TWO-YEAR
POST-GRADUATE DEGREE PROGRAMME (CBCS)
IN

GEOGRAPHY

SEMESTER-III

Paper Code: GEO/CC/T-315

Paper: Geography of Hazards and Disasters

Self-Learning Material

DIRECTORATE OF OPEN AND DISTANCE LEARNING
UNIVERSITY OF KALYANI
KALYANI-741235, WEST BENGAL

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Unit-3: Concept of Hazard Reduction and Disaster Management	
Unit-4: Climatic Hazards: Tropical Cyclones (Prediction, Precaution and Mitigation)	
Unit-5: Marine Hazard: Tsunami (Prediction, Precaution and Mitigation)	
Unit-6: Hydrological Hazards: Flash Floods In Himalayan Region and Floods in Southern Part of West Bengal	
Unit-7: Mountain Hazards: Landslide and Avalanche	
Unit-8: Nuclear Hazards and Radio-Active Contamination	
Unit-9: Plastic Hazards	
Unit-10: Arsenic Contaminations in Deltaic Bengal	
Unit-11: Fluoride Contaminations in Western Part of West Bengal	
Unit-12: Role of National Disaster Mitigation Agency for Management of Hazards and Disasters	

June, 2025

Directorate of Open and Distance Learning, University of Kalyani

Published by the Directorate of Open and Distance Learning, University of Kalyani, Kalyani-741235, West Bengal

Printed by East India Photo Composing Centre, 209A, Bidhan Sarani, Kolkata-700006

Director's Message

Satisfying the varied needs of distance learners, overcoming the obstacle of Distance and reaching the unreached students are the three fold functions catered by Open and Distance Learning (ODL) systems. The onus lies on writers, editors, production professionals and other personnel involved in the process to overcome the challenges inherent to curriculum design and production of relevant Self-Learning Materials (SLMs). At the University of Kalyani a dedicated team under the able guidance of the Hon'ble Vice-Chancellor has invested its best efforts, professionally and in keeping with the demands of Post Graduate CBCS Programmes in Distance Mode to devise a self-sufficient curriculum for each course offered by the Directorate of Open and Distance Learning (DODL), University of Kalyani.

Development of printed SLMs for students admitted to the DODL within a limited time to cater to the academic requirements of the Course as per standards set by Distance Education Bureau of the University Grants Commission, New Delhi, India under Open and Distance Mode UGC Regulations, 2020 had been our endeavor. We are happy to have achieved our goal.

Utmost care and precision have been ensured in the development of the SLMs, making them useful to the learners, besides avoiding errors as far as practicable. Further suggestions from the stakeholders in this would be welcome.

During the production-process of the SLMs, the team continuously received positive stimulations and feedback from **Professor (Dr.) Kallol Paul, Hon'ble Vice-Chancellor, University of Kalyani**, who kindly accorded directions, encouragements and suggestions, offered constructive criticism to develop it with in proper requirements. We gracefully, acknowledge his inspiration and guidance.

Sincere gratitude is due to the respective chairpersons as well as each and every member of the PG-BoS (DODL), University of Kalyani. Heartfelt thanks are also due to the Course Writers-faculty members at the DODL, subject-experts serving at University Post Graduate departments and also to the authors and academicians whose academic contributions have enriched the SLMs. We humbly acknowledge their valuable academic contributions. I would especially like to convey gratitude to all other University dignitaries and personnel involved either at the conceptual or operational level of the DODL of University of Kalyani.

Their persistent and coordinated efforts have resulted in the compilation of comprehensive, learner-friendly, flexible texts that meet the curriculum requirements of the Post Graduate Programme through Distance Mode.

All the Self-Learning Materials are self writing and collected from e-book, journals and websites.

Director
Directorate of Open and Distance Learning
University of Kalyani

• Course Structure •

Semester-III						
Paper Code	**Paper**	**Theory/ Pratical**	**Internal Assessment/ Evaluation**	**Examination/ Report/ Viva-Voce**	**Credit**	**Marks**
Geo CC T-315	**Geography of Hazards and Disassters**	**Theory**	**10**	**40 (Semester-end Examination)**	**4**	**50**

Unit-1: Concept and Types of Hazards and Disasters

Unit-2: Assessment of Risk and Vulnerability

Unit-3: Concept of Hazard Reduction and Disaster Management

Unit-4: Climatic Hazards: Tropical Cyclones (Prediction, Precaution and Mitigation)

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Unit-11: Fluoride Contaminations in Western Part of West Bengal

Unit-12: Role of National Disaster Mitigation Agency for Management of Hazards and Disasters

Mode of Internal Evaluation: Class test

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INTRODUCTION

Geography of Hazards and Disasters is a branch of Environmental Geography. The content of environment, hazard and disaster management is widely used by the several disciplines. But there is a need to write a volume with establishing direct linkages with geography and environment. Several environmental elements and factors originate from the geographical contextual ground and result hazard, disaster, vulnerability and risk. The sub-surface events like earthquake, volcano and gravity flow and wasting; surface and above surface events like climate change, water pollution, air pollution, landslide, flood, Landslide Lake Outburst Flood (LLOF), Glacial Lake Outburst Flood (GLOF), unnatural cloudburst, El Nino, black carbon, biodiversity loss and so on environmental issues are closely associated with the geography of the earth surface. The human death-toll and property loss by several such events are directly linking with the geography of the space. There are several geographical properties like spaces and their dimensions, structures, linkages, human and their activities and coverage. In the course of understanding environmental issues along with hazard, vulnerability and risk; proper scrutiny through geographical perspective is highly essential. Therefore, study of environment through the geographical lens provides a holistic completion. The present volume illustrates the concepts, definitions, types and different aspects of hazards and disasters that occur spatially over the entire earth surface. The scope of this volume is, thus, limiting to basic understanding of environment, hazard and disaster management within the geographical perspective. However, the supporting data, information, materials and methods have been compiled wherever available within the interdisciplinary sources without limiting to geography. The 'environmental geography' has a close linkage with the feature creating forces, involving processes and their consequences over time of geographical space. The disaster, hazard, vulnerability and risk of earth surface are the events created due to the environmental consequences of such different environmental components over the geographical space. Within these circumstances, it is necessary to integrate the contents of geographical studies within the environment, hazard and disaster management. Here the term 'management' has been taken on the ground of human centric perspective. The usual appearance of environmental condition of a geographical space is a causative factor to create hazard and disaster which ultimately losses the lives and properties. Therefore, management of such occurrences requires dealing within the subject matter of geographical content. Therefore, environmental geography needs to incorporate its contents from the man-environmental interaction within the disaster studies perspective. The environmental condition of the surrounding areas is the first concern of the people living in. The hazard and vulnerability situation of the surrounding areas put the people at risk. Therefore, National and international organizations have been giving their attention towards the hazard and disasters. The United Nations General Assembly proclaims the International Decade for National Disaster Reduction begins on 1st January 1990. Since then the international initiatives on understanding and management of hazard and disaster have been increasing all over the world. The UN General Assembly has initiated the United Nations Strategies for Disaster Reduction (UNISDR), Hyogo Framework of Action 2005-2015 and Sendai Framework for Disaster Risk Reduction 2015-2030. Many countries have or are in the process of developing national and local disaster risk reduction strategies towards the global target of the Sendai Framework to sustainability increase the number of countries with national and local disaster risk reduction strategies in place by 2020.

LEARNING OBJECTIVE

The learning objectives of the course are:

i) To understand basic concepts of hazard and disaster, disaster management etc.;
ii) To know the definitions and terminologies used in Disaster Management ;
iii) To recognize the types, sub-types and categories of hazards and disasters;
iv) To learn about prevention and preparedness for hazards and disasters;
v) To be familiar with mitigation strategies & risk reduction steps;
vi) To prepare Disaster Preparedness plans for disaster response and evaluation plan for disaster response;
vii) To study the evolution of Disaster Management in India and the institutional and legal framework for India;
viii) To identify the Policies and Programmers for Disaster In India.

LEARNING ACTIVITIES

The learning activities may involve the understanding of the concept and recognising structural aspect of hazard, disaster, risk, vulnerability etc by group discussion, illustration by teachers, identification of the types and sub-types of different hazards and disasters by self demonstration of the students etc. For better understanding students may be encouraged to perform assignments and project works on the impacts of various types of disasters and correlate the real facts; they may be encouraged to make charts or posters on the risk and vulnerability as well as make out the relationship between capacity, risk and vulnerability; they may be motivated towards participation in tests or exams on the prevention, mitigation and management of various types of disasters and role of national disaster mitigation agency for management of disasters in India.

ASSESSMENT OF PRIOR KNOWLEDGE

To assess the prior knowledge of the students, they may be enquired

- ☐ What is disaster?
- ☐ What do you mean by hazard?
- ☐ Is there any difference between hazard and disaster?
- ☐ How natural disaster occurs?
- ☐ Mention some manmade disasters in India.
- ☐ What do you mean by disaster management?

FEEDBACK OF LEARNING ACTIVITIES

After the completion of the learning process, the internal assessments will be conducted. Bases on the evaluation of the performance in internal, the parts of the course will be revised and reassessed as per requirements of the students.

UNIT-1:

CONCEPT AND TYPES OF HAZARDS AND DISASTERS

INTRODUCTION:

To study different aspects of hazard and disaster, it is essential to describe the conceptual background of these extreme events. The present chapter has, therefore, offered the literary meaning, traditional as well as contemporary definitions, concepts and various types of both the incidents of hazard and disaster. The hazard and disasters both are related terms but have diversity in nature and intensity (Mc. Farlane and Norris, 2006).

Hazard and disaster are related to a variety of disciplines as well as professionals. Hence the definition of these terms differs. An attempt has been made in the present unit to understand the interdisciplinary perspectives of the concepts of hazard and disaster, which will entail a profound and appropriate definition. In defining these two terms, a mere distinction also has been explained. In addition to this, an overview of the typologies of hazard and disaster has been presented.

MEANING AND CONNOTATION

Disaster has undergone a vivid transformation of meaning over time (Quarantelli, 1998b; Quarantelli & Perry, 2005). The word “disaster” originated from Latin *‘dis astro’* or “bad star” (Dombrowsky, 1998:19) and implied a calamity responsible for an adverse situation of the planet as acts of God (Drabek, 1991:4). The Oxford Dictionary of English (1987) describe the term ‘disaster’ as a “sudden or great misfortune; calamity; complete failure.”

Any occurrence that causes damage, ecological disruption, loss of human life, deterioration of health and health services on a scale sufficient to warrant an extraordinary response from outside the affected community. Although consistent with the day-to-day informal usage of the term, this definition is highly inadequate because it fails to distinguish disasters from other adversities (Green, 1996).

The word 'hazard' owes its origin to the word '*hasard*' in old French and '*az-zahr*' in Arabic meaning 'chance' or 'luck'. A hazard is a source of potential harm or a situation with a potential to cause loss. It may also be referred to as a potential or existing condition that may cause harm to people or damage to property or the environment (Middelmann, 2007).

DEFINITIONS OF HAZARD

"Hazards represent the potential occurrence of extreme natural events, or likelihood to cause the severe adverse effects while, disasters result from actual hazard events." (Tobin and Montz, 1997). (1)

"Hazard is an extreme geophysical event that is capable of causing a disaster" (Paul, 2011).(2)

A hazard may defined as the perilous conditions or events that are threatening or have the potential for causing injury to life, property or the environment (Dey& Singh, 2006). (3)

It is also defined as any event, typically occurring suddenly, that causes damage, ecological disruption, loss of human life, deterioration of health and health services, and which exceeds the capacity of the affected community on a scale sufficient to require outside assistance (Landsman, 2001). (4)

"Hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (UNISDR, December 1999). (5)

DEFINITIONS OF DISASTER

The World Health Organization (WHO) defines a disaster as "a sudden ecological phenomenon of sufficient magnitude to require external assistance." (1)

According Carr (1932), "not every windstorm, earth-tremor, or rush of water is a catastrophe. A catastrophe is known by its works; that is, to say, by the occurrence of disaster. So long as the ship rides out the storm, so long as the city resists the earth-shocks, so long as the levees hold, there is no disaster. It is the collapse of the cultural protections that constitutes the disaster proper. (Dombrowsky 1998, p. 18) [(2)]

Disasters may be defined as "non-routine events in societies or their larger subsystems (e.g. regions, communities) that involve social disruption and physical harm. Among the key defining properties of such events are (1) length of forewarning, (2) magnitude of impact, (3) scope of impact, and (4) duration of impact. (Kreps, 1998: p. 28) [(3)]

Disaster is "A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic, and environmental losses and impacts." (UNISDR, December 1999). [(4)]

Disaster can be defined as the severe disorder in the implementation of the community or a society causing extensive substance, economic, social, financial or environmental losses which go beyond the ability of the affected society to manage using its own resources. A disaster occurs as a consequence of the hazards, defenselessness or insufficient capacities or measures to cause a reduction in the risk factors (Dey& Singh, 2006). [(5)]

The International Federation of Red Cross and Red Crescent Societies have published the World Disasters Report, which provides an excellent example of a definition that emphasizes the physical or social impacts of collective crises. In this report, events are considered disasters if (1) 10 or more people are reported killed, (2) 100 or more people are reported affected, (3) an appeal for international assistance is issued, and/or (4) a state of emergency is declared (International Federation of Red Cross and Red Crescent Societies, 2000). [(6)]

CONCEPTS

A natural hazard is associated with geophysical processes that are an integral part of the environment and involves the potential for damage or loss that exists in the presence of a vulnerable human community (Stillwell, 1992); it is an unexpected threat to humans and/or their property (Mayhew, 1997).

These definitions indicate that natural hazards have not only natural, but also social, technological, and political aspects. Natural hazards include geophysical hazards, i.e., hazards where the principal causal agent is climatic and meteorological (e.g., floods, hurricanes, and droughts).

From the above definitions, it is clear that hazards are threats and not the actual events. The originating point of hazards is the natural environment and they represent the likelihood to cause severe impacts. A single hazard may have a cascading effect causing a sequence of secondary and tertiary hazards. These can be determined using hazard sequencing. While among the three definitions of hazard, (1) AND (2) do not take into account the role of human activity in exacerbating the impacts of hazards, but the definition by UNISDR addresses this aspect. The role of human beings in contributing to hazards cannot be ignored.

On the other hand, it is clear that disaster can be looked at from a wide range of perspectives. There is no single definition that we should depend upon. Based on our understanding of disasters, we can adopt any of the definitions that are available in literature or can even contribute our own.

While hazards are threats, disasters are the actual events that cause damage to the society and human welfare. Disasters are a complex combination of natural hazards and human action (Blaikie et al., 2003). Natural hazards such as floods, earthquakes, drought in a region coupled with political unrest and epidemics may be extremely difficult for people to deal with.

Since disasters exceed the community's or society's ability to cope using its own resources, the disaster-affected communities depend on external assistance - national and international Governments, NGOs etc. – to overcome the impact of disasters. Humanitarian agencies also provide long-term rehabilitation and support to disaster-affected communities.

Disasters and development are interlinked. Disasters and development share a two-way relationship. Development leads to disaster and disasters impact development (Collins, 2009). The association is so obvious that it is difficult to ignore and therefore has attained global importance. The international community has recognized the importance of addressing the association by including it in agendas such as millennium development goals and sustainable development goals.

HAZARD VS. DISASTERS

It is established fact that there merely found natural disasters in contrast to the natural hazards in its actual sense. A disaster is the consequence after a hazard or the impact of a hazard on the civilization. Therefore, the severity of a disaster is determined by the extent of a community's susceptibility to the hazard or on the contrary, the capacity of the society to deal with it. This susceptibility or vulnerability is dynamic in nature as the physical, socio-cultural, economic, political and psychological factors that modify individual's living determine the entire environment in which they live. So, vulnerability to disasters is a process resulting from human action or interaction. It describes the degree to which a society is threatened by the impact of natural hazards in social, economic, physical and environmental spheres. On the other hand, the natural hazards are the nature's judgement on what humans have inflicted upon.

HAZARD DISASTER	
Hazard is an event that has potential for causing injury/loss of life or damage to the property or environment.	Disaster is an event that occurs suddenly or unexpectedly in most cases and disrupts the normal course of life in affected area.
Hazards generally occur in the places devoid of inhabitation.	Disasters take place in inhabited areas or over populated areas.
Hazards can lead to disasters.	Disasters are the result of a hazard.
Hazards come with warnings.	Ignoring the warnings by hazards can lead to disaster.
Hazards may be inevitable. **Hazards take its full shape after a series of events, which might have led it to happen. The occurrence probability of Hazards is often predicted.**	Disasters can be prevented. Disasters often happen within short time, causing more severe effects, thus the occurrence probability of Disasters cannot be predicted.
Hazards are well-known to be short-term.	Disasters are well-known to be long-term.

Source: Paul, B. K. (2011). Environmental Hazards and Disasters: Contexts, Perspectives and Management. Germany: Wiley.

NATURAL vs. MAN-MADE DISASTERS

NATURAL DISASTERS	MAN-MADE DISASTERS
Sudden-impact – earthquakes, tropical storms, tsunamis, volcanic eruptions, etc.	Industrial/Technological – pollution, fires, spillages, explosions, etc.
Slow-onset – drought, famine, pest infestation, De forestation, etc.	Complex emergencies – wars, civil strife, armed aggression, etc.
Epidemic diseases – water-borne, food-borne, vector-borne, etc.	Others – transportation accidents, material shortages

Source: Abdallah and Burnham, nd

CLASSIFICATION OF DISASTERS

Disasters are classified as per origin, into natural and man-made disasters. As per severity, disasters are classified as minor or major (in impact). However, such classifications are more academic than real as major disasters could simply be events that received relatively more media coverage (Parasuraman and Unnikrishnan, 2005).

