outburst Flood (GLOF) from South Lhonak Lake, where a massive landslide sent huge chunks of ice into the water. This created large waves that breached the lake's natural dam, releasing a massive amount of water downstream.

One of the biggest reasons behind this disaster was climate change. Over the years, South Lhonak Glacier has been melting rapidly, causing the lake to grow in size from 0.42 km² in 1990 to 1.35 km² in 2019. This made the lake more unstable and prone to sudden flooding. Rising temperatures in the Himalayan region have sped up this melting, increasing the risk of such events.

Another contributing factor was Sikkim's high earthquake risk. The region falls in Seismic Zone V, which makes it prone to earthquakes and landslides. The lake's moraine walls (which naturally hold back the water) may have been weakened over time by ground movements, leading to their sudden collapse.

Human activities also played a major role in making the disaster worse. Unplanned construction along the Teesta River put many buildings and settlements at risk. Some were built just 6 meters from the river, violating safety norms. Many multi-story RCC buildings suffered heavy damage because they were not built to withstand such extreme conditions. The lack of strict building regulations outside town-planned areas made matters worse.

The flood also caused major damage to infrastructure, including the Teesta III hydropower dam, which could not withstand the sudden rush of water. One of the biggest issues was the lack of an effective early warning system. If better monitoring had been in place, people could have been evacuated earlier, reducing the loss of life and property.

Environmental destruction, including deforestation and riverbank encroachment, also increased the damage. Without trees and natural barriers, there was nothing to slow down the floodwaters, leading to more landslides and soil erosion.

Response

1. Search & Rescue Operations

- Immediate rescue efforts began on October 4, 2023, with the ITBP, Sikkim Fire & Emergency Services, and local volunteers carrying out evacuations.
- Sikkim Police teams reached Chungthang on foot on October 5, 2023, while SDRF teams followed on October 6, 2023.
- NDRF teams arrived in Chungthang on October 7, 2023, with additional teams reaching Mangan and being airlifted for further operations on October 9, 2023.
- Helicopters were deployed for air evacuation of stranded tourists, workers, and locals.

2. Relief & Rehabilitation Efforts

- 30 Relief Camps were established across affected districts to house 7,025 displaced people:
 - Gangtok District: 10 camps for 1,910 people
 - Pakyong District: 5 camps for 1,677 people
 - Namchi District: 8 camps for 1,088 people
 - Mangan District: 7 camps for 2,350 people.
- Necessary relief materials, including food, clean water, and medical aid, were distributed.
- Psychosocial counseling was provided for trauma victims.
- Transport arrangements were made for daily wage earners and tourists.
- Sanitation efforts, including de-fogging and cleaning drives, were conducted in affected areas

3. Restoration of Essential Services

- Electricity and communications were restored by October 5, 2023.
- Water supply was reinstated in affected areas.
- Debris clearance and road restoration began immediately.
- Temporary log bridges and Bailey bridges were constructed over Sangkhalang, Chungthang & Zema by Border Road Organization.

4. Government Announcements & Long-Term Support

- Sikkim Punarwas Awas Yojana was launched to construct 2,100 new houses for affected families.
- Sikkim Janta Housing Colony will build 2,000 houses for displaced tenants.
- Financial aid: Relief camp inmates were granted ₹5,000 per month for three months.
- Students affected by the disaster received a one-time grant of ₹10,000 for books and uniforms.
- A technical committee was formed to investigate the causes of the disaster and recommend mitigation measures.
- A loan moratorium was announced for business owners affected by the flood.

5. Disaster Risk Reduction & Preparedness Measures

- Early warning systems were planned for high-risk areas.
- Awareness and sensitization programs were conducted in vulnerable downstream locations, including Chungthang, Mangan, Dikchu, Singtam, Rangpo, and Melli.

Issue and challenges

One of the biggest issues was the disruption of clean water and sanitation services. Many water treatment plants were damaged, forcing people to rely on unsafe water sources, increasing the risk of disease. In some areas, sewage treatment plants were destroyed, leading to poor hygiene conditions.

One more major problem was damage to roads and bridges, especially along the Teesta River. Numerous villages

were cut off, making rescue and relief efforts difficult. The collapse of the Teesta III hydropower project also disrupted electricity, further slowing recovery.

The lack of an effective early warning system meant people had little time to prepare. Many were caught off guard, and communication blackouts made coordination among rescue teams difficult. Health services were also affected, with hospitals in remote areas unable to provide urgent medical care. Survivors faced stress and trauma, but mental health support was limited.

Economically, the disaster was disturbing. Tourism, a major source of income, suffered huge losses, and over 2,000 houses were destroyed, leaving many homeless. Recovery efforts must focus on stronger infrastructure, better early warning systems, and improved disaster preparedness to protect Sikkim in the future.

Recommendation

1. Strengthening River Management and Flood Control

- Implement a riverbank protection policy and manage Teesta River's changing course to reduce future flood risks.
- Conduct dredging of debris deposits with guidance from geologists and river specialists.

2. Improving Building Regulations and Infrastructure

- Amend the Sikkim Building Construction Regulations (1991) to include risk-informed land-use planning.
- Enforce no-construction zones in high-risk areas and conduct structural health audits of existing buildings.

3. Enhancing Early Warning Systems and Technology Integration

- Strengthen early warning systems for GLOFs and flash floods using advanced technology.
- Conduct awareness programs to educate communities about disaster preparedness.

4. Housing and Relocation Strategies

- Develop safe relocation sites, identified and certified by geologists for displaced families.
- Provide rental housing solutions for affected people, especially those without land ownership.

5. Environmental Conservation and Risk Mitigation

- Implement afforestation, watershed management, and soil conservation to reduce landslide risks.
- Develop a sustainable land-use policy to balance development with disaster resilience.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Early Warning & Forecasting	IMD issued heavy rainfall alerts	No dam-linked flood early warning	Mountain floods escalate rapidly	Integrate rainfall forecasts with dam safety alerts
Dam Safety & Operations	Sudden outburst from South Lhonak Lake affected Teesta-III	Inadequate real-time monitoring of GLOFs	Glacial lakes pose growing systemic risk	Install automated GLOF monitoring and alarm systems
Flash Flood Preparedness	Minimal warning time for downstream areas	Absence of flash flood SOPs	Flash floods require specialized preparedness	Develop Flash Flood & GLOF Action Plans
Infrastructure Resilience	Major damage to hydropower projects, roads, bridges	Infrastructure located in high-risk river valleys	Infrastructure amplified disaster losses	Reassess hydropower siting and design norms
Institutional Coordination	Armed Forces, NDRF, SDRF deployed rapidly	Terrain and weather hampered access	Mountain disasters need pre-positioned resources	Pre-position response assets in high-altitude zones
Search & Rescue	Swift rescue in accessible areas	Remote villages remained cut off	Accessibility is a critical challenge	Improve all-weather connectivity and heli-response
Community Vulnerability	Army camps and villages heavily affected	Limited local preparedness	Communities need hazard-specific awareness	Conduct GLOF-specific community training
Communication Systems	Communication lines severely disrupted	Lack of redundant communication	Communication failure delays rescue	Deploy satellite-based emergency communication
Environmental Sensitivity	High ecological damage observed	Cumulative impact of hydropower projects	Fragile ecosystems magnify disaster risk	Enforce cumulative impact assessments
Data & Surveillance	Limited glacier and lake monitoring	Sparse high-altitude data	Data gaps increase uncertainty	Expand high-altitude climate and cryosphere monitoring
Governance & Policy	Post-disaster review initiated	Reactive dam safety governance	Prevention must precede response	Strengthen dam safety oversight in Himalayan states

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Recovery & Reconstruction	Restoration initiated under extreme conditions	Risk of rebuilding in unsafe zones	Reconstruction must reduce exposure	Relocate and redesign infrastructure using BBB principles
Climate Change Linkages	Glacial lake breach linked to warming trends	Climate risks underestimated	Climate change is reshaping Himalayan hazards	Mainstream climate risk into Himalayan development planning

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Silkyara-Barkot Tunnel Disaster, 2023

Introduction

Tunnels have been used since ancient times for various purposes, including religious, hydraulic, and strategic security needs. Over the centuries, they have played a crucial role in transportation, infrastructure development, and military operations, evolving with advancements in engineering and technology.

The Silkyara-Barkot tunnel is a key component of the Char Dham all-weather road project, an initiative aimed at enhancing connectivity to important pilgrimage sites in Uttarakhand. Designed to improve accessibility and reduce travel time, the tunnel was expected to provide a safer and more efficient route, particularly during adverse weather conditions.

However, on November 12, 2023, a section of the tunnel collapsed, trapping 41 workers inside. The incident triggered a large-scale rescue operation involving multiple agencies, including NDRF, SDRF, the Indian Army, and private engineering firms. Despite the challenging circumstances, coordinated efforts led to the successful evacuation of all trapped workers after 16 days.

The geological and structural challenges in the Himalayan region played a significant role in the collapse. Weak rock formations, water seepage, and insufficient geological surveys contributed to the disaster, highlighting the complexities of tunnel construction in such difficult terrain. This incident underscores the importance of comprehensive geological assessments, improved safety protocols, and emergency preparedness in large-scale infrastructure projects.

Overview

The Silkyara Tunnel is a 4.531 km-long, two-lane bi-directional tunnel designed to connect Dharasu to Yamunotri as part of the Char Dham all-weather road project in Uttarakhand. This tunnel aims to improve accessibility and reduce travel time for pilgrims and locals while ensuring a safer passage through the rugged Himalayan terrain.

One of the major challenges in the construction of this tunnel is the geological composition of the region. The area is predominantly made up of weak metamorphic rocks, such as phyllite and meta-siltstone, which are highly susceptible to instability and collapse. These rock formations, combined with continuous water seepage, significantly increase the risk of structural failure.

The collapse occurred between 203m and 240m from the tunnel entrance, primarily due to weak rock formations, inadequate geological surveys, and water infiltration. These factors collectively contributed to the structural failure, leading to the trapping of 41 workers and necessitating a massive rescue operation.

Impact of the Silkyara Tunnel Collapse

- 41 workers trapped inside the collapsed section of the tunnel for 16 days, facing extreme psychological and physical stress.
- Limited access to food, water, and oxygen, requiring emergency life-support systems such as pipeline supply.
- Health concerns for the rescued workers, necessitating medical examinations at AIIMS Rishikesh after the rescue.
- Increased psychosocial distress among workers and their families due to uncertainty and prolonged entrapment.

- Damage to tunnel equipment, including drilling machines, auger machines, and tunnel support systems, requiring costly repairs.
- Structural failure at 203m-240m from the entrance, necessitating extensive reinforcements before resuming work.
- Temporary suspension of construction due to safety concerns and pending investigations.
- Increased geological instability due to the collapse, raising concerns about the safety of the tunnel's alignment.
- Water seepage issues, which could worsen over time and weaken the tunnel structure further.
- Possible landslides or rock falls in nearby areas due to underground disturbances caused by the collapse.
- Need for extensive environmental monitoring before resuming construction to prevent future disasters.

Response to the Silkyara Tunnel Collapse

- The National Disaster Response Force (NDRF), State Disaster Response Force (SDRF), Uttarakhand Police, Indian Army Corps of Engineers, and private engineering firms were quickly mobilized for the rescue operation.
- A 4-inch steel pipe was inserted through the debris to deliver food, water, oxygen, and medical supplies to the trapped workers.
- Authorities established two-way communication with the workers inside the tunnel to provide reassurance and coordinate rescue efforts.
- Due to challenging geological conditions, various rescue strategies were explored, including horizontal drilling, vertical drilling, and manual excavation.
- All 41 workers were rescued and immediately given on-site medical attention. They were airlifted to AIIMS Rishikesh via Indian Air Force Chinook helicopters for further health assessments and psychological support.

Issues, Challenges, and Concerns in the Silkyara Tunnel Collapse

1. Geological Challenges

- The tunnel's location near the Main Central Thrust (MCT) of the Himalayas made construction highly challenging due to weak rock formations. The area is made up of fragile metamorphic rocks like phyllite and meta-siltstone, which are prone to collapse. Water seepage was another major issue, as groundwater weakened the rock structure, increasing the risk of failure. To make matters worse, heavy rainfall had already saturated the soil, making the tunnel even more unstable. A lack of accurate geological predictions further complicated the excavation, leading to unexpected structural weaknesses. These challenges highlight the need for better geological assessments, stronger reinforcement strategies, and improved drainage systems to ensure the tunnel's long-term safety in such a geologically sensitive region.

2. Rescue Difficulties

- Rescue efforts faced major delays due to machinery failures, including technical issues with the American Auger Machine, which required reinforcement. Auger drilling was further obstructed by metallic debris from collapsed tunnel reinforcements, forcing workers to manually remove it using gas cutters. The unstable debris created additional hazards, with continuous small collapses slowing excavation. Multiple failed attempts at both horizontal and vertical drilling extended the rescue timeline even further.

3. Lack of Emergency Exits

- The tunnel did not have an emergency escape passage, which could have allowed the trapped workers to exit safely.
- As per standard operating procedures, any tunnel over 3 km in length should have an escape tunnel for emergencies.
- The absence of an alternate evacuation route forced rescuers to rely on complex excavation methods, prolonging the operation.

Recommendations

- Use forepoling, rock bolts, steel ribs, and lattice girders to reinforce weak sections.
- Install sensors to track underground water movement and rock shifts.
- Conduct routine stability tests to identify potential risks early.
- Build Emergency Escape Routes and construct parallel escape tunnels for worker safety in case of collapse.
- Improve Water Drainage Systems and Implement proper dewatering techniques to prevent water seepage from weakening the tunnel structure.
- Develop Quick Rescue Plans and keep emergency tools and medical aid readily available at all construction sites.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Geological Risk Assessment	Preliminary geological investigations conducted	Inadequate mapping of weak and fractured rock zones	Himalayan geology requires ultra-detailed assessment	Mandate high-resolution geotechnical and seismic studies for tunnels
Tunnel Design & Construction	New Austrian Tunnelling Method (NATM) adopted	Design assumptions did not fully account for geological variability	Design must be adaptable to dynamic ground conditions	Introduce real-time design modification protocols
Monitoring & Instrumentation	Limited instrumentation at collapse site	Absence of continuous deformation monitoring	Early signs can prevent catastrophic failures	Install automated real-time geotechnical monitoring systems
Construction Safety	Workers trapped but survived due to oxygen availability	Inadequate escape shafts and safety redundancies	Safety planning saves lives even in failures	Mandate multiple emergency exits and safe refuges
Emergency Response	Rapid multi-agency mobilisation (NDRF, Army, experts)	Initial uncertainty in rescue strategy	Complex rescues need unified command	Institutionalise Incident Command System (ICS) for infrastructure accidents

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Technical Rescue Operations	Innovative horizontal drilling and pipe insertion	Limited indigenous expertise for tunnel rescues	Specialised skills are essential for rare disasters	Develop national tunnel rescue task forces
Inter-Agency Coordination	Seamless coordination among agencies and experts	Lack of pre-defined SOPs for tunnel disasters	Preparedness enables precision response	Create SOPs for underground and confined-space rescues
Communication & Morale	Continuous communication with trapped workers	No structured protocol for psychological support	Communication sustains survival and morale	Integrate psychosocial support into rescue SOPs
Worker Welfare & Labour Safety	Workers provided food, water, and medical checks	Contract labour safety oversight weak	Occupational safety is a disaster risk issue	Strengthen labour safety compliance and audits
Governance & Oversight	High-level review ordered post-incident	Safety audits largely post-facto	Prevention must precede construction	Enforce independent third-party safety audits
Infrastructure Planning	Project part of Char Dham connectivity	Cumulative impact not fully assessed	Speed of development must match safety	Integrate DRR into infrastructure planning
Environmental Sensitivity	Construction in fragile Himalayan zone	Limited cumulative environmental assessment	Environmental fragility increases construction risk	Enforce cumulative impact and carrying-capacity studies
Preparedness & Drills	Ad-hoc response planning	No mock drills for tunnel collapse	Rare disasters still need preparedness	Conduct periodic tunnel emergency mock drills
Data & Knowledge Systems	Lessons documented after rescue	Knowledge not systematised nationally	Learning must be institutionalised	Create a national database of infrastructure failures
Climate & Extreme Weather Linkages	Ongoing monsoon effects weakened strata	Climate variability not factored in construction timelines	Climate stress compounds geological risk	Integrate climate risk into construction scheduling
Recovery & Continuity	Workers rescued without loss of life	Long-term safety review ongoing	Zero-fatality outcomes must be the benchmark	Redesign tunnels with enhanced safety margins

References

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- 3 Government Reports: NHIDCL, MoRTH, Uttarakhand State Disaster Management Authority.
- 4 Expert Analysis: Australian tunnel experts Arnold Dix and Chris Cooper.

Table 12 : Other Disasters Occurred in the year 2023.

S.no	Name of Disaster	Date and Time	Location	Casualties / Injured
1	Tanur Boat Disaster	May 7, 2023	Tanur, Malappuram, Kerala, India	22 killed 10 injured
2	Visakhapatnam Fishing Harbour Fire	November 19, 2023	Vishakhapatnam, Andhra Pradesh, India	-
3	Indore stepwell collapse	March 30, 2023	Beleswar Mahadev temple, Indore, Madhya Pradesh	36 death 16 injured
4	Ludhiana Gas leak	April 30, 2023	Ludhiana	11 death
5	Andhra Pradesh Train Collision	October 29, 2023	Vizianagaram district	14 death 54 injured
6	Nagpur Flood	September 23, 2023	Vidarbha Regions	
7	Raigad Landslide	July 19, 2023	Raigad Dist.	22 deaths source: NDRF
8	Thathri land subsidence	February 1, 2023	Jammu and Kashmir	
9	Buldhana Bus Accident	July 1, 2023	Buldhana Dist.	25 deaths source: Free Press Journal
10	Cyclone Michaung	5 Dec,2023	Nellore and Machilipatnam in Andhra Pradesh	27 deaths 44 lakh people affected source: Sphere India situation report

DISASTER YEAR 2024

Chemical and Industrial Disaster, 2024

Introduction

An event that causes significant harm or damage to people, property, or the environment due to the release or mishandling of hazardous chemicals, industrial processes, or materials. These disasters can occur in various industries, including manufacturing, oil and gas, mining, and chemical production, and may involve fires, explosions, toxic releases, or chemical spills. The impacts of such disasters can range from local environmental degradation to large-scale loss of life, health issues, and economic disruptions. A notable example is of Bhopal Gas Tragedy (1984), one of the deadliest industrial disasters, when a gas leak at the Union Carbide pesticide plant in Bhopal, India, exposed over 500,000 people to toxic methyl isocyanate gas. Hundreds of lives were lost and many more suffered long-term health effects.



Fig - 96 : A glimpse of Bhopal Gas Tragedy, 1984

Source :- <https://medium.com/kayla-anderson/the-1984-bhopal-disaster-in-india-a-message-for-industrialists-10abb3d1e8b6>

Overview of disaster

In 2024, India witnessed several major industrial disasters, highlighting critical safety gaps in various sectors. On 17 February 2024, an explosion at a firecracker factory in Virudhunagar, Tamil Nadu, killed 10 people and injured dozens, due to mishandling of hazardous materials in an unregulated environment (Deccan Herald, 2024). Another explosion occurred in the same region on 29 June 2024, underscoring the persistent risks in the firecracker industry. On 23 May 2024, a boiler explosion at a chemical plant in Thane, Maharashtra, led to the death of ten workers and severe injuries to several others, attributed to equipment failure and inadequate maintenance (The Hindu, 2024). Similarly, on 21 August 2024, a deadly explosion at a pharmaceutical factory in Atchutapuram, Andhra Pradesh, resulted in at least 15 fatalities, with poor safety protocols and improper chemical handling identified as key factors (The Indian Express, 2024).