Natural disasters:

- Geophysical (result from phenomena beneath the Earth's surface; earthquakes, landslides, tsunamis and volcanic activity)
- Hydrological (avalanches and floods)
- Meteorological (cyclones and storms/wave surges)
- Climatological (extreme temperatures, drought and wildfires)
- Biological (disease, epidemics1 and insect/animal plagues) (Landsman, 2001)

Man-made/ Anthropogenic Disasters:

- Technological (the failure or breakdown of systems, equipment and engineering standards that harms people and the environment;structural collapses, such as bridges, mines and buildings).

- Industrial (disasters caused by industrial companies, either by accident, negligence or incompetence; Chemical and nuclear explosion
- Warfare (disasters caused by sociopolitical conflicts that escalate into violence; war, intra society conflicts)
- Socio-natural Disaster: This term is used for the circumstances where human activity is increasing the occurrence of certain hazards beyond their natural probabilities. It is the phenomenon of increased occurrence of certain geophysical and hydro-meteorological hazard events, such as landslides, flooding, land subsidence and drought that arise from the interaction of natural hazards with overexploited or degraded land and environmental resources.

  This term is used for the circumstances where human activity is increasing the occurrence of certain hazards beyond their natural probabilities. Evidence points to a growing disaster burden from such hazards. Socio-natural hazards can be reduced and avoided through wise management of land and environmental resources

[*United Nations International Strategy for Disaster Reduction. Terminology. Geneva, Switzerland: UNISDR; 2009. http://www.unisdr.org/we/inform/terminology*]

LIST OF VARIOUS DISASTERS IN INDIA

LIST OF VARIOUS DISASTERS	
i. Water and Climate related disasters	a) Floods and drainage management b) Cyclones c) Tornadoes and Hurricanes d) Hailstorms e) Cloud burst f) Heat wave and Cold wave g) Snow avalanches h) Droughts i) Sea erosion j) Thunder and lighting k) Tsunami

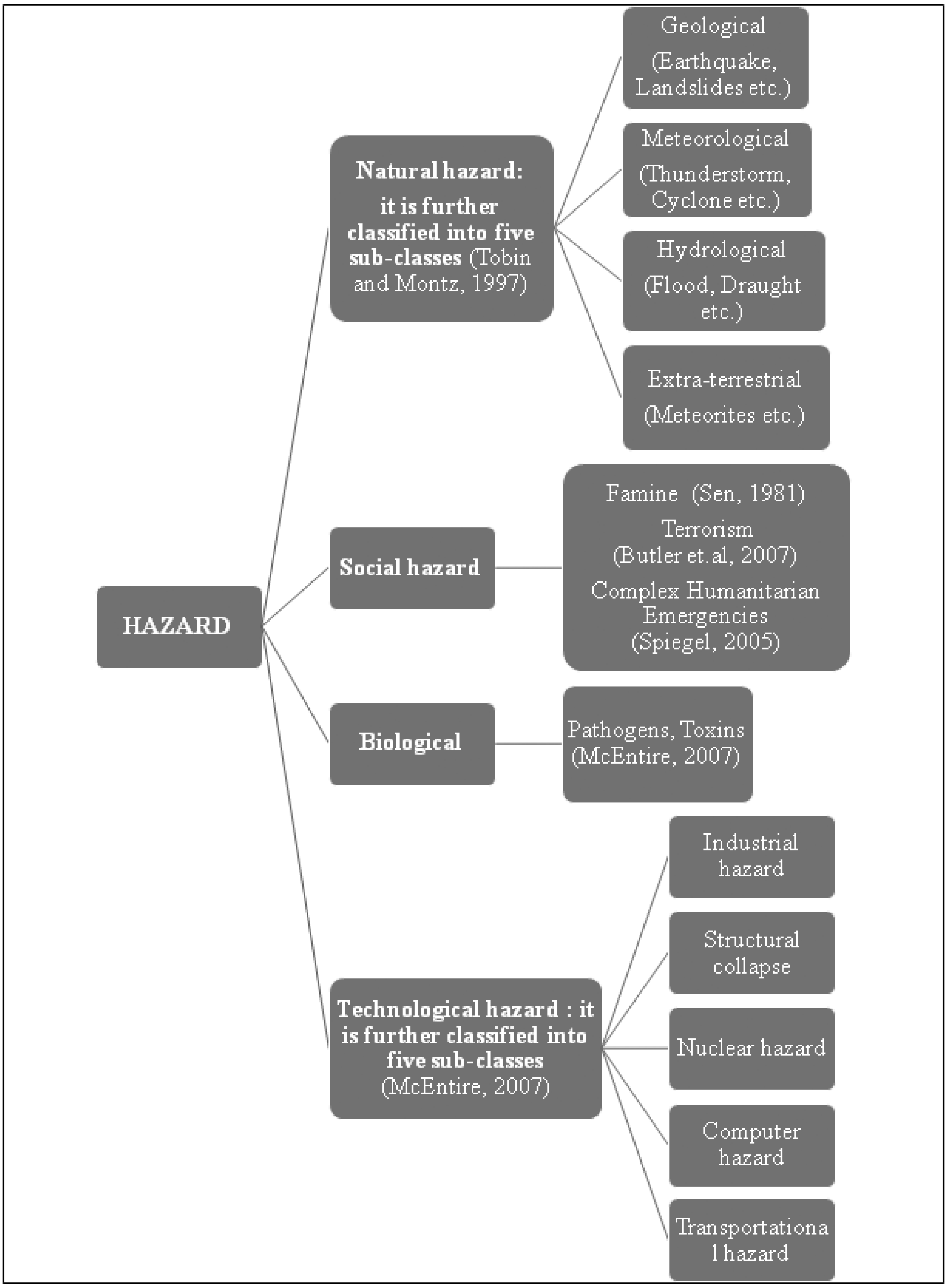
ii. Geological related disasters	a) Landslides and mudflows b) Earthquakes c) Dam failure/Dam bursts d) Mine disasters
iii. Chemical, industrial and nuclear related disasters	a) Chemical and industrial disasters b) Nuclear disasters
iv. Accident related disasters	a) Forest fires b) Urban fires c) Mine flooding d) Oil spills e) Major building collapse f) Serial bomb blasts g) Festival related disasters h) Electrical disasters and fires i) Air, road and rail accidents j) Boat Capsizing k) Village fire
v. Biological related disasters	a) Biological disasters and epidemics b) Pest attacks c) Cattle epidemics d) Food poisoning

Source: https://nidm.gov.in/easindia2014/err/pdf/country_profile/India.pdf

CLASSIFICATION OF HAZARDS

Over the years, many efforts have been made to arrive at a classification system of hazards. The hazards can be classified into two major types such natural or physical and anthropogenic or non-physical hazards (i.e. social, technological, biological etc.) respectively. It may be further sub-categorised into several classes (Paul, 2011). The basis of typology of the hazard is multi-dimensional and hence to categorise the hazard to a single framework is very tough.

Although, hazards are mostly classified based on their sources of origin, there may be other classification systems as well. (Mitchell and Cutter, 1997)



(Source: Paul, 2011; pp. 16-20)

Hazards can occur individually, successively or in combination with each other. A primary hazard can be followed by secondary hazard for example; the earthquake and tsunami with the radiological hazards took place in East Japan in the year 2011 disaster. Hazards can have a short or long duration, and can have different impacts depending on the time of day, week or month when they happen. They can be sudden onset, like an avalanche, or develop slowly over time as the result of a combination of factors. Deforestation, for example, is a slow onset hazard which can stem from factors such as limited resource management, land use planning, economic opportunities, and climate change. (D. Saulnier et. al., 2021)

According to the Truncated WHO Classification of Hazards:

Groups	Sub-groups	Examples of main types
Natural	Geophysical	Earthquake, geo-physically triggered mass movement, volcanic activity
	Hydrological	Flood, wave action, hydro-meteorological triggered mass movement
	Meteorological	Storms, extreme temperature
	Climatological	Drought, wildfire, glacial lake outburst
	Biological	Air-, water-, and vector-borne diseases, animal and plant diseases, food-borne outbreaks, antimicrobial resistant microorganisms
	Extraterrestrial	Impact, space weather
Human-induced	Technological	Industrial hazard, structural collapse, fire, air pollution, infrastructure disruption, cybersecurity, hazardous materials (including radiological), food contamination
	Societal	Armed conflict, civil unrest, financial crisis, terrorism, chemical, biological, radiological, nuclear, and explosive weapons
Environmental	Environmental degradation	Erosion, deforestation, salinization, sea level rise, desertification, wetland loss/ degradation, glacier retreat/melting

Source: Global assessment report on disaster risk reduction 2015: Making Development Sustainable, The Future of Disaster Risk Management. Geneva: UNISDR; 2015. (https://www.undrr.org/publication/globalassessment-report-disaster-risk-reduction-2015 accessed 8 February 2020)

CAUSES OF DISASTERS AND HAZARDS

The causes of disasters and hazards have been extensive and various reasons have been stated as follows: (Dey& Singh, 2006).

Causes of Earthquakes – The earth's crust is a rocky layer of variable thickness; crust comprises of portions called plates which vary in size from a few hundred to thousands of kilometers. When these plates contact each other, stress occurs within the crust. The peripheries of the plates pull away from each other, push against one another or slide sideways relative to each other; these are the major causes for the occurrences of earthquakes.

Causes of Tsunamis –Firstly, the fault movements upon the sea floor, associated by an earthquake release a huge amount of energy and have the capacity to cross through the oceans; secondly, landslide may cause Tsunami that is occurring under the water or above the sea and then plunging into water and thirdly, volcano eruptions may lead to Tsunamis.

Causes of Floods –There are different causes of floods and they differ from one area to another; they may vary from rural area or urban. The causes may be due to heavy rainfall, heavy siltation of the river beds, blockage within the drains also leads to flooding of the region, landslides block the flow of the streams, construction of dams and reservoirs may lead to floods and the areas which are prone to cyclones, winds that are associated with heavy down pour cause floods.

Causes of Drought –Though drought is mainly caused by deficit rainfall, which is a meteorological phenomenon, it is apparent into different spheres because of various vulnerability factors associated with them. Some of these factors are human stimulated. Though drought is a natural disaster, its effects are made worst in developing countries which are over populated; the countries that are over populated in them factors such as over grazing, deforestation, soil erosion, excessive use of ground and surface water for growing crops, loss of biodiversity takes place which causes drought.

Causes of Landslides–The major causes of landslides are weaknesses in the structure of land components such as rock or soil, erosion of slope due to decrease in vegetation, intense rainfall, volcanic eruptions and earthquakes are natural factors.Human excavation of slopes, factors such as mining, deforestation, irrigation, draw down in the reservoir, explosions/blasts and water leakage from services are some of the human made factors that cause landslides. (Kapur, 2018)

CONCLUSION

The module explained the concepts of hazard, disaster and the distinction between them. While hazards (earthquake, floods, drought, and cloudburst) exist in the natural environment, vulnerability (poverty, illness, caste and class discrimination) is socially constructed. Where the two intersect, disasters occur. If a hazard, for example an earthquake, strikes in an unpopulated place and does not result in loss of property and lives, it will not qualify to be called a disaster. Although the accepted notion is that the poor are vulnerable, this is not always the case. According to Cannon (2000), middle-class population living in unsafe buildings in an earthquake-prone area will be more vulnerable than the poor who live in fragile houses because if the latter collapses, not many would death or be injured. Risk is a mental construct. What is perceived as risk by one community may not be regarded as risk by another community. Risk perceptions are important in shaping preparedness strategies. For governments, formulating the right risk reduction measures is better than spending millions in reconstruction post-disasters. The concept and Assessment of risk and vulnerability will be discussed in the succeeding module.

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MODEL QUESTIONS:

1. Define hazard. What is disaster? Where from has the word "disaster" originated?
2. Differentiate hazard and disaster.
3. Distinguish between natural and man-made disasters.
4. Classify the disasters and discuss the types. Give examples of disasters in India.
5. Classify different types of hazards and discuss. Give the Truncated WHO Classification of hazards.
6. Discuss the causes of hazards and disasters in details.

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UNIT-2:

ASSESSMENT OF RISK AND VULNERABILITY

INTRODUCTION:

To understand the idea of risk and vulnerability, the present module is predetermined to talk about the conception, levels and processes of assessment risk and vulnerability. The present chapter is dealing with the conventional definitions, conceptual background and diverse facets of both the terms. It also throws some light on the inter-relation between vulnerability, risk and disaster along with some related terminologies.

A range of efforts have been made in different disciplines to address risk and vulnerability. However, both the level of acceptance of risk and vulnerability varies from one individual to another. Observation also varies from one discipline to other and therefore, there is no universally valid definition of risk and vulnerability.

CONCEPT OF RISK:

Risk is an inevitable part of life, affecting all individuals, irrespective of any geographic or socio-economic limits. Each choice we make as individuals and as a society involves definite or unidentified factors of risk and forestalling of risk utterly is almost impossible.

Each individual is responsible for managing the risks he/she faces but some risks, management is compulsory. For example, automobile speed limits and seatbelt usage etc. For other personal risks, such as those associated with many recreational activities, individuals are free to choose the level of risk exposure. Similarly, the risk of health related to any infectious diseases also controlled by individuals. By employing risk reduction techniques for each life hazard, individuals effectively reduce their vulnerability to those hazard risks.

At the societal level, civilians face the risks of major hazards collectively although these are less frequent but the casualties and fatalities may be of significant in numbers. The potentiality of these hazards may result in many deaths, injuries and damages or loss of properties in a particular event or series of events. In fact, some of these hazards are gigantic in nature that may cause devastation and the capability of local response mechanisms may turn into failure. This situation is called a disaster by definition.

Risk is the potential damage or loss caused by the combination of vulnerability and hazards. A disaster occurs when vulnerable group of people experience a hazard and undergoes severe disruption of their livelihood. Risk is also the chance of harmful consequences or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interaction between natural or human-induced hazards and vulnerable conditions (HPC Report, 2001).

As far as disaster risk is concerned, it refers to the probability of the occurrence of a disaster. It is a subject to the extent of hazard, vulnerability and capacity. In relation to disasters, Kotze and Holloway (1996) define risk as the expected losses (lives lost, persons injured, damage to property and disruption of economic activity or livelihood) caused by a particular phenomena.

For these hazards, vulnerability is most effectively reduced by disaster management efforts collectively, as a society. For most of these hazards, it is the government's responsibility to manage, or at least guide the management of, hazard risk reduction measures. And when these hazards do result in disaster, it is likewise the responsibility of governments to respond to them and aid in the following recovery. (FAO, 2005)

This text focuses on the management of international disasters, which are those events that overwhelm an individual nation or region's ability to respond, thereby requiring the assistance of the international body of response agencies. This chapter, therefore, focuses not upon individual, daily risks and vulnerabilities, but on the risks and vulnerabilities that apply to the large-scale hazards.

CONCEPT OF VULNERABILITY

Vulnerability implicit as a measure of the degree to which a system possibly damaged in response to a incentive; rather it has been widely used in the physical and social sciences in literature dealing with hazards, climate change, ecology, crime, etc. The term "vulnerable" originates in the verb "to wound" and it has been used in a variety of ways to characterise the response of social and ecological systems to perturbations (Timmerman, 1981). As analysed previously, risk is closely associated with vulnerability and can be viewed as a joint product of environmental stresses and human and ecological vulnerability.

The concept of vulnerability indicates a probable potential condition which implies a measure of risk together with a relative incapacity to cope with the resulting stress. Timmerman (1981), looking towards explanation of societal collapse, has reviewed the concepts associated with vulnerability. According to him, “Vulnerability is the degree to which the subject (individual or group) reacts adversely to the occurrence of a hazardous event. The degree and quality of that adverse reaction are partly conditioned by the system’s resilience; the measure of a system’s, or part of a system’s, capacity to absorb and recover from the occurrence of a hazardous event.” Vulnerability is defined in the

(United Nations Disaster Management Training Programme, 1994: *https://www.preventionweb.net/files/10996_N9437604.pdf*) as the “degree of loss to a given element at risk (or set of elements) resulting from a given hazard and a given severity level.”

The concept of vulnerability as ‘the differential susceptibility to loss,’ is a central but still incompletely and incoherently developed concept. In the composite composition of a society, there are some groups that are more prone to damage, losses, and suffering from hazards. Certain factors cause variations of impact including class, caste, ethnicity, gender, disability and age. It is also noticeable that conception of vulnerability has a temporal dimension as long-standing consequences are involved by reduced capacities and enhanced vulnerabilities. Since damage to livelihood is the foremost issue, those who find it the toughest to restructure their livings after a disaster, are more vulnerable.

Vulnerability can be of varied types like:

1) Physical vulnerability: Depending on physical location of people and elements at risk and technical capacity of buildings, structures, and infrastructure. It varies according to construction techniques, materials used and location.

2) Economic vulnerability: Poor people are considered to be more vulnerable as their houses are built of weak material and in dangerous areas. They do not have the essential safety nets to recover as the affluent population. Their loose the essential tools and equipments of their livelihood as well.