Fig - 97 : A massive explosion at a firecracker factory in Vembakottai Virudhunagar district, Tamil Nadu

Source :- <https://www.india.com/tamil-nadu/tamil-nadu-9-killed-10-injured-in-blast-at-virudhunagar-vembakottai-firecracker-unit-watch-viral-video-6731172/>



Fig - 98 : Firefighters at the spot after a fire broke out due to a boiler blast in a chemicals factory, at Dombivli, in Thane district, Maharashtra (PTI picture)

Source :- <https://www.telegraphindia.com/india/seven-dead-more-than-40-injured-in-massive-blast-at-chemical-factory-in-thane-district/cid/2021960>)



Fig - 99 : Tragic accident in Atchutapuram SEZ, reactor blast at Pharma Company

Source :- <https://www.jagran.com/news/national-andhra-pradesh-reactor-exploded-at-gmfc-labs-private-limited-in-anakapalli-district-23314724.html>

Impact

The impact of the 2024 industrial disasters in India specifically the Virudhunagar explosions, Thane boiler explosion, and Atchutapuram pharmaceutical factory explosion was multifaceted, affecting human lives, the environment, and the economy.

- **Human Impact:** These disasters resulted in the tragic loss of lives, with over 50 fatalities across the incidents, mostly workers involved in hazardous processes. Many others sustained serious injuries, some with long-term health complications such as burns, respiratory issues, and trauma. The workers and their families bore the brunt of the tragedies, which also disrupted local communities. Additionally, the psychological impact on survivors and their families cannot be understated, as they often experience long-term emotional distress.
- **Environmental Impact:** The explosions released harmful chemicals into the air, soil, and water, contributing to environmental pollution. In the case of the firecracker factories, toxic fumes and particulate matter affected air quality, while chemical spills in the pharmaceutical and chemical plants threatened local ecosystems. The long-term environmental degradation from such releases could take years to recover from, affecting agriculture, water sources, and wildlife.
- **Economic Impact:** These disasters caused significant financial losses, both for the businesses involved and the surrounding communities. The factories sustained severe damage, resulting in costly repairs, compensation claims, and legal settlements. Local economies also suffered as businesses were disrupted, and reputations of affected industries took a hit, leading to a loss of investor confidence. Furthermore, the need for emergency response, investigations, and safety overhauls added to the financial burden.
- **Regulatory and Public Perception:** These incidents raised questions about the effectiveness of existing safety regulations and prompted calls for stronger enforcement and better oversight. The public's trust in industrial safety was shaken, and the incidents sparked debates over improving workplace safety standards, worker protection laws, and disaster response preparedness.

Possible Causes

The possible causes of the 2024 industrial disasters in India Virudhunagar explosions, Thane boiler explosion, and Atchutapuram pharmaceutical factory explosion can be traced to a combination of poor safety practices, inadequate regulations, equipment failure, and human error. Here's a breakdown of the key causes for each disaster:

1. Virudhunagar Explosions (17 February and 29 June 2024)

- **Improper Handling of Hazardous Materials:** The firecracker manufacturing units involved in both explosions likely mishandled volatile chemicals used in the production process. The use of unstable chemicals and unsafe storage practices can lead to dangerous reactions.
- **Lack of Safety Regulations:** Many small-scale firecracker factories operate in an unregulated or poorly regulated environment, lacking basic safety standards. Inadequate inspections, failure to enforce laws, and poor oversight contribute to the risks.
- **Inadequate Worker Training:** Workers in these facilities often lack proper safety training, which increases the risk of accidents. The lack of knowledge about handling hazardous chemicals and emergency protocols contributes to the severity of such explosions.
- **Overcrowded and Poor Infrastructure:** Some of these factories were likely housed in cramped spaces, with

limited infrastructure for managing dangerous materials, leading to a higher risk of explosions.

2. Thane Boiler Explosion (23 May 2024)

- **Boiler Malfunction or Neglect:** The explosion at the chemical plant in Thane was caused by a boiler malfunction, likely due to either poor maintenance or failure to perform regular inspections. Boilers are high-risk equipment, and when they are not maintained properly, they can lead to catastrophic failures.
- **Inadequate Maintenance Protocols:** The plant did not adhere to rigorous maintenance schedules, and the boiler might not have been properly checked for faults like corrosion or pressure build-up. Industrial boilers require consistent monitoring and upkeep to ensure safety.
- **Lack of Safety Systems:** If the plant had effective safety monitoring systems (such as pressure release valves or automatic shutoff systems), the disaster might have been prevented or minimized. The absence of such systems increased the explosion's impact.
- **Human Error:** Operator error could have contributed to the incident, especially if safety procedures were not followed during the operation or if there was a lack of adequate training for workers handling such dangerous equipment.

3. Atchutapuram Pharmaceutical Factory Explosion (21 August 2024)

- **Improper Chemical Handling:** The explosion at the pharmaceutical factory in Atchutapuram was primarily caused by improper handling of volatile chemicals used in the production of pharmaceutical ingredients. Pharmaceutical factories often deal with reactive chemicals, and any mishandling can lead to catastrophic reactions.
- **Failure in Containment Systems:** A breakdown in the containment systems, such as pressure vessels or ventilation systems, could have led to the explosion. Lack of proper containment for reactive chemicals increases the risk of such incidents.
- **Poor Safety Practices and Lack of Regulation:** Similar to the firecracker factories, the pharmaceutical plant likely had insufficient safety practices in place. The failure to adhere to safety regulations, such as handling hazardous materials with adequate precautions, contributed to the explosion.
- **Inadequate Emergency Preparedness:** The absence of a well-implemented emergency response plan or the failure to act swiftly during the early signs of trouble may have worsened the disaster. Workers were likely not adequately trained to handle chemical leaks or containment breaches, exacerbating the damage.
- **Infrastructure Issues:** The facility may have had substandard infrastructure or outdated equipment that increased the likelihood of a failure. In industries handling hazardous chemicals, aging infrastructure can be a significant risk factor.

Common Causes across all the disasters:

- **Lack of Regulatory Compliance:** A recurring theme across all three incidents is the failure to comply with safety regulations and the lack of effective oversight. This includes poor enforcement of industrial safety standards, weak inspections, and loopholes in regulatory frameworks.
- **Inadequate Safety Culture:** These disasters highlighted the absence of a robust safety culture in many industries, especially smaller and less-regulated factories. There was often a lack of emphasis on worker training, emergency preparedness, and risk assessments.

- **Negligence in Maintenance and Equipment Checks:** Whether in the form of boiler maintenance or chemical containment systems, inadequate maintenance was a significant factor in these disasters. The failure to monitor and replace faulty equipment exacerbated the potential for accidents.
- **Human Error:** Many of these incidents were at least partly caused by human error, whether from lack of proper training, failure to follow safety protocols, or insufficient awareness of the dangers associated with hazardous materials and equipment.

Response

The response during and after the industrial disasters in Virudhunagar, Thane, and Atchutapuram was crucial in minimizing further damage and providing immediate relief, as well as addressing the underlying causes to prevent similar incidents in the future. Upon the occurrence of the explosions, firefighting units, rescue teams, and paramedics were immediately dispatched to the scene. These teams worked quickly to contain fires, rescue survivors, and provide medical aid to the injured. The local authorities carried out evacuations of nearby buildings to prevent further casualties from the widespread impact of the explosions. The emergency medical teams were deployed to local hospitals to treat the injured and manage burn victims, respiratory issues, and trauma.

Challenges

The industrial disasters in Virudhunagar, Thane, and Atchutapuram in 2024 presented several significant challenges both during and after the events. During the disasters, immediate response efforts were complicated by the hazardous nature of the materials involved, such as volatile chemicals and high-risk equipment like boilers. Emergency responders faced difficulties in containing fires, managing toxic fumes, and evacuating affected areas. In each case, the scale of the damage overwhelmed local resources, and the severity of injuries posed a major burden on healthcare facilities. After the disasters, the investigations into the causes faced challenges due to the lack of proper documentation, regulatory compliance, and maintenance records. In particular, unregulated industries like small firecracker factories and poorly maintained industrial plants made it difficult to identify the root causes and hold responsible parties accountable. Long-term recovery efforts were also hampered by the need for extensive environmental cleanup, including the assessment and remediation of chemical contamination in the surrounding areas. Public health concerns, particularly from toxic chemical exposure, added to the complexity of the recovery process. Additionally, improving regulatory oversight, ensuring better worker training, and addressing the gaps in safety enforcement across various high-risk industries remain ongoing challenges. These incidents highlighted the need for a systemic overhaul in safety protocols and stricter enforcement of regulations to prevent future disasters.

Recommendations

To prevent future industrial disasters like those in Virudhunagar, Thane, and Atchutapuram in 2024, a comprehensive approach is required, focusing on regulatory enforcement, worker safety, equipment maintenance, environmental protection, and fostering a safety-first culture. These incidents exposed critical gaps in safety protocols, regulatory oversight, and emergency response systems. To mitigate these risks and avoid similar catastrophes, several recommendations can be made across multiple domains.

• **Strengthening Regulatory Oversight and Compliance**

A key recommendation is to strengthen regulatory oversight and ensure better compliance with safety standards. Regulatory bodies such as Central Pollution Control Board (CPCB), and State Industrial Safety Departments

should enforce stricter safety protocols. Regular and rigorous audits of high-risk industries like firecracker manufacturing, chemical plants, and pharmaceutical factories should become mandatory. These audits would ensure that industries adhere to best practices in safety and environmental management. Additionally, regulatory bodies should implement stricter controls over the handling, storage, and transportation of hazardous chemicals. Given that industries dealing with high-risk materials are often subject to lax oversight, it is essential to close regulatory gaps by imposing substantial penalties for violations, ensuring compliance with industrial safety laws, and upgrading outdated safety standards. Clear guidelines for emergency response, equipment maintenance, and toxic material management must be established to protect both workers and nearby communities.