3) Social Vulnerability: Some sections of the population are more vulnerable than the others like women, children, elderly, physically and mentally challenged and those dependent on critical facilities.

4) Other types of vulnerability: Some other types of vulnerability have also been identified like Environmental vulnerability, Cultural vulnerability, Educational vulnerability, Attitudinal vulnerability and Political vulnerability.

CAPACITY, RESILIENCE, RESISTANCE AND SENSITIVITY

Vulnerability is one side of a coin; the other side representing the resources people have to resist, cope with, or recover from a hazard, or "capacities". Vulnerability is about "not having" while capacities are about "having". Capacity is knowledge, skills, resources, abilities and strength, present in individuals, households and the communities, which enable them to prevent, prepare for, stand against, survive and recover from a disaster.

People's capacities are also highlighted by what are known as "coping strategies". These are responses linked to capacities (or resources) which, in the face of a hazard determine how vulnerable or resilient an individual or household becomes.

Capacity =1/Vulnerability

Some examples of capacity are:

- Permanent houses
- Adequate food and income sources
- Fire stations
- Developed health infrastructure,
- Good Community Networks for support
- Local knowledge
- Strong community leadership and organizations

Other related perceptions of 'resistance' (the ability to absorb impact and maintain functioning) 'resilience' (the ability to maintain a system and to recover after impact), and 'exposure' (the presence of a threat to a group or region) provide a few assistance in explanation of vulnerability. These three aspects deals with most of the discussions related to the general structure of vulnerability. Resilience is explained as fortitude in the face of a potential threat. In one word, it means resistance. Even though, the specific terms, concepts and criteria used to address vulnerability may vary. In addition to this, sensitivity refers to the degree of proneness of a particular 'element at risk' to a particular threat, such as climate risk, land degradation etc. Sensitivity would refer to the degree of change that would be brought about as response in one variable that is correlated to the other. Assessing Sensitivity would involve working out the correlation. (Stewart Carloni and Crowley, 2006)

RISK AND VULNERABILITY

Vulnerability is the extent to which persons or infrastructures are expected to experience damage from a disaster, while risk is the likely quantified losses that would result considering the frequency and intensity of a hazard. Risk also comprises a component of hazard, but both the natural and man-made incidents in the form of hazard, can lead to a disaster if there is high vulnerability.

In order to commence programmes for awareness and risk reduction in any community experiencing hazards, it is essential to identify the specific vulnerabilities and to consider the resilience against the threats present in the area. There is sequence of steps; the most important one is being the assessment and analysis of vulnerability and risk. This must direct the public policies for immediate and long-term preparedness, mitigation and vulnerability reduction.

Vulnerability and risk assessments are both science and arts of disaster management as quantitative estimation of probability of risks and probable damage are attempted using statistical techniques. Socio-economic study to understand communities and specific factors that make them vulnerable is attempted using the insights provided by such measurements and effective conversion attempted through planning and policies. It is especially important to identify that the social vulnerability is much more than the probability of infrastructure getting damaged. This depends on the nature of people, and the differential impacts of a disaster on people.

Disaster risk signifies the possibility of adverse effects in the future. It derives from the interaction of social and environmental processes, from the combination of physical hazards and the vulnerabilities of exposed elements. The hazard event is not the only driver of risk, and there is high confidence that the levels of adverse effects are in good part determined by the vulnerability and exposure of societies and social-ecological systems (UNDRO, 1980; UNISDR, 2004, 2009b; Birkmann, 2006a,b; van Aalst 2006a).

Disaster risk is not fixed but has a constant growth. A disaster is one of its many ‘moments’ (ICSU-LAC, 2010a, b), signifying unmanaged risks that often fabricate distorted development problems (Westgate and O'Keefe, 1976; Wijkman and Timberlake, 1984). Disasters also may be noticed as the manifestation of risk and indicate 'a functional state' of this dormant condition that is in itself a social edifice (Renn, 1992; Adam and Van Loon, 2000; Beck, 2000, 2008).

Disaster risk is associated with various levels and types of adverse effects. The effects may suppose to be catastrophic and commensurate with small disasters. Some are confined to restricted financial costs but very high casualties even loss of life ed; others have very high financial costs but relatively limited human costs. in addition, there is high assurance that the cumulative effects of small disasters can influence the capacities of communities, societies, or social-ecological systems to deal with future disasters at national or local levels (Alexander, 1993, 2000; Quarantelli, 1998; Birkmann, 2006b; Marulanda et al., 2008b, 2010, 2011; UNISDR, 2009a).

Risk is a function of hazard occurrence and the projected losses. A societal element is said to be 'at risk' or vulnerable when it is exposed to hazards and is likely to be adversely affected by the impact of those hazards if and when they occur, especially in situations of limited capacity.

It can be best explained by

$$\text{DISASTER RISK} = \frac{\text{HAZARD} \times \text{VULNERABILITY}}{\text{CAPACITY}}$$

One of the simplest and most common definitions of risk, preferred by many risk managers, is displayed by the equation stating that risk is the likelihood of an event occurring multiplied by the consequence of that event, were it to occur:

RISK = LIKELIHOOD×CONSEQUENCE (Ansell & Wharton 1992)

FACTORS OF VULNERABILITY

The disaster risk scholars put stress on the factors which compound or lessen vulnerability.

i. Political factor

The level of vulnerability in any community can be directly linked to the political will and commitment to developmental concerns. Vulnerability is as much about the exposure to a given hazard as the decision-making linked to development which will address conditions of vulnerability. A set of deep-rooted socio-economic elements which include aspects such as denial of human rights, denial of access to power structures, access to quality education, employment opportunities, land tenure, availability of and access to resources, access to infrastructure, basic services and informatio, together have the ability to create and maintain extreme levels of vulnerability.

Political will is fundamental to disaster risk reduction. Managing risk depends on political will and political will depends on political leadership. A shifting of incentives, pressures and polemics guide this political will. The political costs of redirecting the priorities from visible development projects to addressing abstract long-term threats are great. (Christoplos et al., 2001:195).

ii. Economic factor

The economic status of the population relates not only to the degree of losses in terms of lives, property and infrastructure but also to the capacity to cope with and recover from adverse effects. Virtually all disaster studies show that the wealthiest of the population (women and men) either survive the impact of a hazard without suffering any adverse effects or are able to recover quickly (due mostly to the presence of insurance, savings, investments or some other financial instrument to fall back on). Poverty and lack of access to land and basic services explains why people in urban areas are forced to live on hills that are prone to landslides, or why people settle near rivers that invariably flood their banks. Poverty explains why droughts claim poor subsistence farmers as victims and rarely the wealthy, and why famine, more often than not, is the result of a lack of purchasing power to buy food rather than the absence of food.

Increasingly, poverty also explains why many women and men are forced to move from rural areas to the cities in search of job opportunities or to other parts of a country or even across borders to survive (e.g. Migration from Zimbabwe into South Africa). Such crisis-induced migration and rapid urbanisation pose considerable challenges to the authorities with unplanned settlements and longer-term development, as well as immediate assistance in the case of displaced persons. Poverty and lack of access to land force people to build temporary, unsafe dwellings in crowded, dangerous locations (UNDP, 1992:6).

iii. Demographic factor

There is also an obvious connection between the increase in losses from a disaster and the increase in population. A rapid increase in population makes it inevitable that more people will be affected by the impact of hazards because more will be forced to live and work in unsafe areas. If there are more people and structures where a disaster strikes, then it is likely there will be more of an impact. Increasing numbers of people competing for a limited amount of resources (such as employment opportunities and land) can lead to conflict. This conflict in turn may also result in crisis-induced migration (UN 1992:6).

iv. Physical factor

Physical vulnerability refers to the susceptibility of individuals, households and communities to loss due to the physical environment in which they find themselves (UNISDR 2002:47) (refer back to the question on: "Where do people live?"). It relates to aspects such as access to suitable land, land use planning, housing design, building standards, materials used for building houses, engineering, accessibility to emergency services and other similar aspects. Physical vulnerability may be determined by aspects such as population density levels, remoteness of a settlement, the site, design and materials used for critical infrastructure and for housing (UNISDR, 2002).

Physical vulnerability also relates to remotely located settlements, their location, the design of building structures, and their ability to withstand the elements and hazards, as well as their lack of access to services, infrastructure and information.

v. Physical factor

The level of social well-being of individuals, households and communities directly impacts on their level of vulnerability to hazards. Levels of education, literacy and training, safety and security, access to basic human rights, social equity, information and awareness, strong cultural beliefs and traditional values, morality, good governance and a well-organised cohesive civil society, all contribute to social wellbeing with physical, mental and psychological health being critical aspects.

vi. Social factor

Vulnerability is not equally distributed. Minority groups, the aged, orphans, nursing mothers and their offspring, and the disabled are more vulnerable than others. The issue of gender and in particular the role of women requires special consideration (UNISDR 2002:47)

Transitions in cultural practices inevitably take place and many of the changes that occur in all societies lead to an increase in the societies' vulnerability to hazards. Obviously all societies are constantly changing and in a continual state of transition. These transitions are often extremely disruptive and uneven, leaving gaps in social coping mechanisms and technology.

vii. Environmental factor

The discussion of environmental aspects of vulnerability covers a very broad range of issues in the interacting social, economic and ecological aspects of sustainable development relating to disaster risk reduction. The key aspects of environmental vulnerability can be summarised by the following five distinctions:

a. The extent of natural resource depletion;

b. The state of resource degradation;

c. Loss of resilience of the ecological systems;

d. Loss of biodiversity; and

e. Exposure to toxic and hazardous pollutants (UNISDR 2002:47).

"As natural resources become more scarce the range of options available to communities becomes more limited, reducing the availability of coping solutions and decreasing local resilience to hazards or recovery following a disaster. Over time environmental factors can increase vulnerability further by creating new and undesirable patterns of social discord, economic destitution and eventually forced migration of entire communities" (UNISDR, 2004:43).

ANALYSIS OF RISK AND VULNERABILITY

Vulnerability and risk assessment encompass various approaches and techniques ranging from indicator-based global or national assessments to qualitative participatory approaches of vulnerability and risk assessment at the local level. They serve different functions and goals (IDEA, 2005; Birkmann, 2006a; Cardona, 2006; Dilley, 2006; Wisner, 2006a; IFRC, 2008; Peduzzi et al., 2009).

To carry out vulnerability analysis, we need a clear idea about Vulnerability. The concept and definition already have been discussed in the present module. The concept of vulnerability can be assessed at various levels and from diverse perspectives. Both physical scientists and social scientists are concerned about the assessment of vulnerability. There is growing specialisation of the estimation in the particular fields of hazard and vulnerability assessment. Although specialisation, there is an innate threat of increased separation among respective specialists in physical science and social science streams. Even across the two broad categorizations of physical sciences and social sciences, viewpoints are likely to differ with respect to emphasis areas as per sub-specialisations. Consequently, a scientist in associated fields is expected to recognize vulnerability more in terms of risk, while a social scientist is likely to do that in terms of the probability of occurrence and impacts of related events on the society. The physical perception of vulnerability is parallel to the concept of risk whereas the social science viewpoint defines it more in terms of socio-economic parameters.

Social and Physical Vulnerability

Each of these relates only themselves to a partial understanding of vulnerability. There is a need to rise above specialisations and take an across- the- board, interdisciplinary and cross-cultural view of the issue of vulnerability to present a more holistic and comprehensive analysis of vulnerability for meaningful articulation and strategic development in the area. (Nick Brooks, 2003).

The closer the analysis gets to the fundamental causes rather than the symptomatic aspects of vulnerability, the more difficult and complex vulnerabilities get/are in fact to address. However, the more fundamental the vulnerability addressed, the more hazard-resistant the vulnerable group is expected to develop into as a result.

Social vulnerability is the complicated set of characteristics that include a person’s:

- initial well-being (nutritional status, physical and mental health, morale),
- livelihood and resilience (asset pattern and capitals, income and exchange options, qualifications,

- self-protection (the degree of protection afforded by capability and willingness to build safe home, use safe site),
- social protection (forms of hazard preparedness provided by society more generally, for example, building codes, mitigation measures, shelters, preparedness), and
- social and political networks and institutions (social capital, but also role of institutional environment in setting good conditions for hazard precautions, peoples' rights to express needs and of access to preparedness). (Terry Cannon, 2000)

The method of vulnerability analysis has a clear sense of comparability and convergence in the analysis of vulnerability variables. There is also an understanding that the vulnerability conditions are determined by the methods and factors that are actually quite different from hazard, which is mistakenly held singularly responsible for losses. These root causes or institutional factors, processes and priorities are highlighted in much of the vulnerability analysis work. Vulnerability to disasters is also a function of this broad environment as individual's living, political and economic processes resolve opportunities and their patterns of assets and incomes. These variables are intrinsically connected with individual's livelihoods (lower vulnerability is likely when livelihoods are adequate and sustainable), and their innate resilience related with issues such as poverty (in most disasters). In view of the fact, that mostly poor people are excessively at more risk than the other groups, and also incapable of improve easily.

In a particular hazard, the divergence in the vulnerability level is studied by the diverse segments of population in a given area. It is important to inquire into the differential causes of vulnerability to the inhabitants exposed in this process. It includes the poverty, marginalisation or other deprivations that emphasize the vulnerability to hazard risks or any specific event. Hazards affect predominantly the sections of the population who are disadvantaged, 'at risk', or in other ways in need. Vulnerability involves a predictive feature as it is a method of theoretically considering the situation of wounded under conditions of particular hazards. Specifically, as it have to be predictive, vulnerability analysis (VA) should be capable of directing development aid interventions, as also public policy interventions on the part of governments seeking ways to protect and enhance peoples' livelihoods, assist vulnerable people in their own attempts at self-protection, and support institutions in their role of disaster prevention.

Risk and Vulnerability Assessment: Different Approaches and Methods

The International Standards Organization defines risk assessment as a process to comprehend the nature of risk and to determine the level of risk (ISO, 2009a,b). Additionally, communication within risk assessment and management are seen as key elements of the process (Renn, 2008).

Risk assessment at the local level presents specific challenges related to a lack of data but also the highly complex and dynamic interplay between the capacities of the communities and the challenges they face (including both persistent and acute aspects of vulnerability).

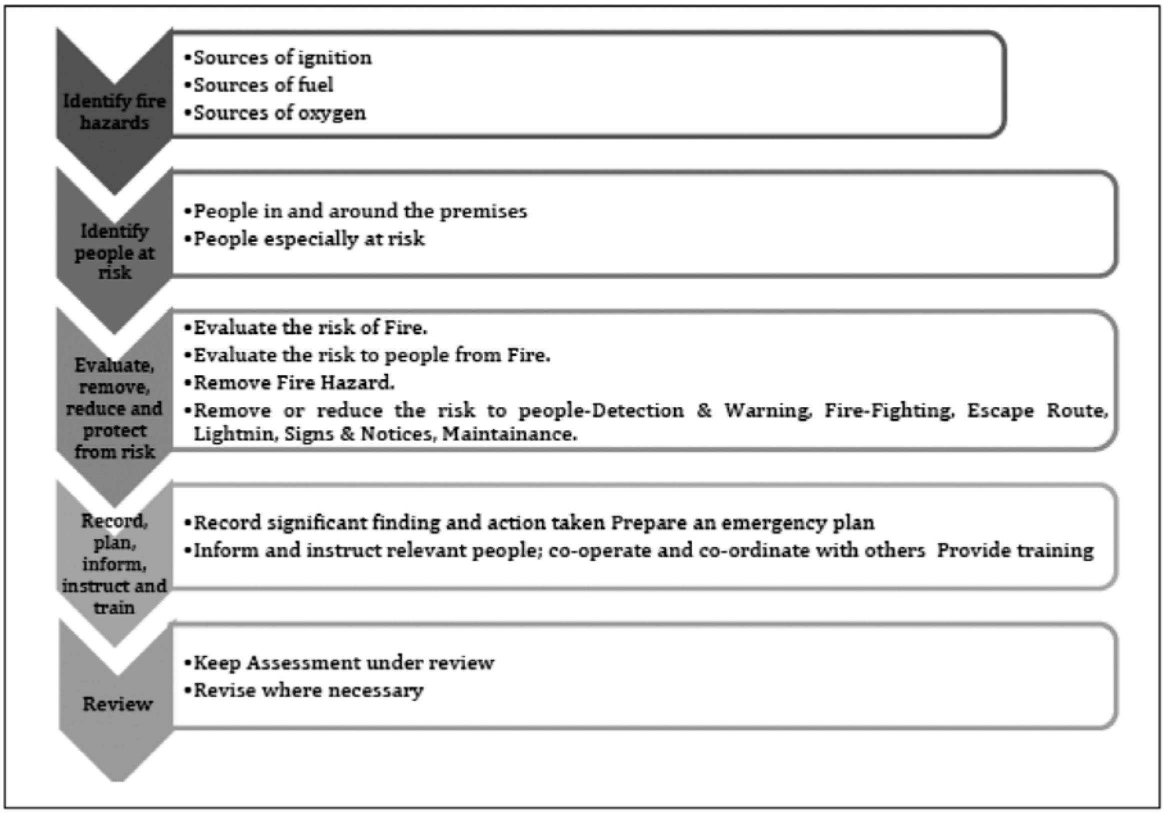
To inform risk management, it is desirable that risk assessments are locally based and result in increased awareness and a sense of local ownership of the process and the options that may be employed to address the risks. Several participatory risk assessment methods, often based on participatory rural appraisal methods, have been adjusted to explicitly address changing risks in a changing climate. Examples of guidance on how to assess climate vulnerability at the community level are available from several sources (Willows and Connell, 2003; Moench and Dixit, 2007; van Aalst et al., 2007; CARE, 2009; IISD et al., 2009; Tearfund, 2009).

Vulnerability and risk indicators or indices are feasible techniques for risk monitoring and may take into account both the harder aspects of risk as well as its softer aspects. The usefulness of indicators depends on how they are employed to make decisions on risk management objectives and goals (Cardona et al., 2003a; IDEA, 2005; Cardona, 2006, 2008, 2010; Carreño et al., 2007b).

However, quantitative approaches for assessing vulnerability need to be complemented with qualitative approaches to capture the full complexity and the various tangible and intangible aspects of vulnerability in its different dimensions. It is important to recognize that complex systems involve multiple variables (physical, social, cultural, economic, and environmental) that cannot be measured using the same methodology. Physical or material reality have a harder topology that allows the use of quantitative measure, while collective and historical reality have a softer topology in which the majority of the attributes are described in qualitative terms. Results can be verified and risk management/adaptation priorities can be established (Carreño et al., 2007a, 2009).

Based on the types of information collected, governments (as well as other stakeholders in risk management) will have a useful stock of information to assist them in: (a) rethinking their overall approaches to risk management, and given the likely disproportion between needs and (public) resources, (b) their decision making processes, as to where to concentrate their activities (e.g., investments, policy reforms) to reduce vulnerability. Most importantly, this type of assessment enhances transparency about risks and risk management capabilities of households, which is a prerequisite to elaborate strategies to reduce vulnerability.

- Information on the sources of risk and vulnerability is the key, as reducing vulnerability of households by improving risk management can not follow a generic blueprint. Rather, risk responses have to be judged against the risks. Moreover, given the unequal distribution of assets and other welfare indicators between different socio-economic groups in a country, risk management has to be judged against the possibilities and constraints. Based on the type of information collected, it will be possible to understand the types of assets,



Source: Risk Assessment & Disaster Management Plan – Ameyatownhomes,Sandor,Vasai, Maharashtra Mahabal Enviro Engineers Pvt. Ltd. NABET ACCREDITED characteristics of risks, and risk management instruments for specific socio-economic groups, and hence obtain information on their vulnerability. Moreover, the information gathered on risk management instruments, will allow identifying gaps and shortcomings with regard to the existing supply of risk management instruments. This will enable analysts to prioritize risks and/or socio-economic groups which should receive primary consideration in terms of improving risk management. (Smith, 2002; Cutter, 1996 https://www.preventionweb.net/files/26081_kp1concepdisasterrisk1.pdf)

The risk analysis examines the natural hazard in relation to the society's vulnerability, in order to first evaluate potential damage and losses. This involves calculating the probability that a natural hazard will occur, identifying vulnerability factors in society, drawing up damage scenarios and evaluating measures for rapid reconstruction in the event of a disaster. A society's ability to continue to function while dealing with a hazard is described as resilience. Prevention and mitigation covers activities whose long-term aim is to mitigate the possible adverse impacts of a natural event and its consequences and provide permanent protection against its effects. Prevention and mitigation measures may be constructional (e.g. dykes) or normative and non-material (e.g. land use restrictions). Appropriate preparedness enables a rapid and effective response to be made to an imminent disaster. Important elements are emergency plans, the availability of rescue and emergency services, emergency medical care, rapid and efficient transmission of warnings and the availability of means of communication. Early warning systems as a component of good preparedness can significantly reduce the impact of disasters. A good early warning system will promptly identify and assess a hazard. Warnings are issued to the affected population and institutions, who respond appropriately. Disaster-preventive reconstruction aims to draw appropriate lessons from the natural disaster and to include disaster reduction criteria and measures directly in the reconstruction process.

CONCLUDING REMARKS

The assessment methodologies of disaster risks are followed by different types, processes or steps of vulnerability and risk analysis along with the disaster management plans. Following are wide-ranging set of recommendations have been suggested below which may help in integration of risk assessment in regional development:

1. There is a need for an institutional setup at various level of administration to ensure the management of disasters during emergencies. The responsibilities and reporting system of the various departments such as Police, Fire Station, Transport & Communication, NGOs, Public or Community level stakeholders, Municipal Corporation and Revenue department etc. should be clearly demarcated within a well-defined structure so that response time may be reduced at the time of disasters.
2. Conventionalise the Disaster Management into development plan may be ensured by adapting land-use zonation according to the exposure of risks, updating and enforcement of the construction related laws as per the disaster resistance codes and retrofitting of life line buildings and other important buildings. The regular practice of these may reduce risk by enhancement of the condition of existing and new constructions.
3. The raising awareness of the general public by enforcing community based disaster management planning schemes in schools education, hospital management, residential and village awareness camps etc. at grass root level so that community as well as social preparedness may be ensured.
4. Geographic Information System and databases focusing on the development of techniques and decision making support tools to integrate, manipulate and display a wide range of risk-related information should be enhanced. Such system may also additionally introduce the techniques to assess the vulnerabilities of buildings, infrastructure and citizens to the adverse impact of hazard that may be supportive for the local authorities in taking decisions during emergency situation.
5. Availability for quantified database at various administrative levels for various aspects is very limited. Hence, a detailed database on disaster risk aspects and the previous events should be developed so specialized studies and assessments. It can be facilitated at all levels of planning and may help in exploring and expanding means of indicators and parameters in improved planning.

On the whole, in the concluding remark it may be asserted that risk management is needed to embrace all the administrative and operational programs that are designed to reduce the risk of emergencies involving acutely hazardous materials. Such programs are not limited to ensure the safety of new and existing designs but also make assurance of the standard operating procedures, preventive maintenance, operator training, accident investigation procedures, and risk assessment for unit operations, emergency planning as well as internal and external procedures. These programs are being executed as premeditated.

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MODEL QUESTIONS:

1. State the concept of disaster risk and vulnerability.
2. What are the different types of vulnerability?
3. Find out the relationship between capacity, resilience, resistance and sensitivity.
4. Give some examples of capacity.
5. Elucidate the relationship between disaster risk and vulnerability.
6. Discuss in details what factors are responsible for the disaster vulnerability.
7. Differentiate social and physical vulnerability. Give a short note on social vulnerability.
8. Discuss the different approaches and methods of risk and vulnerability assessment in disaster management.

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UNIT-3:

CONCEPT OF HAZARD REDUCTION AND DISASTER MANAGEMENT

INTRODUCTION:

The concept of hazard is previously discussed in the first chapter; hence the working module is focussed to deal with the conception and other aspects of hazard reduction and disaster management. It also highlights the equation of disaster risk and risk as well as distinction between disaster risk management and disaster management along with various related terminologies.

The module also gives details about the types and the requirements of successful disaster risk management.

CONCEPT OF RISK REDUCTION:

Risk Reduction involves the measures designed either to prevent hazards from creating risks or to reduce the distribution, intensity or severity of hazards. These measures include flood mitigation works, fire prevention acts, cyclone awareness programmes and appropriate land-use planning etc. These also involve the vulnerability reduction measures such as awareness raising, improving community health security, recovering community shelter and relocation or protection of vulnerable populations or structures etc.

HAZARD REDUCTION:

Hazard reduction means the appropriate reduction of, exclusion of, or encapsulation of any risk followed by acts or treatments that promote exposure ensuing in the likelihood of danger or menace.

Hazard reduction means measures designed to decrease or eliminate human exposure to events or hazards through methods including provisional controls or abatement or a combination of the two.

HAZARD RISK REDUCTION:

Hazard Risk Reduction is also recognized as **Disaster Risk Reduction**. It is defined as the concept and practice of reducing disaster risks through methodical efforts to analyse and manage the fundamental factors of disasters. It include the reduced exposure to hazards, lessened vulnerability of persons and assets, judicious management of land and the environment, and improved preparedness for adverse effects.

The strategies of disaster risk reduction is comprised of, the first and foremost, vulnerability and risk assessment as well as a number of institutional capacities and operational abilities. The estimation of the vulnerability of critical facilities, social structure and economic infrastructure, the use of successful early warning systems and the function of many different types of scientific, technical, and other skilled abilities are indispensable features of disaster risk reduction. (UNISDR, 2009).

Disaster Risk Reduction (DRR) refers to the conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development (*www.un.org/ esa/sustdev*).

Social Science Perspective of DRR

A focus on the development of disaster risk reduction and management would therefore be incomplete without a discussion of the roots of disaster studies and research both within the social science. Some of the earliest recorded ideas on disaster and risk within the social sciences were expressed by the likes of Carr (1932) and Sorokin (1942) who questioned the influence of catastrophe on social patterns.

Gilbert (1998:11) indicates that the social science perspective approached the study of disaster from three different paradigms, that of content research, chronological development and, lastly, cleavages. In the first instance disaster was viewed as a duplication of war - an external agent can be identified which requires communities to react globally against the “aggression”. The second (chronological development) views disaster as an expression of social vulnerability – disaster is therefore the result of underlying community logic or social processes. Thirdly, disaster is an entrance to a state of uncertainty – disaster is the impossibility of identifying and defining (real or perceived) dangers. It is therefore an attack on our perception and known reality. (Cardona, 2003:14 and Kreps, 1998:33)

DISASTER RISK MANAGEMENT:

Disaster risk management is the systematic process of using administrative directives, organisations, and operational skills and capacities to implement strategies, polices and improved coping capacities in order to minimize the adverse impacts of hazards and their likelihood of disaster. Disaster risk management aims to avoid, lessen or transfer the adverse effects of hazards through activities and measures for prevention, mitigation and preparedness (UNISDR, 2009).

The interaction between disaster risk reduction and disaster risk management is clear. Disaster risk reduction is concerned with the activities more purposeful on a strategic level of management, whereas disaster risk management is the planned and functioning implementation of disaster risk reduction.

The previous chapters focussed an understanding of core concepts about the terms hazard, disaster, vulnerability, capacity and risk etc. The present chapter will examine how the interaction between hazards and vulnerability translate into disaster risk. The political, economic, physical, social, and ecological factors that interact to increase the susceptibility of individuals, households and communities to the impact of hazards are also examined in the present module. The detection of these variables provides the basis for the prioritisation of schemes which will contribute to reducing vulnerability and thus to eliminating and/or reducing disaster risk. (UNISDR 2002:41).

Disaster Risk Management (DRM) includes but goes beyond **Disaster Risk Reduction (DRR)** by adding a management perspective that combines prevention, mitigation and preparedness with response. In comparing the above two (DRM and DRR) it is therefore obvious that DRM is the application of DRR. (ISDR Terminology version 2007)

Hazards in themselves do not constitute disasters. The magnitude of a disaster is usually described in terms of the adverse effects which a hazard has had on lives, property and infrastructure; environmental damage; and the costs attached to post-disaster recovery and rehabilitation. In other words there is a direct link between the capacity of those affected to withstand, cope and recover from the adverse affects of a hazard using only their own resources, and what constitutes disaster risk. Put simply disaster risk is the product of the combination of three elements – vulnerability, coping capacity and hazard (UNISDR 2002:41). The following notation illustrates this interaction:

1) **Disaster risk (R) =** $$\mathbf{\frac{Vulnerability\ (V) \times Hazard\ (H)}{Capacity\ (C)}}$$

OR

2) **Risk (R) = Hazard × Vulnerability/Level of Preparedness**

It is common cause that in countries where the majority of the population have been marginalised the adverse effects of hazards are of far greater magnitude. The interaction of political, physical, social, economic and environmental conditions which are linked to the marginalised state of those communities translates into extremely unsafe and fragile conditions thus rendering them most vulnerable to the impact of hazards (UNISDR 2002:47).

TYPES OF DISASTER RISK MANAGEMENT

Disaster risk management actions can be distinguished between prospective disaster risk management, corrective disaster risk management and compensatory disaster risk management, also called residual risk management.

a) **Prospective disaster risk management** activities address and seek to avoid the development of new or increased disaster risks. They focus on addressing disaster risks that may develop in future if disaster risk reduction policies are not put in place. Examples are better land-use planning or disaster-resistant water supply systems.

b) **Corrective disaster risk management** activities address and seek to remove or reduce disaster risks which are already present and which need to be managed and reduced now. Examples are the retrofitting of critical infrastructure or the relocation of exposed populations or assets.

c) **Compensatory disaster risk management** activities strengthen the social and economic resilience of individuals and societies in the face of residual risk that cannot be effectively reduced. They include preparedness, response and recovery activities, but also a mix of different financing instruments, such as national contingency funds, contingent credit, insurance and reinsurance and social safety nets.

d) **Community-based disaster risk management** promotes the involvement of potentially affected communities in disaster risk management at the local level. This includes community assessments of hazards, vulnerabilities and capacities, and their involvement in planning, implementation, monitoring and evaluation of local action for disaster risk reduction.

e) **Local and indigenous peoples' approach to disaster risk management** is the recognition and use of traditional, indigenous and local knowledge and practices to complement scientific knowledge in disaster risk assessments and for the planning and implementation of local disaster risk management.

DISASTER RISK MANAGEMENT VS. DISASTER MANAGEMENT

To gain a better understanding of disaster management and disaster risk management, the interrelatedness between them should be studied. The subject of disaster and risk reduction draws its relevance from earlier contributions and previous practices in the disaster management fields, where conventionally the focus has been on preparedness for response. Disaster risk management comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards. In comparing disaster risk management and disaster risk reduction it therefore clear that disaster risk management is the application of disaster risk reduction. Traditionally disaster management as defined by the UNDP (1992:21) is "the body of policy and administrative decisions and operational activities which pertain to the various stages of a disaster at all levels".

DRM as "the systematic process of using administrative decisions, organisation, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards." (ISDR, 2004:3)

Disaster Management is "the body of policy and administrative decisions and operational activities which pertain to the various stages of a disaster at all levels." (UNDP, 1992:21)

Disaster Management is defined by the South African Disaster Management Act 57 of 2002 as a continuous and integrated multi-sectoral and multidisciplinary process of planning and implementation of measures aimed at:

- reducing the risk of disasters;
- mitigating the severity of disasters;
- emergency of preparedness;
- rapid and effective response to disasters;
- post-disaster rescue and rehabilitation.

DISASTER MANAGEMENT CYCLE

The Disaster Management Cycle depicts the aspects of risk DRM and DRR through various stages. Disaster management cycle in its international form entails the integration of pre-disaster and post-disaster activities in order to safeguard lives and property against possible disasters.

The Disaster Management Cycle consists of the following phases: a) Prevention/ Mitigation and Preparedness in the pre-disaster stage, and b) Response and Rehabilitation/ Reconstruction in post-disaster stage. In the "Prevention/Mitigation" phase, efforts are made to prevent or mitigate damage (for example, construction of dikes and dams against floods). Activities and measures for ensuring an effective response to the impact of hazards are classified as "Preparedness" (for example, emergency drills and public awareness) and are not aimed at averting the occurrence of a disaster. "Response" includes such activities as rescue efforts. In the "Rehabilitation/Reconstruction" phase, considerations of disaster risk reduction should form the foundations for all activities. Taking appropriate measures based on the concept of disaster risk management in each phase of the disaster risk management cycle can reduce the overall disaster risk.

One significant problem with the disaster management cycle is that it has a disaster-oriented focus. This means that all activities and resources are geared towards a disastrous event. A focus on the underlying causes of these disasters (e.g. risk, hazards and vulnerability) is in most cases not considered, or it is the product of bureaucratic ignorance. Many disaster managers still choose to refer to the “causal factors of disasters” as espoused by the UNDP Disaster Management Training Programme over two decades ago. When one critically judges these “causal factors” it becomes evident that most of them can be ascribed to some form of vulnerability created by human activity. Another weakness in the application of the disaster management cycle is that a number of practitioners viewed the implementation of the cycle as a phased approach where the activities follow a sequential path. The recognition that each of the cycle’s processes is simultaneously did not materialise in most cases.