- **Improving Worker Safety and Training**

Another crucial recommendation is to enhance worker safety and training. In many of these disasters, a lack of proper worker training and safety measures exacerbated the severity of the accidents. Workers should undergo regular, comprehensive training on hazard identification, safe chemical handling, emergency protocols, and the use of personal protective equipment (PPE). Regular safety drills, including fire evacuations and chemical spill response simulations, would ensure that employees know how to act quickly in the event of an emergency. These programs should not be one-time events but rather part of a continuous, evolving process, with refresher courses and hands-on training provided at regular intervals. Furthermore, industries should invest in providing workers with high-quality PPE, such as fire-resistant clothing, gloves, masks, and protective eyewear. Ensuring that employees are well-equipped and well-prepared to handle hazardous situations is critical to reducing injuries and fatalities in case of an industrial accident.

- **Enhancing Maintenance and Equipment Safety**

The maintenance of industrial equipment is another significant challenge highlighted by these disasters. Boilers, chemical reactors, and other high-risk machinery need to be regularly inspected, maintained, and upgraded to prevent malfunctions that could lead to catastrophic failures. In the case of the Thane boiler explosion, inadequate maintenance was likely a contributing factor to the incident. To prevent such incidents, rigorous maintenance schedules should be implemented and followed strictly. Regular inspections of critical equipment, such as pressure vessels, pipelines, and reactors, must be conducted by certified technicians, with a focus on identifying early signs of wear, corrosion, or potential malfunctions. Additionally, companies should prioritize upgrading outdated machinery that may pose safety risks. This includes the installation of advanced safety systems, such as automatic pressure relief valves, real-time monitoring sensors, and automated shutoff systems that can prevent an accident from escalating. The use of IoT-based monitoring systems can provide real-time data on equipment health, which can help in early fault detection and preventive maintenance.

- **Fostering a Safety-First Culture**

One of the fundamental changes needed to prevent industrial disasters is fostering a safety-first culture within organizations. Industrial safety cannot be an afterthought; it must be embedded in the company's core values and practices. Management should lead by example, promoting a proactive safety culture where workers are encouraged to report safety hazards without fear of retaliation. Creating a safety-first mindset requires continuous engagement from top management to frontline workers. Companies should establish clear channels for workers to report hazards, suggest improvements, and participate in safety planning. This involvement can significantly reduce the risk of human error, as employees are more likely to identify potential risks early on and take preventive actions. Safety protocols should be treated as dynamic, evolving processes, where companies constantly review and update safety measures based on new information or past incidents. Regular meetings with employees to discuss safety concerns and the implementation of corrective measures can help ensure that safety is always a top priority.

- **Improving Emergency Response and Preparedness**

A well-coordinated and effective emergency response is critical in minimizing the impact of industrial disasters. Companies and local authorities must work together to develop robust emergency response plans that can be swiftly activated in the event of an accident. These plans should be regularly updated and tested through simulated drills. A key element of this is the establishment of clear communication protocols, ensuring that emergency services, company officials, and affected communities are informed of the situation promptly. Additionally, companies should invest in creating on-site emergency teams trained to handle specific types of incidents, such as chemical spills, fires, and explosions. These teams should be equipped with the necessary resources to mitigate damage and prevent further harm. Local fire departments and medical facilities should also be part of these plans, ensuring a rapid and coordinated response when needed.

- **Environmental Protection and Cleanup**

After an industrial disaster, environmental protection and cleanup are of paramount importance, especially when toxic chemicals or hazardous materials are involved. Regulatory bodies should enforce stringent post-disaster environmental assessments to determine the level of contamination in air, water, and soil. For example, in the Atchutapuram pharmaceutical explosion, immediate action was needed to assess and mitigate environmental damage caused by the release of toxic chemicals into the atmosphere and surrounding areas. Industries must be held accountable for cleaning up the contamination caused by their operations, and they should be required to establish contingency plans for environmental restoration. Companies should also adopt green technologies and sustainable practices that reduce the risk of chemical spills and pollution, while minimizing their environmental footprint.

- **Public Awareness and Transparency**

Lastly, increasing public awareness and transparency is essential in preventing industrial disasters. Industries must be more transparent about their safety practices, emergency protocols, and compliance with environmental regulations. Public reporting of safety audits, incident investigations, and corrective actions would increase accountability and foster trust between industries and communities. Public engagement is also essential in educating communities living near high-risk industries about potential hazards and what to do in case of an emergency. Community-based safety programs, including the distribution of information on local industrial risks and emergency response actions, can empower residents to act quickly if a disaster occurs.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Safety Audits	Post-incident inspections	Weak preventive oversight	Prevention is better than response	Strengthen periodic safety audits
Emergency Preparedness	Ad-hoc response arrangements	Lack of mock drills	Preparedness reduces casualties	Mandatory emergency drills
Worker Safety	Contract workers affected	Poor safety compliance	Occupational safety is DRR	Enforce labour safety norms
Governance	Inquiries ordered	Reactive governance	Safety must be proactive	Strengthen regulatory enforcement
Data & Reporting	Incident data fragmented	No national database	Learning must be institutionalised	Create industrial accident database

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Wayanad (Kerala)

Landslide, 2024

Introduction

The Wayanad Landslide, which occurred on the 31st of July, 2024, was one of the most devastating natural disasters to strike the region of Kerala in recent years. Located in the Western Ghats, Wayanad is a picturesque district known for its lush forests, wildlife sanctuaries, and steep, undulating terrains. However, the landscape's natural beauty belies its vulnerability to landslides, especially during the monsoon season. On this fateful day, heavy rainfall triggered a massive landslide, which claimed numerous lives and caused significant damage to property, infrastructure, and the local ecosystem.

This tragic event is a stark reminder of the increasing risks posed by climate change, deforestation, and unregulated development in ecologically sensitive areas. The landslide not only devastated the local communities but also highlighted the urgent need for better disaster preparedness, environmental management, and sustainable development practices in Kerala. This report aims to examine the causes, impact, and response to the Wayanad Landslide, and to explore long-term strategies for disaster risk reduction and resilience building in the region.

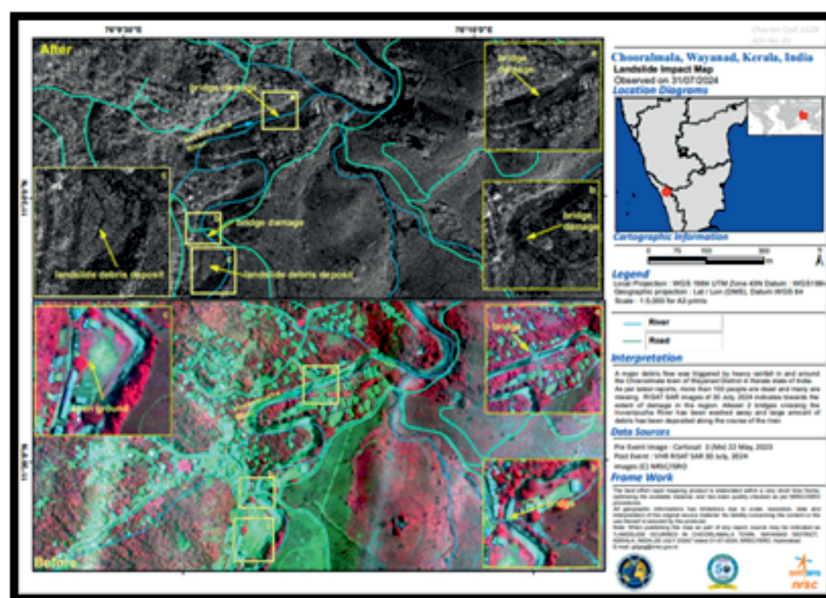


Fig - 100 : Landslide Impact Map- Chooralmala, Wayanad, Kerala (NRSC)

Source :- NDEM NRSC; klwayanadlandslide_31072024.pdf

Overview of disaster

The Wayanad Landslide on 31st July 2024 was a catastrophic event that struck the district of Wayanad in Kerala, India. The region, known for its steep slopes, dense forests, and fragile geology, is particularly prone to landslides, especially during the monsoon season. On this particular day, relentless rainfall over the preceding weeks,

combined with the unstable terrain, resulted in a massive landslide that buried entire villages, destroyed homes, and led to the loss of many lives.

The landslide occurred in the early hours of the morning, following a period of heavy rainfall that had already caused localized flooding in parts of the district. Wayanad's rugged topography, characterized by slopes ranging from 30 to 60 degrees, and deforestation due to agricultural expansion, compounded the vulnerability of the region. As a result, the landslide displaced thousands, with villages like Puthumala and others being hit hardest. Homes, roads, and essential infrastructure were destroyed, isolating communities and making rescue and relief efforts extremely challenging.

The immediate impact of the disaster included the loss of at least 100 lives, while dozens more were injured or reported missing. The landslide also disrupted essential services, including transportation, electricity, and communication networks. In addition to human casualties, the environmental toll was significant, with large-scale damage to the natural habitat, including flora, fauna, and water sources, which further complicated recovery and rehabilitation efforts.

The Kerala government, along with local authorities and national disaster management teams, mobilized resources for rescue and relief operations. These efforts were supported by various NGOs, volunteers, and military personnel, who worked tirelessly to locate survivors and provide emergency assistance.

This disaster has drawn attention to the urgent need for improving disaster preparedness, enhancing early warning systems, and adopting sustainable land-use practices to reduce the risk of future landslides in the region. The Wayanad Landslide serves as a reminder of the growing impact of climate change on vulnerable regions, particularly in ecologically sensitive areas like Kerala's Western Ghats.