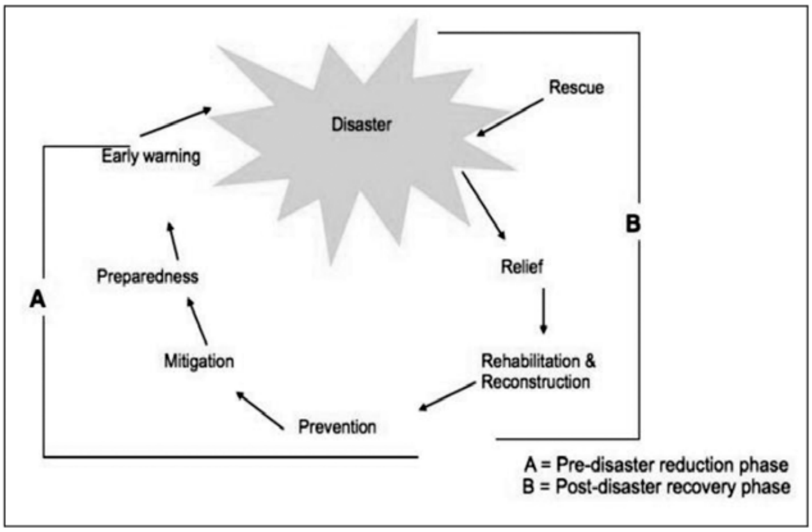


Figure.1: The traditional disaster management cycle

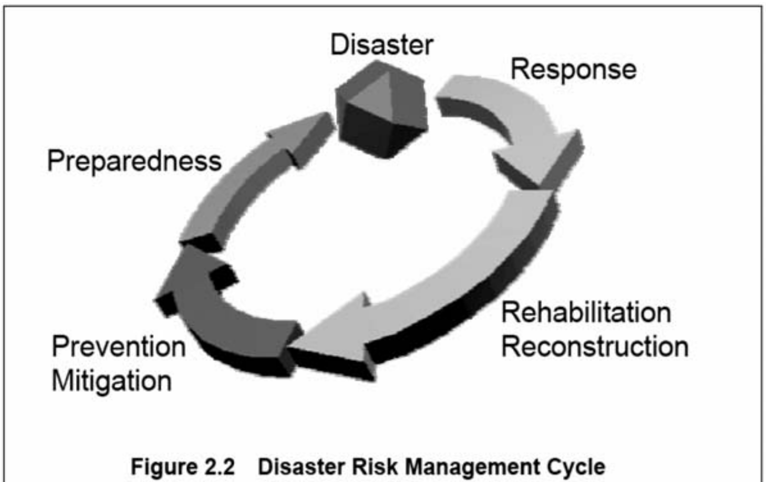


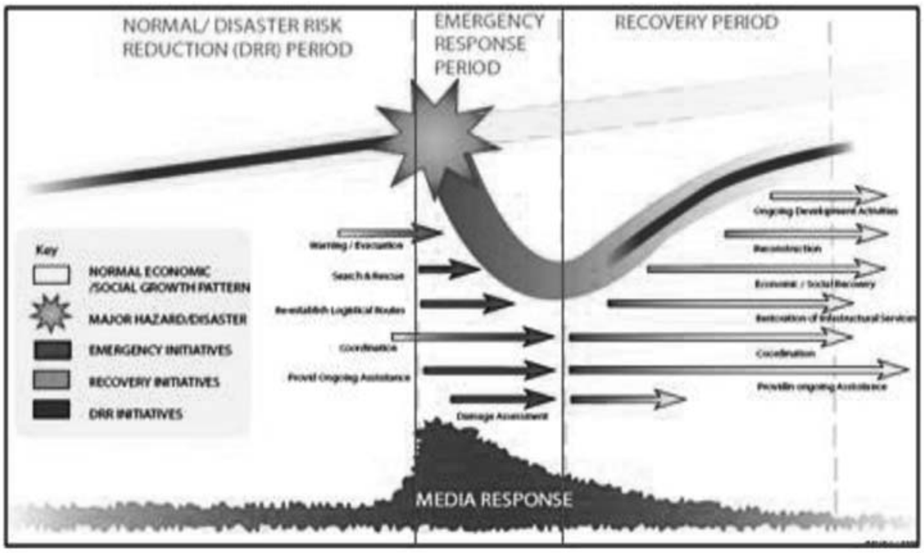
Figure.2: The contemporary disaster management cycle
(Source: ISDR Terminology, version 2007, *www.unisdr.org/terminology*)

DISASTER RISK MANAGEMENT FRAMEWORK

The purpose of Disaster Risk Management framework is to reduce the underlying factors of risk and to prepare for and initiate an immediate response should disaster hit. The Disaster Risk Management (DRM) framework distinguishes, conceptually, the different phases of the DRM cycle: pre-disaster, response and post-disaster.

The elements of the framework of Disaster Risk Management Cycle (DRMC) include both structural (physical and technical) and non-structural (diagnostic, policy and institutional) measures in the three phases.

(ISDR Terminology, version 2007, *www.unisdr.org/terminology*)



Elements of Disaster Risk Management (DRM) framework
Pre-disaster
☛ Risk assessment – Diagnostic process to identify the risks that a community faces
☛ Prevention - Activities to avoid the adverse impact of hazards
☛ Mitigation – Structural/non-structural measures undertaken to limit the adverse impact
☛ Preparedness - Activities and measures taken in advance to ensure effective response
☛ Early warning - Provision of timely and effective information to avoid or reduce risk
Disaster response
☛ Evacuation - temporary mass departure of people and property from threatened locations
☛ Saving people and livelihoods – Protection of people and livelihoods during emergency
☛ Immediate assistance – Provision of assistance during or immediately after disaster
☛ Assessing damage and loss – Information about impact on assets and loss to production
Post-disaster
☛ Ongoing assistance – Continued assistance until a certain level of recovery
☛ Recovery - Actions taken after a disaster with a view to restoring infrastructure and services
☛ Reconstruction - Actions taken after a disaster to ensure resettlement/relocation
☛ Economic & social recovery – Measures taken to normalise the economy and societal living
☛ Ongoing development activities – Continued actions of development programmes
☛ Risk assessment - Diagnostic process to identify new risks that communities may again face

Source: UNISDR. 2007. Words into Action: a guide for implementing the Hyogo Framework. Geneva

A number of international policies and frameworks have been developed since the 1990s; these include the Yokohama Strategy and Plan of Action (1990-1999), the Hyogo Framework of Action: Building the Resilience of Nations and Communities (2005-2015), the African Regional Disaster Risk Reduction Framework and its Plan of Action as well as the draft SADC Disaster Risk Reduction Framework. The above are examples of how disaster risk reduction has become a policy priority for governments world-wide. Such policies can well be mentioned as the first stepping stones towards sound disaster risk governance.

The originality and value of this framework is its ability to promote a holistic approach to DRM and demonstrate the relationships between hazard risks/disasters and development. For instance, the activities on **mitigation and prevention** comprise the **development** portion, while **relief** and **recovery** comprise the **humanitarian assistance** portion, with **preparedness** linking both types of efforts. (UNISDR, 2004)

Furthermore, the framework provides the basis to address public commitment and institutional systems, including organizational capacities, policy, legislation and community action as well as environmental management, land-use, urban planning, protection of critical facilities, application of science and technology, partnership and networking and financial instruments. The framework also provides the space to positively value and constructively includes communities and households traditionally coping strategies, recognizing the importance of their ownership of the DRM process, therefore diminishing the dependency typically generated by relief offered by outsiders. (ISDR, 2004).

DISASTER RISK MANAGEMENT PLAN

Disaster Risk Management is a plan prepared by an authority, sector, organization or enterprise that sets out goals and specific objectives for reducing disaster risks together with related actions to accomplish these objectives. National-level plans need to be specific to each level of administrative responsibility and adapted to the different social and geographical circumstances that are present. The time frame and responsibilities for implementation and the sources of funding should be specified in the plan.

Linkages to sustainable development and disaster risk reduction plans should be made where possible. Sustainable development means that we are using our current resources and doing our development planning in such a way that we do not compromise the abilities of future generations to also develop, utilising the same set of resources. The same scenario applies to the disaster risk reduction field. Successful disaster risk reduction depends on its integration with much bigger issues such as the development agenda. (UNISDR, 2004)

The sustainable development context consists of socio-cultural, political, economic, and ecosystems or environmental domains (compare these aspects with the factors of vulnerability to identify the similarities). Each of these domains can either contribute to overcoming or exacerbating disaster risk.

A change in behaviour could be or result in the needed political commitment for disaster risk reduction. In turn political commitment leads to changes in policy and governance aimed at enhancing disaster risk reduction capabilities and institutional capacities. We have many examples where political will has a direct impact on community actions and the ability of communities to take ownership of their own disaster risk reduction effort. However, a favourable environment is needed. Through political commitment certain disaster risk reduction measures can be implemented. This is where the trans-disciplinary nature of disaster risk reduction comes into play. Such actions could include sound environmental management and socio-economic development practices such as: poverty alleviation; securing and enhancing livelihoods; gender equality; increased health; emphasis on sustainable agricultural practices; and even certain financial mechanisms such as social safety nets or even market-based insurance schemes. Certain physical and technical measures, for example land-use planning, urban and town planning, and the protection of critical infrastructure such as water and sanitation, electricity and communications are necessary for disaster reduction.

However, in an ideal world we will not have disasters if the aspects discussed above are all adhered to and functioning. We must make peace with the fact that we will never have complete knowledge on disaster risks, nor the full capacity to reduce their consequences. Some planning for disaster preparedness is necessary. Information linked to the hazard analysis and monitoring put us in a position which helps us to understand the various hazard characteristics. This in turn feeds into possible early warning systems. Identifying of hazard characteristics will provide us with triggers to monitor. These triggers are the tipping point in the hazardous impact which will guide either our preparedness or activation of appropriate emergency management contingencies.

From the framework it is thus clear that the actual disaster impact is neither the starting nor the ending point, but the main element which must be removed from the framework through all of the disaster risk reduction aspects discussed above. It should now be clear that disaster risk reduction functions in a much broader domain than a narrow focus on a disaster event. The UNISDR Framework is not complete, neither is it fully tested. It does, however, provide us with a very good indication and starting point for disaster risk reduction. The section to follow will provide information about the development/disaster reduction interaction and this in turn will be relayed to other crosscutting issues influencing our ability to reduce disaster risks.

Good governance (effective political institutions, responsibilities and resources that are clearly allocated according to the subsidiary principle and the state's responsible handling of political power and public resources) promotes successful disaster risk management. The aim of disaster risk management is to reduce disaster risk to a socially acceptable and manageable level. As a contributor to sustainable development, disaster risk management should be integrated into poverty reduction strategies.

CONCLUSION

This chapter aimed to provide a broad understanding of disaster risk management and how the study of disasters and disaster risk is evolved. Various aspects which constitute disaster risk were discussed and it was shown how the main concepts in disaster risk studies relate. Emphasis was placed on the various domains of Disaster Risk Management and the stages of DRM framework were also discussed.

Some of the cross-cutting aspects of disaster risk were also alluded to. You are encouraged to further and deepen your knowledge of the various issues of disaster risk reduction.

Disaster risk is a societal commonality. It affects everyone and all the systems on which we depend. Solving these intricate problems requires a trans-disciplinary approach and focus. It is important that we adjust our “lens” of reality to include issues of disaster risk. The linkage with development provides us with an ideal opportunity to address and solve many of the issues associated with disasters and their impact.

Several recommendations can be distilled from this overview and are provided here to develop a roadmap towards the effective implementation of global, dynamic exposure databases. Finally, exposure data collection should be regarded as a continuous process sustaining a continuous re-evaluation of risks to enable an effective DRR.

Ultimately, its concluded that improved risk models supported by larger and more refined evidence derived from the observation of what actually happens after real events is for the benefit of risk mitigation measures, be they structural or non - structural.

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MODEL QUESTIONS:

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1. What is risk reduction? What id hazard reduction? State the concept of hazard risk reduction.

2. What do you mean by DRR? Illustrate the social science perspective of DRR.
3. Describe the concept of disaster risk management.
4. What are the types of disaster risk management? Discuss the types.
5. Differentiate disaster management and disaster risk management.
6. What is disaster risk management cycle?
7. Evaluate the disaster risk management framework according to UNISDR.
8. Represent the disaster risk management plan and found its linkage with sustainable development.

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UNIT-4:

CLIMATIC HAZARDS: TROPICAL CYCLONES (PREDICTION, PRECAUTION AND MITIGATION)

INTRODUCTION:

The study of climatic hazards is a good instance of the practical importance of environmental climatology. This review of climatic hazards specially the tropical cyclone not only outlines the great range of such events and their impacts, but also illustrates the prediction, precaution and mitigation of these types of hazards.

The present module describes tropical cyclone as a form of the climatic hazard. It also focuses on the concept, causes and types of climatic hazards, studies the distinguishing features of tropical cyclones in particular. The module also highlights different stages of development of tropical cyclone lifecycle and describes the changes in intensity of tropical cyclones.

The objective of the present work is to illustrate the hazards of tropical cyclones particularly those at the prediction, precaution and mitigation with special reference to India.

CLIMATIC HAZARD

Climatic Hazards are weather-related, hydro-meteorological events which can cause harm to humans, property, livelihoods, resources, and the environment. Climatic hazards are also sometimes called extreme weather events. It is a physical process or event (hydro-meteorological variables or phenomena) that can harm human health, livelihoods, or natural resources. (Tyndall Centre, 2003).

Climate hazards are the media through which climate-related disasters occur. In other words, they trigger climate-related disasters. In the first decade of the 21st century, it was estimated that climatic hazards were responsible for 75% of all global disasters.

Natural hazards related to deficiency or excess of precipitation, with destructive winds and anomalous temperatures, are described. Moisture deficiency causes dry winds, dust storms and vegetation fires, and surplus moisture causes cyclonic storms, river and lake floods, snowfalls and ice growth. Wind is a major danger presented by tropical and extra-tropical cyclones (especially wind-induced surges caused by wind and striking coastlines), spouts and tornadoes. Extreme frost and dangerous heat are related to anomalous temperatures. (https://www.eolss.net/sample-chapters/c01/E4-06-02-00.pdf)

Climatic hazards are agents of disaster in terms of what they may do to human settlements or to the environment. Potentially hazardous atmospheric phenomena include **tropical cyclones**, thunderstorms, tornadoes, drought, rain, hail, snow, lightning, fog, wind, temperature extremes, air pollution, and climatic change. (Hobbs, 1987).

CAUSES OF CLIMATE HAZARDS

Changes in atmospheric or oceanic circulation cause climatic hazards. They are also caused by significant alterations to ecosystems and also human activities. Nowadays, **climate change** plays a significant role in creating climate hazards. There is high agreement among scientists that the effects of climate change, in combination with other factors, will increase the displacement of people (IPCC 2014). This includes:

i) Climate change is expected to increase the frequency and intensity sudden-onset natural hazards which can lead to internal or cross border disaster displacement;

ii) Climate change is also expected to increase slow onset hazards which can reduce the threshold at which point people are forced to flee, and also hinder the potential for displaced persons to return to their places of habitual residence;

iii) Climate change impacts may further serve as a “threat multiplier” that exacerbates potential for conflict and consequent displacement, although these interlinkages are complex, multi-causal and should not be oversimplified.

CLIMATE REFUGEE

The term "Climate Refugee" is often used in the media, however, this concept is misleading and does not exist in international law, as a "refugee" has crossed an international border "owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion" (1951 Convention relating to the Status of Refugees). Climate change affects people inside their own countries, and typically creates internal displacement before it reaches a level where it pushes people across borders. Nonetheless, there may be situations where the refugee criteria of the 1951 Convention may apply, for example if drought-related famine is linked to situations of armed conflict and violence. Regardless, the term "**climate refugee**" is not endorsed by the UNHCR or by the Platform on Disaster Displacement, and it is preferable to refer to "persons displaced in the context of disasters and climate change".

(https://www.studysmarter.co.uk/explanations/geography/living-with-the-physical-environment/climatic-hazards/)

TYPES OF CLIMATIC HAZARDS

Potentially hazardous atmospheric phenomena include tropical cyclones, thunderstorms, tornadoes, drought, rain, hail, snow, lightning, fog, wind, temperature extremes, air pollution, and climatic change. These hazards are classified by intensity and degree of manifestation and their interactions.

There are four major types of climate hazards: i) Tornadoes; ii) Droughts; ii) Tropical storms and iv) Flooding;

Among these, the **tropical cyclone** is an example of a climatic natural hazard.

CONCEPT OF CYCLONE

In 1848 the word "**cyclone**" was first used to refer to rotating storms. This term was inspired by the Greek word which means "coiled like a snake."**Cyclone** refers to any spinning storm that rotates around a low-pressure center. The low-pressure center is also referred to as the 'eye' of the storm. It is accompanied by powerful winds blowing anti-clockwise in northern hemisphere and clockwise in southern hemisphere. They are known by different names in different countries. **Typhoons** in northwest pacific ocean, **Hurricanes** in north Atlantic ocean and northeast and south pacific ocean, **Tropical Cyclones** in southwest pacific ocean, southeast and southwest Indian ocean. It is also famous as **Willy Willy** in Australia, **Baguio** in China Sea, **Taifu** in Japan and **Tornado** in South America.

MOVEMENT OF CYCLONES

It is often hard to foresee where a cyclone will hit. When it starts moving from oceans towards the land area, a cyclone can change track and hit areas other than those anticipated.

The path of a cyclone depends very much on the wind belt in which it is located. A cyclone originating in the eastern tropical Pacific, for example, is driven westward by easterly trade winds in the tropics. Eventually, these storms turn north-westward around the subtropical high and migrate into higher latitudes. In time, cyclones move into the middle latitudes and are driven north-eastward by the western-lies, occasionally merging with mid-latitude frontal systems.

Cyclones draw their energy from the warm surface water of the tropics and latent heat of condensation which explains why cyclones dissipate rapidly once they move over cold water.

(Source: Report of GSDMA, NIDM, 2014 https://nidm.gov.in/research.asp)

TROPICAL CYCLONES

The generic name "**tropical cyclones**" may be used anywhere in the world for tropical storms with peak wind speeds (1-minute mean, 10-minute mean or gust wind speed are used in different regions) exceeding 17 m s-1.**Tropical Cyclone (TC)** is a storm system characterized by a large low-pressure center and numerous thunderstorms that produce strong winds and heavy rain. Tropical cyclones fall under the purview of warm core system of storms. (NIDM, 2014)

Tropical cyclones are one of the biggest threats to life and property even in the formative stages of their development. They include a number of different hazards that can individually cause significant impacts on life and property, such as storm surge, flooding, extreme winds, tornadoes and lighting. Combined, these hazards interact with one another and substantially increase the potential for loss of life and material damage. As per study (1970-2019), 33% of hydro-meteorological disasters are caused by TCs. One out of three events that killed most people globally is tropical cyclones (TC). Seven out of ten disasters that caused biggest economic losses in the world from 1970-2019 are tropical cyclones. It is the key interest of 85 WMO Members prone to tropical cyclones. (IMD, 2019)

CHARACTERISTICS OF TROPICAL CYCLONES

A tropical cyclone is a rapid rotating storm originating over tropical oceans from where it draws the energy to develop.

- It has a low pressure center and clouds spiraling towards the eye-wall surrounding the “eye”, the central part of the system, where the weather is normally calm and free of clouds.
- Its diameter is typically around 200 to 500 km, but can reach 1000 km.
- A tropical cyclone brings very violent winds, torrential rain, high waves and in some cases, very destructive storm surges and coastal flooding. The winds blow counter clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.
- Tropical cyclones above certain strength are given names in the interests of public safety. Parts of the Atlantic region, Pacific Ocean, Indian Ocean witness tropical cyclones affecting Gulf Coast of North America, North-Western Australia, Eastern India and Bangladesh along with other areas. (Source: Report of GSDMA, NIDM, 2014, https://nidm.gov.in/research.asp)

FORMATION OF TROPICAL CYCLONES

Cyclones are atmospheric and oceanic phenomena. Listed below are some of the favourable conditions identified through observational facts and scientific studies for the formation of TCs. The weightage of individual conditions is, however, yet unknown.

i) A warm sea surface (temperature in excess of 26o–27oC) and associated warming extending up to a depth of 60m with abundant water vapour in the overlying air (by evaporation),

ii) The moist air moves up and comes in contact with the cold air in the upper level of atmosphere and gets condensed. High relative humidity in the atmosphere up to a height of about 5,000 metres, atmospheric instability that encourages the formation of massive vertical cumulus clouds due to condensation of rising moist air,

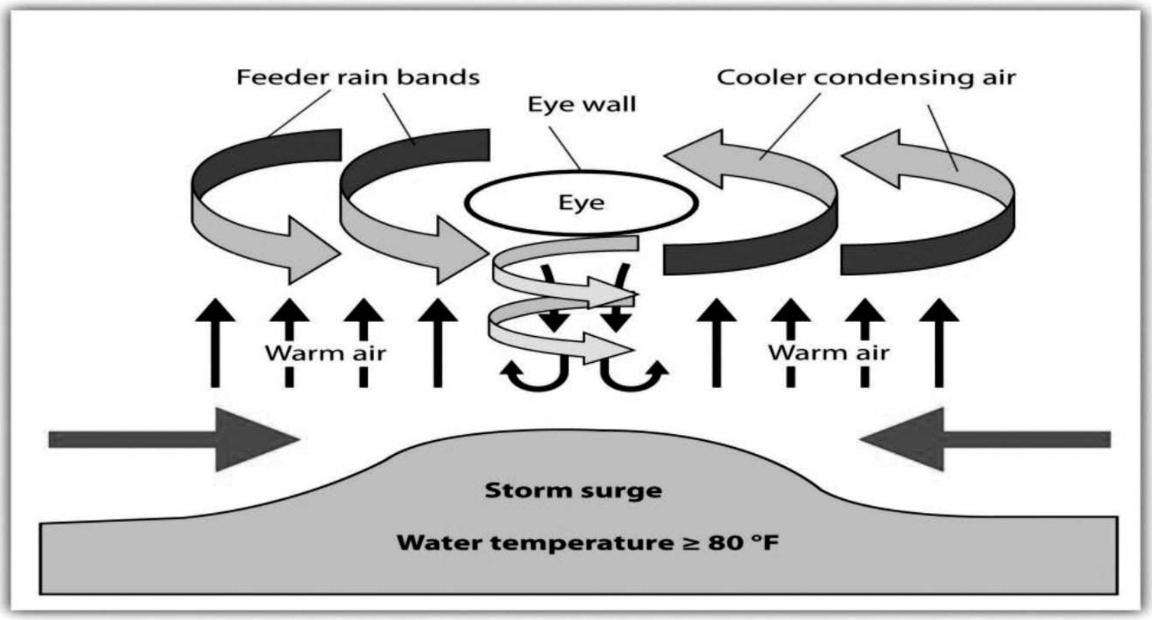
iii) Low vertical wind shear between the lower and higher levels of the atmosphere that do not allow the heat generated and released by the clouds to get transported from the area (vertical wind shear is the rate of change of wind between the higher and lower levels of the atmosphere),

iv) The presence of cyclonic vorticity (rate of rotation of air) that initiates and favours rotation of the air cyclonically, and

v) Location over the ocean, at least 4–5o latitude away from the equator.

vi) Tropical disturbance is born when this moving mass of thunderstorm maintains its identity for a period of 24 hours or more.

(Source: Report of GSDMA, NIDM, 2014, https://nidm.gov.in/research.asp)



https://courses.lumenlearning.com/atd-herkimer-worldgeography/chapter/5-5-tropical-cyclones-hurricanes/

CLASSIFICATION OF TROPICAL CYCLONE

Many types of tropical cyclones are observed all over the world. Based on its location and severity tropical cyclone can be classified as typhoon, tropical storm, cyclonic storm, tropical depression and hurricane. Normally, tropical cyclones are classified as per their wind speed. (https://nidm.gov.in/PDF/pubs/NDMA/4.pdf)The classification, however, varies from region to region. Indian classifications of these intense low pressure systems or cyclonic disturbances are as follows:

Indian Classification of Cyclonic Disturbances in the North Indian Ocean (Bay of Bengal and Arabian Sea), Source: IMD

Type	Wind Speed in km/h	Wind Speed in Knots
Low Pressure area	Less than 31	Less than 17
Depression	31–49	17–27
Deep Depression	50–61	28–33
Cyclonic Storm	62–88	34–47
Severe Cyclonic Storm	89–118	48–63
Very Severe Cyclonic Storm	119-221	64–119
Super Cyclone	222 or more	120 or more

In the US, cyclones are classified into five different categories on the basis of their wind speed as measured on the Saffir-Simpson scale:

Saffir-Simpson Hurricane Scale

Scale Number (Category)	Sustained Winds in m/h	Damage	Storm Surge
1	74–95 (64–82 kt)	Minimal: Unanchored mobile homes, vegetation, and signs	4–5 feet
2	96–110 (83–95 kt)	Moderate: All mobile homes, roofs, small craft; flooding	6–8 feet
3	111–130 (96–113 kt)	Extensive: Small buildings, low-lying roads cut off	9–12 feet
4	131–155 (114–35 kt)	Extreme: Roofs destroyed, trees down, roads cut off, mobile homes destroyed, beach homes flooded	13–18 feet
5	156 or more (135 kt or more)	Catastrophic: Most buildings destroyed, vegetation destroyed, major roads cut off, homes flooded	Greater than 18 feet

Source: National Weather Services (NWS), National Oceanic and Atmospheric Administration (NOAA)

**Note: Tropical Storms: winds 39–73 mph (34–63 kt)*

NAMING OF TROPICAL CYCLONES

The concept of assigning individual names to tropical cyclones was initiated in the late 19th century by an Australian meteorologist, Clement Wragge. Wragge used the Greek alphabet and names of politicians whom he did not like. Later, the names came from the military alphabet. (Newmann, C. J., 1999)

In the 1960s the WMO stepped in and developed a consistent, regionally-applicable naming convention for tropical cyclones in each of the affected ocean basins. While the early lists consisted only of women's names, by the 1970s the lists were broadened to include both male and female names and to encompass the languages of all of the affected countries.

The names of people are no longer used for storms in the western North Pacific: storm names for this region are drawn from a list of generic words. If a tropical cyclone moves from one region to another, it is typically renamed to the next name on the list in the new region. This means that in rare cases, the same storm is assigned two names depending on its track.

(WMO,http://www.wmo.ch/pages/prog/www/tcp/documents/FactShtTCNames1July05.pdf NOAA NHC, http://www.nhc.noaa.gov/aboutnames.shtml)

The WMO/ESCAP Panel on Tropical Cyclones at its twenty-seventh Session held in 2000 in Muscat, Sultanate of Oman agreed in principle to assign names to the tropical cyclones in the Bay of Bengal and Arabian Sea. The first name was 'ONIL' which developed over the Arabian Sea (30 September to 03 October, 2004). According to approved principle, a list of 64 names in eight columns has been prepared. The name has been contributed by Panel members. The RSMC-tropical cyclones, New Delhi gives a tropical cyclone an identification name from the above name list.

INDIAN CYCLONES

The 7517 km long coastline of India is world's most cyclone affected stretch, of which 5,400 km along the mainland, 132 km in Lakshadweep and 1,900 km in the

Andaman and Nicobar Islands. Although the North Indian Ocean (NIO) Basin (including the Indian coast) generates only around 8% of the total land area in India is prone to cyclones. West Bengal, Odisha, Gujarat, Andhra Pradesh, Karnataka, Goa and Kerala are the most cyclone affected states of India. The frequency of cyclones in the NIO Basin is bi-modal, which is specific to this region. Cyclones occur in the months of May–June and October–November, with their primary peak in November and secondary peak in May. Tropical cyclones generally originate in the eastern side of the NIO Basin and initially move in a west-north westerly direction. More cyclones form in the Bay of Bengal than in the Arabian Sea and the ratio is 4:1. It has been observed that between 1891 and 2006, 308 cyclones crossed the east coast, out of which 103 were severe. Less cyclonic activity was observed on the west coast during the same period, with 48 cyclones crossing the west coast, out of which 24 were of severe intensity.

Cyclone Phailin originated in Vietnam in October 2013. This cyclone affected Odisha, Jharkhand, West Bengal, Chhattisgarh, Bihar and eastern parts of Uttar Pradesh. A total of 1,34,426 people were eventually evacuated. Power and communication lines went down across many districts. Besides economic losses Odisha recorded casualties of 44 people. About 7% of the world's cyclones, their impact is comparatively high and devastating, especially when they strike the coasts bordering the North Bay of Bengal.

Different types of cyclonic disturbances formed in Bay of Bengal between 1891 and 2000

Types of Disturbance	Cyclonic Disturbance	Depression/ Deep Depression	Cyclonic Storm	Severe Cyclonic Storm and Above
Number	1087	635	279	173
Maximum (1891 – 1991)	158 (Aug.)	131 (Aug.)	51 (Oct.)	38 (Nov.)
Minimum (1891 – 1991)	4 (Feb.)	1 (Mar)	0 (Feb.)	1(Jan)
Yearly Average	10	6	3	1.5
Wind Speed (Km/h)	31 or less	31-61	62-88	89 and more

Source: IMD

The 10 most severe tropical cyclone disasters in world history are shown in the following table:

World's Deadliest Tropical Cyclones in the History

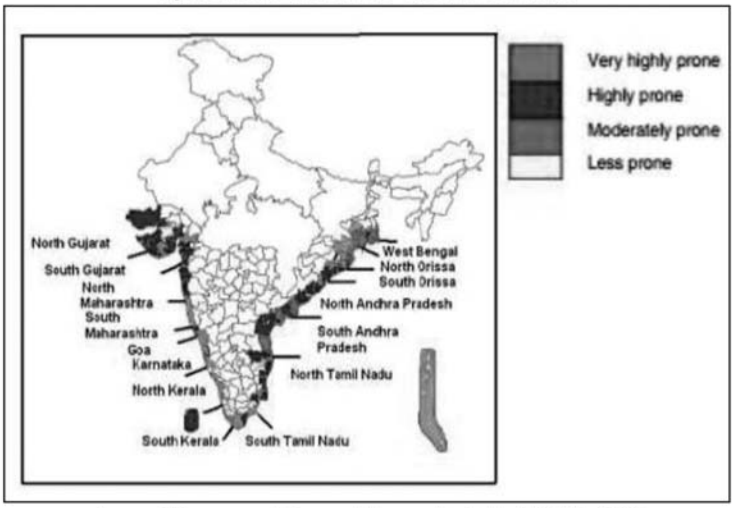
Rank	Name/Areas of Largest Loss	Year	Ocean Area	Deaths
1	Great Bhola Cyclone, Bangladesh	1970	Bay of Bengal	500,000
2	Hooghly River Cyclone, India and Bangladesh	1737	Bay of Bengal	300,000
3	Haiphong Typhoon, Vietnam	1881	West Pacific	300,000
4	Coringa, India	1839	Bay of Bengal	300,000
5	Backerganj Cyclone, Bangladesh	1584	Bay of Bengal	200,000
6	Great Backerganj Cyclone, Bangladesh	1876	Bay of Bengal	200,000
7	Chittagong, Bangladesh	1897	Bay of Bengal	175,000
8	Super Typhoon Nina, China	1975	West Pacific	171,000
9	Cyclone 02B, Bangladesh	1991	Bay of Bengal	140,000
10	Cyclone Nargis, Myanmar	2008	Bay of Bengal	140,000

Source: Journal of Geoscience and Environment Protection, 7, 26-36, May 17, 2019

CYCLONE HAZARD PRONE DISTRICTS OF INDIA:

Cyclone hazard proneness of districts of India based on frequency of total cyclones, total severe cyclones, actual/estimated maximum wind strength, Probable Maximum Storm Surge (PMSS) associated with the cyclones and Probable Maximum Precipitation (PMP) for all districts is presented in the figure below.

Cyclone Hazard Prone Districts of India



Source: Map prepared by committee constituted by NDMA in 2012

Ninety-six districts including 72 districts touching the coast and 24 districts not touching the coast, but lying within 100 km from the coast have been classified based on their proneness. Out of 96 districts, 12 are very highly prone, 41 are highly prone, 30 are moderately prone, and the remaining 13 are less prone. Twelve very highly prone districts include South and North 24 Parganas, Medinipur, and Kolkata of West Bengal, Balasore, Bhadrak, Kendrapara, and Jagatsinghpur districts of Odisha, Nellore, Krishna, and east Godavari districts of Andhra Pradesh and Yanam of Puducherry. The remaining districts of Odisha and Andhra Pradesh, which touch the coast, are highly prone districts. The north Tamil Nadu coastal districts are more prone than the south Tamil Nadu districts (south of about 10æ%N latitude). Most of the coastal districts of Gujarat and north Konkan are also highly prone districts. The remaining districts in the west coast and south Tamil Nadu are either moderately prone or less prone districts.

LOSSES DUE TO CYCLONE

Recurring cyclones account for large number of deaths, loss of livelihood opportunities, loss of public and private property and severe damage to infrastructure, thus seriously reversing developmental gains at regular intervals. The historical cyclones resulted in a catastrophic loss of lives, assets, and livelihoods.

In the year 1977 cyclone with a fatality of 10,000 people in Andhra Pradesh in India; the 1990 Super Cyclone with a fatality of 967 people in Andhra Pradesh again; the 1996 Very Severe Cyclonic Storm with a fatality of 1,057 people in Andhra Pradesh, and the 1999 Super Cyclone in Odisha with a fatality of about 10,000 people, destroying 275,000 homes and leading to 1.67 million homeless.

On October 12 2013, Cyclone Phailin hit the states of Odisha and Andhra Pradesh with maximum sustained wind gusting up to 220 km per hour, heavy rains measuring up to 25 cm and storm surge over 3 m; the sea pushed in as much as 40 m along parts of the coast. It was the strongest cyclone to hit the Indian coast, similar to the Super Cyclone of 1999 which hit Odisha. The cyclone hit a densely populated area, with 4.5 million people within the hurricane force wind path and significant informal housing.

TROPICAL CYCLONE FORECAST OR PREDICTION

Current knowledge of the structure of tropical cyclones has come from studies made for over a hundred years of different cyclone-prone regions of the world. Early studies using ship reports and measurements from coastal and island observatories gave a reasonably good picture of the surface level features of the cyclone, but that of their three-dimensional structure has been derived mainly from 'reconnaissance flights' using specially equipped aircraft that were flown into the cyclone at various levels, measuring winds, temperatures, humidity and pressure. Direct sensing as well as remote sensing methods, especially compositing of data from routine balloon soundings of the atmosphere has also yielded a wealth of information (Gray 1979, pp 155-218).

Over the past decade findings from several United States (US) study panels emphasized the importance of effective communication of meteorological forecasts (National Research Council 1989, National Science and Technology Council 2005).

New opportunities were created for meteorologists and social scientists to work together, such as the Weather and Society*Integrated Studies (WAS*IS) workshops and networks (Demuth et al. 2007). Similar calls for societal and economic research related to weather forecasts have been made in international forums (Morss et al. 2008). Social factors affecting forecast response is now a topic at international meteorological meetings (e.g. King and Anderson-Berry 2010). Similar improvements are occurring in severe weather forecasting in other countries, such as South Africa (Poolman et al. 2008).

Cyclone forecasting and warning is a complex process of physical (hydro-meteorological) and social processes. While significant investment in understanding the physical processes have improved forecast and warnings and improved outcomes, our understanding of social processes (communication. vulnerability, response, decision-making, values, etc.) is less well developed. With explicit or implicit goals of saving lives and reducing damages, advances in understanding social processes likely represents the best opportunities to improve socio-economic outcomes in the tropical cyclone warning process. The social sciences bring a range of theories, methods, applications, and knowledge to complement the hydro-meteorological sciences. (National Research Council, 1989; National Science and Technology Council, 2005).