Fig - 101 : Landslide Impact Map- Chooralmala, Wayanad, Kerala (NRSC)

Source :- NDEM NRSC; klwayanadlandslide_31072024.pdf



Fig - 102 : Satellite images of Wayanad landslide before and after

Source :- Planet Labs (after landslide); Google © 2024 Maxar Technologies, Airbus

Impact

The Wayanad Landslide on 31st July 2024 had devastating consequences for the local population, infrastructure, economy, and environment. The impact of this disaster was both immediate and far-reaching, affecting various facets of life in the region :-

- Human Loss and Casualties:** The most significant impact of the Wayanad Landslide was the tragic loss of human lives. At least 100 people were confirmed dead, with many more injured. The landslide buried entire homes, and several residents were trapped under the debris. Rescue operations faced immense challenges due to the difficult terrain and continuous rainfall, with many missing persons feared to be trapped in the rubble. In addition to the fatalities, many individuals suffered serious injuries, while countless others were left displaced, creating a crisis of both physical and mental health for survivors.
- Displacement of Communities:** The landslide resulted in the displacement of thousands of people. Villages in the affected areas, particularly Puthumala and surrounding regions, were devastated. Entire families were left homeless as their houses were buried under the mud and debris. Shelters were set up in temporary relief camps, but the uncertainty of returning home and the trauma of the event led to significant distress among displaced populations. Many families lost not just their homes but also their livelihoods, leading to a long-term displacement crisis.
- Infrastructure Damage:** The landslide caused extensive damage to the region's infrastructure. Roads, bridges, and communication lines were severed, isolating entire villages. The collapse of transportation networks made rescue operations and the delivery of essential supplies difficult. Essential services, such as electricity, water, and healthcare, were disrupted for days, exacerbating the suffering of the affected communities. The damaged roads also hindered the movement of relief teams and delayed the provision

of aid to remote areas.

- **Environmental Destruction:** The landslide had severe ecological consequences. The massive flow of mud and debris uprooted trees, damaged the local biodiversity, and destroyed habitats for wildlife in the region. The Western Ghats, a UNESCO World Heritage site, are known for their rich biodiversity, and the disaster disrupted ecosystems, particularly in areas that were home to endangered species. The destruction of vegetation also worsened the risk of soil erosion, which could contribute to further landslides and environmental degradation in the future. Furthermore, natural water sources like streams and rivers were polluted or blocked by the debris, affecting the local water supply and agriculture.
- **Economic Impact:** The economic repercussions of the landslide were severe. Wayanad's economy is largely dependent on agriculture, including tea, coffee, and spice cultivation, which suffered significant losses due to the destruction of farmland. The loss of crops, along with the displacement of farmers, set back agricultural productivity and incomes for the local population. Additionally, the tourism industry, which is a vital economic driver for Wayanad, was heavily impacted. The destruction of infrastructure, as well as the environmental damage, could affect the region's appeal as a tourist destination for years to come.
- **Social and Psychological Impact:** The emotional and psychological toll on the affected communities was profound. The trauma of losing loved ones, homes, and livelihoods in such a sudden disaster left many people in a state of shock. There was also widespread anxiety about the possibility of further landslides, as the region remained vulnerable to continued heavy rainfall. Mental health issues, such as post-traumatic stress disorder (PTSD), anxiety, and depression, became an emerging concern for survivors. The social fabric of the community was also strained as displaced people struggled to cope with the changes in their living conditions.
- **Challenges in Rescue and Relief Operations:** The challenging terrain and ongoing heavy rainfall made the rescue and relief efforts difficult. Despite the best efforts of government agencies, local authorities, and volunteer organizations, the process of locating survivors and providing timely relief was slow. The lack of proper access roads and communication in some affected areas further delayed the delivery of aid. Many rescue operations were conducted manually, with local volunteers working alongside military and police personnel to clear debris and search for survivors.

Possible Causes/ Reasons

The Wayanad Landslide was primarily triggered by a combination of natural and human factors, exacerbated by the region's topography and ongoing climate change :-

- **Heavy Rainfall and Monsoon Conditions:** The immediate cause of the landslide was the exceptionally heavy rainfall experienced during the monsoon season. Continuous and intense rainfall over several days led to saturated soil, increasing its weight and making it prone to sliding. The heavy downpour on the 31st of July was the final trigger, causing the soil to become unstable and collapse under its own weight.
- **Topography and Geology of Wayanad:** Wayanad's steep and hilly terrain, with slopes of 30-60 degrees, is highly vulnerable to landslides, especially during periods of heavy rainfall. The region's fragile geology, with loose and weathered rocks, made the ground more susceptible to mass movements like landslides. The lack of natural barriers such as strong vegetation to anchor the soil further contributed to the risk.
- **Deforestation and Unregulated Land Use:** Wayanad has experienced significant deforestation, particularly in areas where agriculture and development have encroached into sensitive ecosystems. The clearing of trees and vegetation reduces the land's ability to hold soil together, increasing the likelihood of landslides. In addition, unregulated land use, particularly the expansion of plantations on steep slopes, has contributed to soil instability.

- **Climate Change and Extreme Weather Events:** Climate change has led to more extreme and unpredictable weather patterns, including heavier rainfall during the monsoon season. Increased rainfall intensity is believed to be a significant factor in the frequency and severity of landslides in the region. The changing climate pattern makes it harder to predict when such events will occur, amplifying the risk to vulnerable communities.

Response

In the wake of the Wayanad Landslide, a comprehensive response was initiated by local, state, and national authorities, as well as humanitarian organizations. The response was focused on immediate rescue operations, relief efforts, and long-term recovery. They are mainly :-

- **Rescue and Relief Operations:** The immediate priority was to search for survivors and provide emergency relief to those affected. Local authorities, along with the Kerala State Disaster Management Authority (KSDMA), the National Disaster Response Force (NDRF), and the Indian Army, mobilized quickly to carry out rescue operations. Heavy machinery, along with teams of rescuers, worked tirelessly to clear debris and search for people trapped under the rubble. Additionally, medical teams were deployed to treat the injured and prevent the spread of diseases in the aftermath. Temporary shelters and relief camps were established to house the displaced population, and food, water, and other essentials were distributed.
- **Temporary Infrastructure Restoration:** In the wake of the disaster, restoring basic infrastructure became a critical focus. Efforts were made to clear blocked roads, repair damaged bridges, and restore electricity and water supplies to affected areas. Emergency communication systems were set up to enable better coordination among rescue teams and government authorities. The government also worked on re-establishing transportation links to ensure that aid could reach the isolated regions.
- **Psychosocial Support:** In addition to physical aid, there was a strong emphasis on providing psychosocial support to survivors. Many of the displaced residents and survivors were severely traumatized by the loss of their loved ones, homes, and livelihoods. Mental health professionals and social workers were deployed to provide counseling and support to the affected communities, particularly to help them cope with post-traumatic stress and anxiety.
- **Post-Disaster Rehabilitation and Recovery:** After the initial response, the long-term recovery phase focused on rebuilding homes, restoring livelihoods, and providing compensation to victims. The government announced compensation packages for the families of the deceased and injured, and efforts were made to rehouse displaced families. Rebuilding infrastructure, including roads, schools, and health centers, was also prioritized to restore normalcy. The government also initiated rehabilitation programs for farmers, providing them with financial aid and resources to help them re-establish their agricultural activities.
- **Disaster Preparedness and Mitigation Measures:** In the longer term, the landslide underscored the need for improved disaster preparedness and mitigation strategies in the region. The state government began focusing on strengthening early warning systems for landslides, incorporating better monitoring technologies such as remote sensing and weather forecasting. There was also increased emphasis on regulating land use, including enforcing building codes and restricting construction in high-risk areas. Furthermore, the need for reforestation and soil conservation programs was highlighted to prevent future landslides and protect the fragile ecosystem.
- **Community Involvement and Awareness:** The response also included engaging local communities in disaster preparedness and building resilience. Community-based disaster management programs were initiated to empower residents with the knowledge and skills to mitigate the risks associated with future landslides. This included educating people about landslide-prone areas, proper construction practices, and the importance of maintaining vegetation to stabilize the soil.



Fig - 103 : Rescue operations underway after landslides triggered by heavy monsoon rains, at Chooralmala in Wayanad district. (PTI Photo)

Source :- <https://indianexpress.com/article/india/wayanad-meppadi-chooralmala-landslide-live-updates-9483772/>



Fig - 104 : Kerala Govt. to set-up townships, announces rehabilitation project

Source :- <https://www.msn.com/en-in/news/India/wayanad-landslide-kerala-govt-to-set-up-townships-announces-rehabilitation-project/ar-AA1wOq9D>

Challenges encountered

The Wayanad Landslide presented numerous challenges that hindered both immediate response and long-term recovery efforts. These challenges were multifaceted, involving geographical, infrastructural, environmental, and socio-political factors.

- **Difficult Terrain and Accessibility:** Wayanad's steep, rugged terrain, which made it prone to landslides in the first place, also posed significant challenges to the response teams. The landslide itself blocked roads, collapsed bridges, and made many areas inaccessible, delaying the arrival of rescue teams and emergency supplies. In the immediate aftermath, the lack of clear access to remote areas made it difficult to conduct search-and-rescue operations effectively, leading to delays in locating survivors and providing critical aid. The terrain also made the use of heavy machinery and equipment complicated and slow.
- **Continuous Rainfall and Weather Conditions:** The ongoing monsoon rains continued to hamper relief operations. Not only did the persistent rain create further landslide risks, but it also slowed the rescue and restoration efforts. The rainwater exacerbated flooding in some areas, worsening the living conditions for survivors and hindering access to vital supplies. The weather also complicated the task of rebuilding infrastructure, as construction could not proceed in the face of heavy downpours and unstable soil conditions.
- **Logistical and Communication Challenges:** Communication infrastructure was severely damaged by the landslide, making coordination among disaster response teams difficult. Cell towers were destroyed, and in many isolated areas, residents had no means of contacting authorities or receiving information about rescue efforts. Furthermore, transportation networks were severely disrupted, further complicating the delivery of aid and the movement of emergency personnel. The lack of reliable communication channels slowed the flow of real-time information, preventing timely and efficient decision-making during the critical initial hours of the disaster.
- **Human and Financial Resources Constraints:** Despite the deployment of various disaster management teams, the scale of the disaster overwhelmed available human and financial resources. The sheer number of people affected, the extensive damage to infrastructure, and the difficulty in accessing affected areas stretched the capacity of local and state authorities to respond adequately. Additional resources from the central government and humanitarian organizations were required, but these were often insufficient or delayed due to logistical constraints. There was also a need for skilled personnel, such as medical teams and engineers, to support relief efforts, but their mobilization was slow, given the scale of the disaster.
- **Psychosocial Impact and Mental Health Support:** The psychological trauma faced by survivors posed a significant challenge to the recovery process. Losing homes, loved ones, and livelihoods in such a sudden and violent manner left many people struggling with grief, anxiety, and trauma. Mental health resources were limited in the region, and there was insufficient infrastructure to provide adequate psychological support for the affected population. Given the nature of the disaster, many survivors faced long-term mental health challenges, complicating the rehabilitation and rebuilding phases of recovery.
- **Environmental Degradation and Long-term Recovery:** The environmental impact of the landslide was not limited to the immediate destruction of forests, agricultural land, and wildlife habitats; it also presented long-term challenges. The loss of vegetation contributed to increased soil erosion, making the region more vulnerable to further landslides during subsequent monsoon seasons. Additionally, the damage to the natural water systems, including rivers and streams, disrupted local water supplies for both drinking and irrigation, complicating efforts to restore agricultural activities. Addressing these environmental concerns required both immediate intervention, such as soil stabilization and reforestation efforts, and long-term sustainable land management practices.