THE CYCLONE WARNING SYSTEM

The first systematic, statistically-based seasonal forecasting methodology for TCs dates back to 1970s (Nicholls, N., 1979) and focused on Australian Region. Until 1984 that scientists from Colorado State University began publishing regular forecasts of annual tropical cyclone activity for the North Atlantic basin. (Gray, W. M., 1984: Part I and II).

Gray et al (1991) studied the technical aspects of this issue at the instance of the American Meteorological Society and found that although weather satellites are absolutely essential for tropical cyclone observation, satellite measurements of position, intensity, and ambient wind distribution etc. of a cyclone are sometimes degraded leading to inaccuracy in forecasts. Additional data from reconnaissance flights can offset this drawback.

Early in statistical predictions of North Atlantic seasonal hurricane activity, forecasts relied predominantly on the phases of ENSO (either of the seasons). A recent innovation in seasonal tropical cyclone forecasting is dynamically-based forecasts. In this approach, global forecast models are run out for the season and the number of tropical cyclone-like vortices predicted in these models is counted.

CYCLONE WARNING SYSTEM IN INDIA

Cyclone disaster mitigation arrangements were organised in the maritime states of India only during the last 25 years. This relatively young field requires more developmental work, particularly in coastal area planning to reduce property losses, and exploration of alternative approaches to large-scale evacuation of the coastal population threatened by cyclones to distant temporary shelters. (Porathur V Joseph, 1968)

Cyclone warning is one of the most important functions of the India Meteorological Department and it was the first service undertaken by the Department as early as in 1865 and thus the service started before the establishment of the department in 1875. The storm warning scheme for west coast ports (Mumbai, Karachi, Ratnagiri, Vengurla, Karwar and Kumta) came into force in 1880. Meteorological Atlas of the Indian Seas and the North Indian Ocean published in 1908. First Surface Observatory over Bay Islands started in the year 1952. First Surface Observatory in Lakshadweep and Kerala came into existence in 1960. Government of India appointed a committee called the Cyclone Distress Mitigation Committee (CDMC) for Andhra Pradesh to examine various measures to mitigate human suffering and reduce loss of life and property due to cyclonic storms in 1969. Subsequently similar committees were set up for Odisha and West Bengal. First cyclone detection radar was set up at Visakhapatnam in 1970. Storm warning centre was set up at Bhubaneshwar for catering to the needs of Odisha; and Regional Meteorological Centre (RMC) for Tropical Cyclones, New Delhi came into existence in 1973 with the formation of WMO/ESCAP Panel. Cyclone monitoring was initiated by Indian satellite, INSAT in the year 1983. (Elsberry 1987, pp. 1-12, 91-131)

Cyclone Warning Directorate co-located with RSMC Tropical Cyclones New Delhi was established in 1990 in the Office of the Director General of Meteorology, New Delhi to coordinate the cyclone warning work in the country in totality. Deployment of 12 Meteorological Buoys by NIOT over the NIO in 1997 and First Doppler Weather Radar established at Chennai in 2002. Introduction of Ensemble Prediction System Model for Track Prediction and Web enabled E-Atlas was developed in the year 2011. Launching of a dedicated website for RSMC, New Delhi (www.rsmcnewdelhi.imd.gov.in) and SMS service to farmers through farmers portal from cyclone "*HUDHUD*" with hourly updates around the time of landfall from cyclone started in 2014. Severe Weather Forecast Demonstration Project -Bay of Bengal (SWFDP-BoB) started since May 2016. Entire Indian coast is covered with Doppler Weather Radar (DWR) and introduction of Extended Range forecast of cyclogenesis for next 2 weeks was established in the year 2018. Probabilistic forecast extended to 72 to 120 hrs. And started Track forecast from Depression stage instead of Deep Depression stage. In 2020 the country introduced cyclone track on interactive GIS platform. It also started the new list of names for cyclonic storms from June, 2020 with "*Nisarga*" (Bangladesh). (IMD, Ministry of Earth Sciences, GOI, 2021)

Since 2009, IMD has started SMS based weather and alert dissemination system through AMSS (Transmet) at RTH New Delhi. To further enhance this initiative, India Meteorological Department has taken the leverage of Digital India Programme to utilize "Mobile Seva" of Department of Electronics and Information Technology, Ministry of Communication and Information Technology; Govt. of India for SMS based Warnings /Weather information dissemination for a wide range of users.

The ACWCs/CWCs issue warnings to ships in the high seas, ships in coastal waters, ports, fishermen, government officials and the general public regarding adverse weather likely to be experienced in their respective areas. The bulletins and warnings issued by ACWCs/CWCs for their respective areas of responsibility include:

- Four stage warning bulletin
- Sea area bulletins for ships plying in High Seas
- Coastal weather bulletins for ships plying in coastal waters
- Bulletins for Indian Navy
- Port Warnings
- Fisheries Warnings
- Four stage warnings for Central and State Govt. Officials
- Bulletins for broadcast through AIRs for general public
- Warning for registered users
- Bulletins for press
- Warnings for Aviation (issued by concerned Aviation Meteorological Offices)

FOUR STAGE WARNING SYSTEMS FOR TCS

The **First Stage** warning known as **"PRE CYCLONE WATCH"** issued 72 hours in advance of commencement of adverse weather contains early warning about the development of a cyclonic disturbance in the NIO, its likely intensification into a TC and the coastal belt likely to experience adverse weather. The **Second Stage** warning known as **"CYCLONE ALERT"** is issued at least 48 hrs in advance of the expected commencement of adverse weather over the coastal areas. It contains information on the location and intensity of the storm, likely direction of its movement, intensification, coastal districts likely to experience adverse weather and advice to fishermen, general public, media and disaster managers. The **Third Stage** warning known as **"CYCLONE WARNING"** is issued at least 24 hours in advance of the expected commencement of adverse weather over the coastal areas. These warnings give the latest position of cyclone and its intensity, likely point and time of landfall, associated heavy rainfall, strong wind and storm surge along-with their impact and advice to general public, media, fishermen and disaster managers. The **Fourth Stage** of warning known as **"POST LANDFALL OUTLOOK"** is issued atleast 12 hours in advance of expected time of landfall. It gives likely direction of movement of the cyclone after its landfall and adverse weather likely to be experienced in the interior areas. However, this is applicable for the TCs developing over open sea like central Bay of Bengal or Arabian Sea.

WAYS TO DISSEMINATE CYCLONE WARNINGS

The different telecommunication channels used for warning dissemination are as follows;

- Landline/ Telephone
- Telefax
- VHF/HFRT (Internal)
- Police Wireless
- AFTN (Aviation)
- Internet (e-mail)
- Websites
- Radio/TV network
- Interactive voice response system(IVRS)
- Mobile Phones (including SMS)
- Satellite Phones, etc.

CYCLONE TRACKING/WARNING WEB SITES

For Cyclone tracking/warning IMD's Web Site is official for the State government which is; India Meteorological Department - http://www.imd.gov.in/section/nhac/dynamic/cyclone.htm

However, there are few other renowned global Web Sites which can be helpful for Cyclone tracking. The Web Sites are as shown below;

➢ National Hurricane Centre - http://www.nhc.noaa.gov/

- Central Pacific Hurricane Centre - http://www.prh.noaa.gov/hnl/cphc/
- Japan Meteorological department - http://www.jma.go.jp/jma/indexe.html
- Bureau of Meteorology (Australia) - http://www.bom.gov.au/
- Cooperative Institute for Meteorological Satellite Studies -http://cimss.ssec.wisc.edu/tropic2/
- Fleet Numerical Meteorology and Oceanography Center from (FNMOC) US Navy Portal - http://www.usno.navy.mil/FNMOC/tropical-applications

PRECAUTION AND MITIGATION OF CYCLONES

Broad risk mitigation strategies available and applicable to all the coastal hazards can be classified into three main types namely; protection, accommodation and retreat. These strategies include both structural and non-structural measures. Structural measures refer to any physical (natural or artificial) construction to reduce or avoid possible impacts of hazards. Structural measures can range from engineering structures that are added to the landscape to protect from hazards. Non-structural measures refer to policies, regulations and plans that promote good coastal management practices to minimize risks from coastal hazards. Education and outreach campaigns that increase the public's awareness of risks, vulnerability and preparedness responses can be considered as non-structural measures.

"Protection" involves the use of natural or artificial measures to protect landward development. Traditionally, protection against coastal erosion, flooding, storm surge and tsunami inundation has been approached through mitigation by hard structural response. Examples of common protection measures include constructing groynes, seawalls, offshore breakwaters. In some heavily populated areas susceptible to storm surges, dykes, levees, dams, and flood gates have been built to protect coastal communities during extreme sea-level events. *(Source: National Cyclone Risk Mitigation Programme (NCRMP). 2005)*

CYCLONE MITIGATION AND MANAGEMENT PLAN

The following are the long term plan for extenuating the threat of cyclone.

1. Construction of cyclone shelter

2. Construction / renovation of canals and embankments for improved drainage
3. Shelter belt plantation
4. Construction of missing road links
5. Institutional capacity building and hazard reduction studies
6. Improvement of on-shore warning system
7. Retrofitting of life-line /key /vital installations (roads / culverts / bridges)
8. Awareness generation for cyclone risk mitigation

1. CONSTRUCTION OF CYCLONE SHELTER

A large number of people in the coastal area do not have access to safe shelters, which could withstand the fury of cyclone. So studies along the entire coastline needs to be conducted to find out villages, where people do not have access to safe shelters within a range of 1.5 km and without having to cross a natural barrier. Cyclone shelters may be constructed in such places to ensure physical safety of people those who have no access to safe shelters. Livestock need to be provided with shelter to ensure their sustenance during a disaster.

Therefore, the cyclone shelters should be designed for multi-purpose use such as school building, community center, or any other public utility buildings so as to ensure that these building are used and maintained during normal times. For proper maintenance of these specially designed buildings in hostile terrains communities should have a sense of ownership of these. Therefore, Cyclone shelter management and maintenance committees may be constituted for upkeep of these shelters. A corpus fund may be placed with the committee for routine maintenance of the buildings. The committees may be encouraged to generate funds by collecting fees from people for using the buildings for social / cultural functions. Designing and building of robust cyclone proof shelters, which have storage and resting areas sufficiently high above the ground using corrosion resistant and durable materials need to be addressed.

Design criteria

If the storm- surge level is more than 1.5 m and less than 4.5 m, then the plinth should be taken as 1.5 meters and the ground floor should be used as stilt with a height varying from 2.5 meters to 4.5 meters. If the storm-surge level is more than 4.5 m, then, the roof of the first floor / terrace could be used as cyclone shelter. To make use of the space provided as stilt on the ground floor the temporary partitions could be erected and concrete benches could be provided, which are easy to maintain and clean after a cyclone. Rain water harvesting technique could be adopted so as to make drinking water available to people in the cyclone shelter at the time of cyclone /storm-surge. In general the shelters are in RCC frame with non-load bearing, laterally supported filler walls and deeper foundation on elevated ground so as to avoid submergence of the main structure during cyclonic events.

2. CONSTRUCTION / RENOVATION OF CANALS AND EMBANKMENTS FOR IMPROVED DRAINAGE

In the deltaic areas surface communication is a major handicap for response activities. The widths of the tidal rivers are linked to the sea tide and may not have a stable embankment. This makes it difficult to construct bridges on these. An alternative to road communication could be a coastal canal system. A canal network in the coast would also be an effective tool of water management. Besides improvement to minor drains in the coastal areas, it may be considered for effective drainage of water, which may include repair and reconstruction of damaged and other vulnerable flood embankments. Saline embankments protect people, live stocks and agricultural fields from saline water inundation / storm surge. Hence, there is a need to protect vulnerable areas by renovating the existing embankments and creating new ones.

3. SHELTER BELT PLANTATION

Shelterbelts are barriers of trees that are planted to reduce wind velocities and prevent wind erosion. In coastal areas shelterbelt plantation of Casuarinas is one of the most suitable and effective alternative to minimize the impact of wind velocity and saline ingress. They also provide direct benefits to provide shelter to livestock. Main objective of windbreaks and shelterbelts is to protect the human habitations and agricultural crops. Shelterbelt protects an area over a distance up to its own height on the windward side and up to 20 times its height on the leeward side, depending on the strength of the wind. When designing shelterbelt, the direction of the wind must be considered. A barrier should be established perpendicular to the direction of the prevailing wind for maximum effect. The trees selected for such salt-breaks must have some degree of salt tolerance. Species that has been used successfully tried in India include *Casuarina equisetifolia*. In the selection of tree or shrub species for shelterbelts, the characteristics like rapid growth, straight stems, wind firmness, deep root system which does not spread into nearby field, resistant to drought are considered very important. If there is a Cyclone shelter / building or a construction projects with e”20,000 sq. m and <150,000 sq. m of built-up area, it will require prior Environmental Clearance as per the EIA notification of 2006.

4. CONSTRUCTION OF MISSING ROAD LINKS

Effective road connectivity ensures fast deployment of men, materials and machinery to affected areas. It helps in ensuring speedy evacuation of people from vulnerable places to safer areas in the face of an impending disaster threat. Thus there is a need for development of a reliable road network in the vulnerable areas so as to ensure coordination of relief and response in the event of a cyclone. The link roads to existing cyclone shelters are also very crucial for evacuation of people. Roads are always associated with culverts and bridges to make them fit throughout the year.

5. CAPACITY BUILDING AND HAZARD REDUCTION STUDIES

While the hazards due to tropical cyclones cannot be reduced, mitigation strategies to reduce their impacts can be devised. Mitigation measures like timely communication of warnings, land use planning, enforcement of cyclone resistant construction etc. go a long way in reducing the vulnerability of structures to cyclonic impacts and the resulting losses. Assessment of risks to physical assets is fundamental before devising any successful mitigation strategies or plans. Thus the institutional capacity building measures need to be emphasized for knowledge update to handle the unforeseen hazards.

6. IMPROVEMENT OF ON-SHORE WARNING SYSTEM

Early reliable warning is one of the important short term mitigation measures that can reduce the severity of the cyclone related disasters if acted upon timely. The degree to which this reduction can be effected will depend upon the accuracy of the warning, the length of time between the warning's being issued and the expected onset of the event and the state of pre-disaster planning and readiness. The public response to warning in the form of correct precautionary action is another important component for the reduction of loses of lives and properties. It is often seen that the fishermen out at sea and unorganized weaker section of the coastal communities are among the first causalities of tropical cyclone disasters. The strengthening of onshore warning communication system is therefore an important intervention that can save many valuable human lives.

7. RETROFITTING OF VITAL INSTALLATIONS (ROADS / CULVERTS / BRIDGES)

Roads/culverts/bridges in the cyclone prone areas need to be maintained well. If they are in a bad shape their repair and strengthening works also needs to be given utmost attention. Roads are always associated with culverts and bridges and routine maintenance of these infrastructures is crucial for post disaster response. Bridge foundations in alluvial soils lead to deep scour near some piers when large discharges due to cyclonic storms occur which may result in tilting of foundations. Where the general road condition is found to be bad their restoration work has to be accorded high priority. Repair and retrofitting work is a specialized job and requires the use of special materials and expertise.

8. AWARENESS GENERATION FOR CYCLONE RISK MITIGATION

The public awareness programme is an important component of disaster risk management. Involvement of community under threat is essential for the success of any disaster risk reduction programme. Prior knowledge about the warning system and its limitations, source of warnings makes the community better equipped to fight a disaster. Mechanisms like distribution of circulars, Dos and Don'ts, posters and publicity about precautionary measures through media are in existence but past experience shows that such actions are not sufficient and more need to be done. Man to man contact is essential for the success of awareness programme. Such activities not only to be continued but also these are to be frequent and regular. A well informed awareness programme involving the community is essential.

Thus a multi-pronged approach is needed to mitigate the risk of tropical cyclone, which shall be certainly helpful for minimal loss of life and resources.

(Source: National Cyclone Risk Mitigation Project II (A World Bank Funded Project). 2014.)

MANAGEMENT AND MITIGATION OF CYCLONES IN INDIA

There has now been a paradigm shift in Government of India (GoI)'s approach to cyclone risk reduction. The approach shifted from a merely reactive emergency response to adopting a holistic approach to disaster management and being proactive in implementing disaster preparedness and risk reduction activities. This change has led to an increased focus on implementation of risk mitigation programs and strategies covering the entire disaster management cycle.

There is a great importance of cyclone disaster management in India to mitigate casualties and economic losses. Let us read about a few governmental initiatives for cyclone management in India:

NATIONAL CYCLONE RISK MITIGATION PROJECT

India initiated this project to undertake structural and non-structural measures to mitigate the cyclone's effects:

- It is designed for coastal States and Union Territories of India.
- The aim of the project is to protect the vulnerable local communities from the impact of cyclones and other hydro-meteorological calamities.
- The phase-I of the project spans from 2015-2020.
- The World Bank is providing financial assistance for this project.
- It is being implemented by the National Disaster Management Authority (NDMA)

  Integrated Coastal Zone Management (ICZM) Project

- In August 2019, a draft of Environmental and Social Management Framework (ESMF) for integrated coastal management was released by the Ministry of Environment, Forest and Climate Change (MoEF&CC.)
- It aims to bring a comprehensive plan to manage coastal areas.