- **Resettlement and Livelihood Restoration:** A significant challenge in the recovery process was providing resettlement and livelihood restoration for the displaced population. Many survivors lost their homes and lands, and the relocation process posed logistical challenges. Rebuilding homes on unstable slopes was not feasible, and finding safe and sustainable areas for resettlement required careful planning. Moreover, the loss of agricultural land, which many families relied on for their livelihood, further complicated recovery. Efforts to restore farming, provide alternative livelihood opportunities, and ensure economic stability for the affected population were long-term and resource-intensive processes.
- **Sustainable Development and Risk Mitigation:** The landslide underscored the need for sustainable development practices in a region prone to such disasters. However, balancing the need for infrastructure development, agriculture, and tourism with environmental preservation is a complex task. The challenge lies in enforcing land-use policies that prevent further deforestation, overdevelopment, and the encroachment of vulnerable areas. Moreover, developing effective disaster risk reduction strategies—such as early warning systems, improved infrastructure, and community resilience programs—requires investment, long-term planning, and coordination among multiple stakeholders, including government, NGOs, and local communities.

Recommendations and Preventive Measures for Landslide Risk Reduction in the Region

It is imperative to implement a range of recommendations and preventive measures to reduce the risk of future disasters, enhance disaster preparedness, and promote long-term resilience in the region. These measures should focus on environmental conservation, infrastructure development, community engagement, and disaster risk management.

- **Strengthening Early Warning Systems:** One of the key recommendations is the development and enhancement of early warning systems for landslides, especially in vulnerable regions like Wayanad. Real-time weather monitoring, combined with soil moisture and terrain stability sensors, can help predict landslide risks and provide timely alerts to local communities. Integration of these systems with mobile apps and public notification platforms will ensure that residents in high-risk areas are informed well in advance, allowing for evacuations and preparatory measures to be taken before disasters strike.
- **Reforestation and Soil Conservation:** Deforestation in the region has exacerbated the vulnerability of the land to landslides. A comprehensive reforestation program should be implemented to restore native vegetation and promote soil conservation. Planting trees and shrubs on slopes can help stabilize the soil by preventing erosion and reducing the risk of landslides. Additionally, soil conservation techniques, such as terracing, check dams, and mulching, should be promoted to prevent soil degradation and maintain the integrity of the landscape.
- **Regulating Land Use and Urban Planning:** To mitigate future landslide risks, it is critical to regulate land use and construction in landslide-prone areas. Strict zoning laws should be enforced to prevent construction on steep slopes and in flood-prone zones. This would involve limiting the expansion of agriculture, settlements, and infrastructure in areas with a high risk of landslides. Additionally, implementing sustainable building practices, such as using materials that are more suited to the region's terrain and ensuring that structures are built to withstand the pressure of potential landslides, is essential.
- **Building Resilient Infrastructure:** Given the vulnerability of the region to natural disasters, it is vital to build infrastructure that is resilient to landslides and other environmental hazards. Roads, bridges, and drainage systems should be designed with improved engineering techniques that account for soil stability and weather conditions. For example, reinforced retaining walls, proper drainage systems, and slope stabilization measures can help prevent landslides from damaging infrastructure. Investments in flood-resistant and earthquake-proof buildings will also reduce the long-term impact of disasters.

- **Community Awareness and Capacity Building:** Raising awareness among local communities about landslide risks and disaster preparedness is a crucial preventive measure. Training programs and workshops should be organized to educate residents about the signs of impending landslides, evacuation routes, and basic survival skills. Additionally, community-based disaster management systems should be established, empowering local residents to take the lead in response efforts. Community engagement in identifying risk areas and formulating disaster management plans will ensure more effective risk reduction strategies and enhance resilience.
- **Improving Disaster Preparedness and Response Plans:** Comprehensive disaster preparedness plans, including evacuation strategies, stockpiles of essential supplies, and clear communication protocols, must be developed and regularly updated. These plans should involve not just the government but also local authorities, community leaders, and NGOs. Simulation exercises and drills should be conducted periodically to ensure that all stakeholders are familiar with their roles in the event of a disaster. A dedicated disaster response team with specialized equipment should be trained and ready for rapid deployment in the aftermath of future landslides.
- **Monitoring and Maintenance of Vulnerable Areas:** Regular monitoring of vulnerable slopes and hillside settlements is crucial to detect early signs of instability. Geotechnical surveys and the use of remote sensing technologies (such as drones and satellite imagery) can help identify areas at risk of landslides before they occur. These monitoring systems can be linked with early warning systems, allowing for quicker identification and intervention. Maintenance of drainage systems and regular inspection of slopes and hillside construction sites will also help mitigate risks over time.
- **Strengthening Financial and Social Support for Affected Communities:** Following a landslide disaster, it is essential to provide affected communities with financial support for resettlement and livelihood restoration. This can include government grants, insurance schemes, and low-interest loans to help rebuild homes and infrastructure. Additionally, providing training and support for alternative livelihoods, such as sustainable farming practices or eco-tourism initiatives, will help residents recover and reduce their dependence on vulnerable sectors like agriculture. Community-led initiatives should be encouraged to restore social cohesion and promote long-term economic resilience.
- **Environmental and Climate Change Adaptation Measures:** Given the increasing unpredictability of weather patterns due to climate change, it is vital to incorporate climate adaptation strategies into local development plans. This includes implementing flood control measures, improving water management, and strengthening infrastructure to withstand extreme weather events. Integrating climate change predictions into disaster risk assessments will help to develop more effective long-term strategies for the region's resilience.
- **Strengthening Collaboration among Stakeholders:** A holistic approach to disaster management requires coordination and collaboration among various stakeholders, including government agencies, environmental organizations, research institutions, local communities, and private sector players. Joint initiatives, such as shared disaster response plans, knowledge exchanges, and funding partnerships, can strengthen the region's ability to prevent and respond to future landslide risks. The involvement of local communities in planning and decision-making ensures that the solutions are context-specific and sustainable.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Landslide Early Warning	Rainfall alerts issued	No slope-specific warnings	Rainfall alerts alone insufficient	Expand landslide early warning systems
Land Use	Settlements in high-risk slopes	Weak enforcement of land-use norms	Land-use decisions drive risk	Enforce hazard zonation strictly
Environmental Degradation	Quarrying and deforestation observed	Poor regulation	Ecosystem degradation increases landslides	Strengthen environmental compliance
Search & Rescue	SDRF/NDRF deployed rapidly	Access constraints	Accessibility determines response speed	Improve hill connectivity and access
Community Awareness	Limited preparedness	Low risk perception	Community awareness saves lives	Conduct landslide risk education
Climate Linkages	Intense rainfall events	Climate risks underestimated	Landslides are climate-amplified	Integrate climate risk into hill planning

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Heat Waves, 2024

Introduction

The year 2024 witnessed one of the most severe heat waves and North India region is majorly impacted, characterized by soaring temperatures, widespread health crises, and significant disruptions to daily life. From March to June 2024, 37 cities saw temperatures exceeding 45 degrees Celsius (Down to Earth, 2024). The heat wave not only resulted in a tragic loss of lives but also exposed vulnerabilities in public health systems and infrastructure. This phenomenon, driven by prolonged high-pressure systems and exacerbated by the dry season, highlights the urgent need for proactive measures, including heat action plans, climate adaptation strategies, and public awareness campaigns to address the growing threat of extreme heat events.

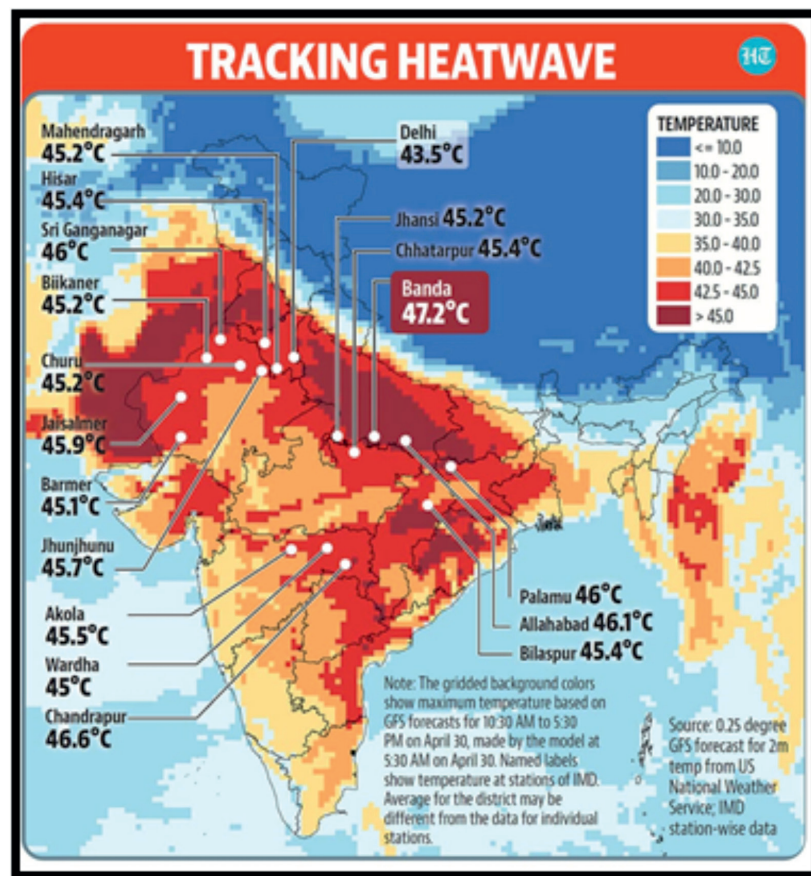


Fig - 105 : Tracking Heat Waves

Source : The Hindustan Times <https://www.hindustantimes.com/india-news/surface-temp-tops-60-c-satellite-images-show-101651343166998.html>)

Overview of the Disaster

In 2024, North India faced an intense heat wave, with temperatures soaring to unprecedented levels. Churu, Rajasthan, recorded 50.5°C on May 29, marking one of the highest temperatures in India in eight years (IMD Press Release, 2024). Similarly, New Delhi witnessed extreme conditions, with a temperature of 52.9°C initially reported but later corrected due to a faulty sensor. The heat wave severely impacted public health, resulting in over 219 deaths and more than 25,000 cases of heatstroke by early June (Times of India, 2024 and New India Express, 2024). From March to June, the region reported 143 fatalities and nearly 42,000 heat-related illnesses (New India Express, 2024). Contributing factors included prolonged high-pressure systems and the dry season's extreme conditions. In response, the National Disaster Management Authority (NDMA) held workshops to enhance preparedness, while the India Meteorological Department issued regular warnings. Studies have highlighted an increase in the frequency and intensity of heat waves, driven by climate change, emphasizing the need for robust heat action plans, public awareness, and improved infrastructure to mitigate future risks.

Impact

The 2024 heat wave in North India stands as a stark reminder of the growing challenges posed by climate change and extreme weather conditions. This event, marked by soaring temperatures and widespread repercussions, affected millions across the region and highlighted critical gaps in infrastructure, preparedness, and climate resilience.

One of the most alarming aspects of the 2024 heat wave was the record-breaking temperatures. Churu, Rajasthan, recorded a staggering 50.5°C on May 29, the highest temperature in India in eight years. Similarly, Delhi faced severe heat, with an initial report of 52.9°C in Mungeshpur later corrected to approximately 50°C due to a faulty sensor (IMD Press Release, 2024). These extreme conditions pushed human tolerance to its limits, affecting public health and overall well-being. The heat wave's impact on public health was devastating. By early June, over 219 deaths and more than 25,000 cases of heatstroke were reported. Between March and June alone, 143 fatalities and nearly 42,000 cases of heat-related illnesses were documented (New India Express, 2024). Vulnerable populations, including the elderly, children, and outdoor workers, bore the brunt of these conditions. Hospitals and healthcare systems struggled to manage the influx of patients, revealing the need for stronger healthcare preparedness during such events. Moreover, the heat exacerbated pre-existing health conditions, particularly cardiovascular and respiratory illnesses, amplifying the crisis. Infrastructure across the region was heavily strained. The extreme heat led to widespread power outages as the demand for electricity surged, driven by increased use of air conditioning and cooling devices. This placed additional pressure on already overstretched power grids, particularly in urban areas. Water scarcity became another pressing issue, with reservoirs and water bodies drying up, further intensifying challenges for both rural and urban populations. The heat wave also took a toll on agriculture, as crops suffered from heat stress, reducing yields and threatening food security. Livelihoods dependent on farming were severely impacted, creating economic hardships for many families. The environmental impact of the heat wave was equally concerning. Urban areas faced an increased risk of fires due to the dry and hot conditions, stretching emergency services to their limits. The heat wave also contributed to a rise in urban heat island effects, where densely populated cities retained and amplified heat, exacerbating the discomfort and health risks for residents. Several factors contributed to the severity of the 2024 heat wave. Prolonged high-pressure systems remained stationary over northern India, trapping heat and preventing cooling winds or precipitation. The region's dry season, typically spanning March to July, further intensified the extreme conditions. Climate change has also played a significant role, with studies indicating a marked increase in the frequency and intensity of heat waves in India, particularly after 2000.

Causes

The 2024 North Indian heat wave was driven by a combination of natural weather patterns and anthropogenic factors, amplifying its intensity and persistence. Understanding these causes is critical to addressing the growing frequency and severity of such events.

a) High-Pressure Systems

High-pressure systems played a pivotal role in the 2024 North Indian heat wave. These atmospheric conditions occur when air is forced downward, creating a “sinking air” effect. This suppresses cloud formation, eliminates chances of rainfall, and traps heat closer to the Earth’s surface. In such scenarios, the lack of cloud cover allows more solar radiation to reach the ground, further intensifying surface temperatures. The persistence of these high-pressure systems over North India created prolonged periods of intense heat, with no cooling relief from winds or precipitation. Such stationary systems are often linked to broader atmospheric anomalies, making them difficult to dissipate without external changes, such as incoming weather fronts or monsoonal systems.

b) Seasonal Dryness

The heat wave occurred during India’s dry season, a period typically marked by limited rainfall and high solar intensity. The absence of moisture in the air reduces humidity levels, which might seem beneficial for reducing discomfort but actually contributes to faster heating of the land. Regions like Rajasthan, already arid, become particularly vulnerable during this season as the sun’s rays directly heat the exposed ground, raising temperatures to dangerous levels. Additionally, dry soils fail to moderate temperatures as they cannot store and release moisture through evaporation, a natural cooling process. This seasonal dryness set the stage for the extreme heat observed in 2024.

c) Urban Heat Island Effect

The urban heat island (UHI) effect significantly intensified the heat wave’s impact in cities like Delhi. Urbanization leads to the replacement of natural landscapes with concrete, asphalt, and other heat-absorbing materials. These surfaces absorb solar radiation during the day and release it slowly at night, causing temperatures to remain elevated even after sunset. The lack of green spaces and water bodies further reduces the cooling effects of shading and evaporation. In 2024, cities recorded significantly higher temperatures than their rural counterparts due to this phenomenon. Moreover, air pollution in urban areas can trap heat, exacerbating the warming effect and worsening air quality, which has direct health implications during heat waves.

d) Climate Change

Climate change is a major driver behind the increasing frequency, intensity, and duration of heat waves globally, including in India. Rising greenhouse gas emissions have raised the average global temperature, creating a higher baseline from which extreme weather events emerge. For North India, this means that heat waves are becoming hotter and more prolonged, with their occurrence nearly doubling since the year 2000. Climate models predict that without significant reductions in emissions, extreme heat events like the 2024 heat wave will become more common. The rising sea surface temperatures linked to global warming also alter weather patterns, making heat waves more likely to occur and persist.

e) Deforestation and Land Use Changes

Human activities such as deforestation and agricultural expansion have disrupted natural ecosystems, reducing the Earth’s capacity to regulate temperatures. In North India, deforestation for urban and industrial development has eliminated vast areas of vegetation, which play a critical role in cooling the environment. Trees and plants release

water vapor through a process called evapotranspiration, which cools the surrounding air. Without this natural cooling mechanism, heat waves intensify in both rural and urban areas. Additionally, changes in land use, such as paving over open fields for roads or buildings, increase heat retention and exacerbate the impact of extreme temperatures.

f) Global Weather Patterns

Global climatic phenomena, such as El Niño, often contribute to extreme heat events. El Niño involves the warming of ocean surface temperatures in the central and eastern Pacific Ocean, which disrupts global weather patterns. For South Asia, El Niño is often associated with hotter and drier conditions. Although data on the direct impact of El Niño in 2024 requires further analysis, similar patterns in previous years suggest that such global factors can amplify regional heat waves by altering monsoon patterns and increasing baseline temperatures.

g) Delayed Monsoon Onset

The southwest monsoon is a crucial weather event that brings relief from the intense summer heat in India. Typically arriving in North India by mid-June, it provides much-needed rainfall and cooler temperatures. In 2024, a delayed onset of the monsoon extended the duration of the heat wave, leaving the region exposed to extreme temperatures for a longer period. The absence of monsoon rains during the expected timeframe not only prolonged the heat wave's impact but also exacerbated water scarcity, as reservoirs and groundwater sources were not replenished. This delay had cascading effects on agriculture, drinking water supplies, and overall living conditions.

Response

The 2024 North Indian heat wave demanded a swift and coordinated response to mitigate its severe impacts. Health services were scaled up, with hospitals equipped to handle the surge in heat-related illnesses, including heatstroke and dehydration. Mobile health units were deployed to rural areas, ensuring access to medical care for vulnerable populations. Public awareness campaigns educated citizens on staying hydrated, avoiding outdoor activities during peak heat hours, and recognizing early symptoms of heat-related conditions. Heat action plans were activated, providing immediate relief through temporary cooling centers, water distribution points, and revised work schedules for outdoor laborers to minimize exposure.

Efforts were also directed toward managing strained water and energy resources. Authorities ensured uninterrupted power supplies to hospitals and cooling centers, while water tankers were deployed to combat shortages in high-risk areas. The crisis highlighted the importance of climate adaptation measures, spurring initiatives like urban greening to reduce heat retention, restoration of natural water bodies, and rainwater harvesting to mitigate future water scarcity. Urban planning reforms aimed to address the urban heat island effect, particularly in densely populated cities like Delhi. Advanced weather forecasting and data-driven tools played a vital role, providing timely warnings and real-time updates to authorities and citizens. These tools enabled better allocation of resources and informed decision-making during the crisis. The heat wave underscored the need for integrating immediate emergency responses with long-term strategies to build resilience against extreme weather. Climate action, sustainable development, and preparedness are essential to safeguard lives and livelihoods as heat waves become more frequent and severe in a warming world.

Challenges

The 2024 North Indian heat wave revealed significant challenges in managing extreme weather events, exposing systemic gaps in preparedness, infrastructure, and resilience. Healthcare systems were overwhelmed by a sudden surge in heat-related illnesses, including heatstroke and dehydration. Hospitals, especially in rural and underserved areas, struggled with shortages of beds, cooling systems, and medical supplies. Limited trained medical personnel

further delayed timely treatment, increasing the risk of fatalities. Vulnerable populations, such as the elderly, children, outdoor workers, and low-income communities, faced heightened risks due to inadequate access to drinking water, cooling systems, and sufficient shelter. Informal workers in agriculture and construction were particularly affected, as their livelihoods necessitated prolonged exposure to extreme heat.

Water and energy scarcity posed additional challenges. The heat wave depleted reservoirs and groundwater sources, impacting drinking water supplies and agricultural activities, exacerbating food security concerns. Simultaneously, increased energy demand from cooling devices strained fragile power grids, leading to frequent outages and disruptions. Urban areas faced the compounded impact of the urban heat island effect, where dense construction, heat-absorbing materials, and limited green spaces amplified heat retention, even at night. Poor urban planning in cities like Delhi exacerbated these issues, leaving residents with little relief.

While Heat Action Plans have been developed and implemented in several states, certain operational challenges have been observed in terms of time taken for response and coordination. In some instances, the availability and efficient distribution of essential resources such as water supply, cooling arrangements, and medical support systems require further strengthening. Instances of heat wave also highlight the importance of further strengthening climate resilience through long-term systematic investments in sustainable water management, urban cooling strategies, and energy-efficient systems.

Economic disruptions added to the challenges. Agricultural productivity declined due to heat stress on crops, while industries relying on manual labor experienced delays and reduced output. Informal workers, a significant portion of the workforce, faced income losses from reduced working hours and health issues. These challenges underscored the need for systemic improvements in healthcare infrastructure, urban planning, and climate resilience. Proactive governance, community engagement, and sustained investments in sustainable development are essential to better prepare for and mitigate the impacts of future heat waves in a warming world.

Recommendations

The 2024 North Indian heat wave highlighted the urgent need for comprehensive and proactive measures to mitigate the impacts of extreme heat events. The following recommendations aim to address the immediate and long-term challenges posed by heat waves, enhancing resilience and minimizing vulnerabilities.

- **Strengthen Heat Action Plans**

Heat action plans (HAPs) are critical for managing the impacts of heat waves. These plans should be tailored to local conditions, considering the geographical, demographic, and socioeconomic characteristics of the area. They must include protocols for issuing early warnings, setting up cooling centers, and mobilizing emergency services during heat waves. Periodic updates to these plans, based on the latest climate models and simulations, are essential for staying ahead of evolving challenges. Governments should also enhance coordination between local, state, and national agencies to ensure timely implementation and resource allocation.

- **Improve Healthcare Preparedness**

Healthcare infrastructure must be equipped to handle the surge in heat-related illnesses. Hospitals should have dedicated cooling zones for treating heatstroke and dehydration cases, along with an adequate stock of essential medicines such as oral rehydration solutions (ORS). Rural areas, which often lack adequate healthcare facilities, require mobile health units to ensure access to care. Training programs for medical staff on managing heat-related conditions should be conducted regularly. Additionally, public health programs should integrate heat wave preparedness to address these emergencies comprehensively.

- **Enhance Public Awareness**

Public awareness campaigns are vital for educating people about the risks associated with heat waves and the preventive measures they can take. Campaigns should use a mix of traditional media (radio, television, newspapers) and digital platforms (social media, apps, websites) to reach diverse audiences. Information should include tips on hydration, avoiding outdoor activities during peak heat hours, and recognizing symptoms of heat-related illnesses. Special efforts should be made to reach vulnerable populations, such as the elderly, children, and low-income communities, through community outreach and local workshops.

- **Promote Sustainable Urban Planning**

Sustainable urban planning can mitigate the urban heat island (UHI) effect and reduce heat retention in cities. Increasing green cover through urban forests, parks, rooftop gardens, and tree-lined streets provides shade and natural cooling. Cities should also encourage the use of reflective or light-colored building materials, cool roofs, and permeable pavements that absorb less heat. Expanding shaded areas in public spaces, creating water features like fountains, and improving ventilation in urban layouts can further alleviate heat impacts.

- **Invest in Water and Energy Security**

Water scarcity during heat waves can be addressed through initiatives such as rainwater harvesting, groundwater recharge, and restoring natural water bodies. These measures ensure water availability for drinking, agriculture, and cooling purposes. Simultaneously, energy infrastructure should be upgraded to handle increased demand from air conditioners and cooling devices. Renewable energy sources, like solar and wind power, can be promoted to provide sustainable and uninterrupted power, especially in critical facilities like hospitals and cooling centers.

- **Foster Climate Resilience**

Long-term strategies to combat heat waves must focus on addressing climate change. Reducing greenhouse gas emissions, transitioning to renewable energy, and adopting sustainable agricultural practices are crucial steps. Governments should integrate climate adaptation strategies into disaster management frameworks and collaborate with NGOs, private sectors, and international agencies to pool resources and expertise. Strengthening community resilience through education, skill development, and resource provision is equally important.

- **Support Vulnerable Populations**

Special attention must be given to vulnerable groups, such as the elderly, children, outdoor workers, and low-income communities, who are disproportionately affected by heat waves. Governments and employers should ensure access to cooling centers, subsidized cooling devices, and clean drinking water. Flexible work hours, shaded rest areas, and mandatory breaks for outdoor workers can reduce heat exposure. Targeted financial assistance or subsidies can help low-income families cope with increased energy costs during heat waves.

- **Advance Research and Monitoring**

Continuous research and monitoring are essential for understanding heat wave patterns and improving mitigation strategies. Expanding meteorological networks with advanced sensors can provide real-time data on temperature, humidity, and heat risks. Using artificial intelligence and machine learning, predictive models can enhance early warning systems. Collaboration with academic and research institutions can lead to innovative solutions, such as heat-resistant building materials, sustainable cooling technologies, and efficient energy systems.

Lessons Learned Matrix

Thematic Area	Observed Practice / Outcome	Key Gaps Identified	Lessons Learned	Actionable Recommendations
Early Warning	IMD issued early and extended heatwave alerts	Alerts not uniformly converted into local action	Warnings must trigger automatic response	Link IMD alerts to district Heat Action SOPs
Public Health	Heat Action Plans activated in select states	Uneven implementation across districts	Heat preparedness saves lives	Scale up HAPs to all heat-prone districts
Occupational Safety	Outdoor workers severely affected	Lack of enforceable work-hour advisories	Heat risk is a labour safety issue	Mandate heat safety protocols for workers
Urban Design	High heat stress in dense urban areas	Limited cooling infrastructure	Built environment amplifies heat	Promote cool roofs, urban greening
Mortality Surveillance	Heat deaths under-reported	Weak attribution mechanisms	Heat impacts are underestimated	Strengthen heat-related mortality tracking
Climate Linkages	Record-breaking temperatures observed	Climate risks not mainstreamed	Heatwaves are climate-driven disasters	Integrate heat risk into climate adaptation plans

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Conclusion

The period from 2019 to 2024 marks a critical phase in India's disaster risk trajectory, characterised by recurrent and overlapping water, climate and geological hazards with human-induced disasters. Collectively, these events resulted in significant human casualties, large-scale displacement, and substantial economic losses across multiple regions. The disaster patterns during this period reflect the combined effects of climate variability, environmental degradation, unplanned urbanisation, and socio-economic vulnerabilities. This reinforces the need for a multi-hazard, risk-informed development pathway aligned with the Sendai Framework for Disaster Risk Reduction and the PM's 10 Point Agenda for DRR.

Analysis of disaster occurrence during the period confirms the dominance of hydrometeorological hazards, with floods remaining the most frequent disaster type, followed by cyclones and landslides. Flooding was exacerbated by intense and erratic monsoon rainfall, encroachment on floodplains, inadequate urban drainage, and watershed degradation. Cyclones affecting both eastern and western coasts displayed increasing variability in track and intensity. Landslides intensified in hilly regions due to extreme rainfall combined with fragile geology and infrastructure expansion. Human-induced disasters, including industrial accidents, structural collapses, fires, and transport incidents, continue to reflect the importance of strengthened safety regulations, robust enforcement framework, and integrated approach.

Disasters in India between 2019 and 2024 have led to significant human impacts, with hydrometeorological hazards accounting for the majority of disaster-related losses. Events such as floods, cyclones, lightning, heatwaves, and landslides have been the primary contributors to mortality during this period. Fatalities have been largely concentrated in flood-prone river basins, coastal districts exposed to cyclonic storms, landslide-prone regions of the Western Ghats and the Himalayas, and densely populated urban areas facing extreme rainfall and heat stress. Improvement in early warning system, particularly for cyclones, have helped reduce mortality in certain contexts. Overall disaster-related deaths have shown an increasing trend in recent years, reflecting growing exposure and vulnerability.

Disasters between 2019 and 2024 have resulted in significant economic losses across multiple sectors, including housing, agriculture, infrastructure, public utilities, and private assets, etc. Floods and cyclones have accounted for a major share of these losses, largely due to repeated damage to roads, bridges, power systems, irrigation networks, and housing. Agriculture and allied sectors have faced recurring impacts from flooding, cyclonic events, droughts, and heat stress, affecting rural livelihoods and long-term economic stability. Indirect losses such as disruption of livelihoods, interruptions in education, and reduced productivity have further increased the economic burden.

Several cross-cutting trends emerge from the aggregated disaster experience of 2019–2024. First, climate change is acting as a risk multiplier, intensifying rainfall extremes, heat stress, and storm behaviour. Second, despite advances in early warning and emergency response, disaster losses continue to rise due to increasing exposure of people and assets.

Third, impacts are unevenly distributed, disproportionately affecting the poor, marginalised, and those living in exposed locations. These trends underscore the urgency of transitioning from a response-centric approach to comprehensive disaster risk reduction and resilience building. From a policy perspective, the 2019–2024

evidence highlighted the need to strengthen risk-informed land-use planning and investment in resilient and climate-adaptive infrastructure.

It also emphasizes integrating ecosystem-based approaches, improving urban flood and heat management, and enhancing safety standards to reduce human-induced disasters. The stronger alignment of disaster risk reduction with climate change adaptation and sustainable development planning is essential to reverse rising loss trends.

This compendium consolidates national disaster impacts and trends for 2019–2024, providing robust evidence base for decision-making. It further supports policy reform, investment prioritisation, and institutional strengthening toward a safer, more resilient, and sustainable India.

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