  Coastal Regulation Zones (CRZ) – The CRZ Notification 2018 and 2019 bring new reforms w.r.t sustainable development of coastal areas.
- IMD's Colour Coding of Cyclones: It is a weather warning that is issued by the IMD to aware people ahead of natural hazards. The four colours used by IMD are Green, Yellow, Orange, and Red.
- Recently, in December 2020, IMD's DG announced the introduction of a dynamic and impact-based cyclonic warning system. IMD will work with NDMA, INCOIS and various state governments to successfully introduce this system.

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MODEL QUESTIONS:

1. What is climatic hazard? Discuss the causes of climate hazards.
2. Give the concept of climate refugee.
3. What are the types of climatic hazards?
4. What is the concept of cyclone? Discus the types of cyclone.
5. What is tropical cyclone? Discuss the characteristics and the formation of tropical cyclones.
6. Describe the types and naming of tropical cyclones
7. Give a short note on Indian cyclones with the description of cyclone prone states of India.
8. Describe the tropical cyclone forecast system in India.
9. Discuss about the cyclone mitigation and management plan.
10. Mention the characteristics of National Cyclone Risk Mitigation Project in India for the disaster management.

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UNIT-5:

MARINE HAZARD: TSUNAMI (PREDICTION, PRECAUTION AND MITIGATION)

INTRODUCTION:

Considering that geological hazards are unavoidable and will certainly continue to occur in the future, mitigation measures (for risk reduction) should therefore be focused on decreasing the risk (exposure and vulnerability) and increasing resilience. These measures should be based on the scientific knowledge of events that occurred in the past, their triggering mechanisms and the propagation of their consequences. (www.marineboard.eu)

The present module emphasises on the concept and types of marine hazards with special reference to the tsunami. The chapter also deals with the detailed discussion of the origin of the Tsunami, prediction and warning system, precautions or preparedness and mitigation measures etc.

MARINE HAZARD:

The **Marine Hazards** are generally the coastal hazards, which are physical phenomena that expose a coastal area to the risk of property damage, loss of life, and environmental degradation. Rapid-onset hazards last for few minutes to several days and encompass significant cyclones accompanied by high winds, waves, and surges or tsunamis created by submarine earthquakes and landslides.

Ocean waves are generated from various sources which are mostly created by the wind. These waves can occur over oceans, seas, lakes, and intra-coastal waterways and are constantly changing and can grow quickly. Rough seas build rapidly as winds approach gale force (34 knots or 39 mph) and likely to build to 12 feet or more. When seas build to five or six feet, it could become deadly and act as disasters. Natural disasters in the marine environment are events that are out of human control and are usually caused by weather. Such disasters include storms, **tsunamis**, typhoons, flooding, tides, waterspouts and storm surge etc. (Schwartz, 2005). Hazardous events in coastal areas affect millions of people. Around ten million people globally are affected by coastal problems yearly. (Adger, N., & Hughes, T.2005).

TYPES OF MARINE HAZARD:

Marine hazards are of different types including the marine biological hazards, meteo-climatic event-related hazards and the geological marine hazards or marine geo-hazards.

1) Biological marine hazards

Traditionally, some **biological hazard**s arise in marine environment from exposure to biogenic substances or microorganisms resulting from an-thropogenic activities. For many years, microbial contamination of recrea-tional waters represented a relatively well-known source. Conversely, the effects of other naturally-occurring processes such as bacte-rial and parasitic pathogens are less known, let alone how people with under-lying diseases or inherent genetic susceptibilities may react to equivalent bi-ohazard dose and route exposures. Multidisciplinary and holistic perspectives are needed to understand the cu-mulative impact of global warming and anthropogenic drivers on the hazard-ous role of biogenic invaders of oceans and seas. (Bouwknegt et al., 2018).

Meteo-climatic event-related hazards

Marine hazards caused by extreme short-term (heat waves, extreme storms) and long-term (erosion, sea-level rise) **meteorological** events adversely impact on the human habitation, social well-being, the cul-tural heritage and ecosystem services. In the future, only considering hazards related to sea-level rise and storminess, such as coastal flooding and erosion, it is estimated that in regions with low-lying coasts they can produce losses amounting to several percent of GDP by 2100 (IPCC, 2019). The influ-ence of **climate change** in the increasing frequency and intensity of extreme events in marine environment is well-documented for some of them (e.g. sea-level rise, heat waves). (Schiermeier, 2018). Another climatic hazard such as **Marine Heat Waves (MHWs)** are “periods of extreme warm sea surface tem-perature that persist from day to month and can extend up to thousands of kilometres”. The mean duration and frequency of MHWs have increased sig-nificantly over the past century, and they are expected to keep increasing. They have severe impacts on marine ecosystems health and productivity (Smale et al. 2019). Also hazard like **storm surge** is the sea level rise caused by the accumulation of water in the coast produced by wind-generated currents. Extreme storm surges are a se-vere threat in coastal areas as they may cause loss of life and large economic and ecological damage. Coastal erosion at sandy coasts can be defined as the process by which strong wave action, storm surges resulting from storm events, river floods and/ or sea level rise carry away soils and sands along the coast (Mentaschi et al., 2018).

Marine Geo-hazards

Marine geo-hazards are generated from diverse geological conditions, ranging from broad-scale to local scale. Major marine geo-hazards include **tsunamis**, offshore earthquakes, submarine landslides, gas hydrate dissociation, seabed and coastal erosion, volcanic eruptions, and flank collapses. Geo-hazards originate from submarine or deep geological regions. Their distribution, frequency, magnitude and coupled effects define their destructive capability. In the twentieth century, tsunamis caused by offshore earthquakes, eruptions and submarine landslides killed over a million people. Marine geo-hazards such as **tsunamis, storm surges or harmful algal blooms**, are of particular socio-economic concern. Marine hazards affect the physical status of the ocean and also the biological realm, which is driven by the changes accounted for in the seawater and sediments. A **tsunami** is a succession of waves of extremely long wavelength generated by a powerful, underwater disturbance that causes a sudden displacement of a large volume of water from the sea floor. Tsunamis may be triggered by earthquakes, volcanic eruptions, submarine landslides, and by onshore landslides in which large volumes of debris fall into the water (USGS, 2006).

TSUNAMI (CONCEPT AND ORIGIN)

Tsunami is a Japanese word, meaning ‘harbour waves’. The term consists of three Japanese words: ‘tsu’ means harbour, ‘noh’ and ‘me’ c in combined meant waves. The height of a tsunami wave in the deep Ocean is typically a few decimetres, and the distance between wave crests can be up to 100 km. The speed at which the tsunami travels decreases as water depth decreases. In open water, where the water depth reaches 4-5 kilometres, tsunami speeds can be more than 700 kilometres per hour. As tsunamis reach shallow water around islands or on a continental shelf, the speed decreases but the height of the waves increases manifold. Depending on the seafloor morphology, wave heights may reach more than 20 m. The great distance between wave crests prevents tsunamis from dissipating energy as breaking surf; instead, tsunamis cause water levels to raise rapidly along coastlines much like very strong and fast-moving tides (i.e. strong surges and rapid changes in sea level). Much of the damage inflicted by tsunamis is caused by strong currents and floating debris. Tsunamis travel much further inland than normal storm waves.

Causes of Tsunami Generation

Confusion prevails over the processes of Tsunami generation. Tsunamis are traditionally described as tidal waves. Tsunami is generated as the disturbed water level attempts to attain equilibrium. The disturbed ocean water moving under the influence of gravity radiates across the sea/ocean similar to ripples in a pond. Because there is very little energy loss during the propagation of the Tsunami waves over the ocean water, the harbour waves, which finally strike the coastal areas, assume awesome ferocity. (Roy, 2014)

The process of Tsunami generation sets off with abrupt dislodgement of blocks of ocean floor rocks due to faulting with a strong vertical component of displacement. Two different situations are possible. Faulting can lift a part of the ocean floor vertically upward which in turn would push up the column of water above it creating a local bulge over the normal sea level (Figure: A). On the other hand, if faulting causes down-sagging of the ocean floor relative to the adjacent part, a local depression in the sea water level is created causing ebbing tide. Such a situation may develop in Subduction Zones where the heavier Oceanic Lithosphere slides down below the lighter continental Crust (Figure : B).

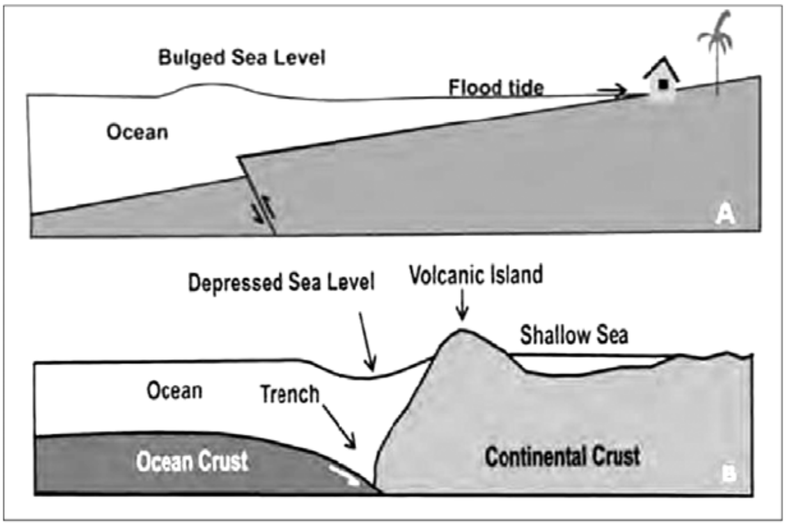

Fig. A: Schematic diagram is showing the development of local bulge over the sea level because of uplifting of a block of Ocean Crust. This causes flood tide in coastal region.

Fig. B: Where fault causes down-sagging of a block as in Subduction Zone, a local depression in the sea level is created.

The Circum-Pacific Belt is the most Tsunami-prone stretch in the world today which is characterised by the presence of deep Trenches over the Subduction Zones associated with an inclined zone of seismicity (Benioff Zones). Because of the down-sagging movement at regular intervals; a space is created virtually coinciding with the zone of Trenches. This in turn creates a sudden depression in the water column above the zone, leading to imbalance. The process that follows in attaining the equilibrium leads to generation of Tsunami waves.

The tectonic situation of the 2004-Indian Ocean Tsunami is comparable to those that develop along the Circum-Pacific belt.T he similarity is perceptible with regard to the source and nature of tsunami generation, due to massive down-sagging of the Indian Ocean Crust along the Java Trench.

Sudden displacement of huge mass of water (enough to cause a Tsunami) could also be due to processes other than faulting. These include:

- Volcanic eruptions near sea or underwater. The most horrifying example recorded in history was the eruption of Krakatao in Indonesia on 26-27 August, 1883.
- Large meteorite impacts on ocean water (no known instance is recorded in human history). However, presence of some 'erratic' deposits along the Gulf coast of Mexico and the United States was presumed to have resulted during the apparent impact of a meteorite about 65 million years ago near the tip of the Yucatan Peninsula of Mexico
- Underwater testing of nuclear bombs (Nuclear testing by the United States in the Marshall Islands in the 1940s and 1950s generated Tsunamis).
- Massive landslides generated Tsunamis. The most famous example of a landslide induced Tsunami occurred at Lituya Bay in Alaska (USA) on 9 July, 1958, producing a giant water wave that reached 524 metres up the local mountains. However, there was virtually no effect outside the bay region.

Besides these, a Tsunami could generate, if a landslide drops a huge mass of rock debris or an avalanche pours in huge chunks of ice mixed with rubbles of rocks and soils into sea or ocean. The Tsunamis generated by such processes generally have a localised influence. The waves generated usually dissipate quickly, and rarely affect the coastlines distant from the source because of the small area of the affected sea.

CHARACTERISTICS OF TSUNAMI

The following are the characteristics of tsunami:

i. The tsunamis are generally classified into two types: a) deep sea tsunami (where wave travel speed is 500 – 1000 km/hour) and b) local tsunami (where wave travel speed is 10 km/hour);

ii. The speed of tsunami increases with the increase of ocean depth;

iii. The height of tsunami waves become comparatively low in the deep sea water but their height increase near the coast;

iv. The waves in tsunami are categorised into two: negative waves or retreat rise cycle and positive waves or rise retreat cycle. The tsunami occurs in retreat and rise cycle with a period of 30 minutes between each peak. If the crest of a tsunami arrives first, there won't be any recession and the sea level will increase rapidly with mass inundation in the path;

v. Tsunami detection is not ease as it originates in the deep sea with minimum height. Strong sensors and communication satellites are required to detect and warn the situation.

TSUNAMI-EARTHQUAKE LINK

All the Tsunamis in the Circum-Pacific belt are invariably associated with earthquakes. So intimate is the association that these 'harbour waves' are conventionally described as 'earthquake generated Tsunami' or 'seismic sea waves' (Roy, 2008).

Without refuting the Tsunami-earthquake link, the usage appears misleading because scientifically speaking, both earthquake and Tsunami are manifestations of sudden dislodgement of rock masses during faulting, and the association does not bear any cause-and effect relationship (Roy, 2008). Earthquakes are vibrations in the Crust caused by moving energy waves released during the breaking (faulting) of 'strained rocks'. 'Elastic Rebound Theory' aptly explained how the energy released during disruption (or faulting) of strained rocks radiated from the source of origin as elastic waves along the San Andreas Fault (Reid, 1906).

It would be wrong to say that the earthquake waves can provide energy for generating a Tsunami. A point to remember is that no Tsunami was generated during severe earthquakes along the San Andreas Fault as the movement along the fault causing earthquake was of translational or strike-slip type, and did not displace water in any significant way. The 'Troika of Catastrophe' that marked the 1st November, 1755, Lisbon event, an earthquake-induced massive landslide into the Atlantic water generated a mega-Tsunami that destroyed many settlements all along the coastlines. But, even in that case, it cannot be said that the Tsunami waves were generated directly by the earthquake. Earthquake can definitely be the cause of a type of 'enhanced' waves called ***'Seiche'*** (also a Japanese term, pronounced ***'saash'***).

HISTORICAL PERSPECTIVE OF TSUNAMI

There is a long record of tsunamis affecting the coastlines of the Indian Ocean, principally along the western coast of Sumatra, although there have been none in recent history.

- In 1861, an estimated M 8.8 - 9.2 earthquake ruptured much of the subduction zone along the west coast of Sumatra, causing damage all along the coast and on the offshore islands of Sumatra.
- Other major tsunami-generating earthquakes had occurred along segments of the subduction zone in 1797 and in 1833, when huge tsunamis flooded the southern part of western Sumatra claiming tens of thousands of lives in each incident.
- The largest previous event on this section was in 1881, when an estimated M8 earthquake in the Andaman Islands caused a modest 1-m (3-ft) tsunami recorded on tide gauges in Chennai, India.
- Further, the plate boundary to the north of the fault rupture broke in a great earthquake along the whole of the western Arakan coast of Myanmar in 1762, causing significant coastal uplift and a moderate tsunami in the northern Indian Ocean. A 2-m (7-ft) rise in the water level was reported near Dhaka, Bangladesh after the event.
- A tsunami generating event took place in the region in 1883, when a cataclysmic volcanic eruption suddenly collapsed the island volcano of Krakatau located between Sumatra and Java in Indonesia, causing the deadliest tsunami in the region prior to 2004. Over 36,000 died from the waves, which had a maximum run-up of 40 m (130 ft) along the surrounding shorelines of the islands.

- The most destructive Pacific-wide Tsunami of recent history was generated along the coast of Chile on May 22, 1960. The combined Tsunami and earthquake toll included 2,000 killed, 3000 injured 2,000,000 homeless and $550 million damages. Wave heights varied from slight oscillations in some areas to range of 12.2 meters (40 feet) at Pitcairn Islands; 10.7 meters (35 feet) at Hilo, Hawaii and 6.1 meters (20 feet) at various places in Japan.
- The hydro-graphic survey in Japan after the great Kwato earthquake of September 1, 1923 showed that vertical displacements of the order of 100 meters had occurred over a large area of sea floor.

Tsunamis are very common in the Pacific Ocean because it is surrounded on all sides by a seismically active belt. In the Hawain Islands, Tsunamis approach from all directions, namely, from Japan, the Aleutian Islands and from South America.

Year	Place	Number of Lives lost
1692	Port Royal, Jamaica	3000
1703	Tsunamis in Honshu, Japan following a large earthquake	5000
1707	38 foot Tsunami, Japan	30,000
1741	Following Volcanic eruptions 30 feet wave in Japan	1400
1753	Combine effect of an earthquake and Tsunami in Lisbon, Portugal	50,000
1783	A Tsunami in Italy	30,000
1868	Tsunami Chile and Hawaii	More than 25000
1883	Krakatoa Volcanic explosion and Tsunami Indonesia	36,000
1896	Tsunami Sanrika , Japan	27,000
1933	Tsunami, Sanrika Japan	3000
1946	32 foot high waves in Hilo, Hawaii	159
22 May, 1960	Along the coast of Chille	Approx. 2000 (+ 3000 person missing).
1946	Honsu, Japan Earthquake Spawan Tsunami	2000
1964	195 foot waves engulf Kodiak, Alaska after the Good Friday Earthquake	131
17 Aug. 1976	Philippines	8000
19 Aug. 1977	Indonesia	189
18 July 1979	Indonesia	540
12 Sept. 1979	New Guinea	100
12 Dec. 1979	Columbia	500
26 May 1983	Sea of Japan	Approx. 100
1998	Papua New Guinea	

Source: NIDM, Ministry of Home Affair, Government of India,Tsunamis in India, 2006

TSUNAMIS IN INDIA

The Indian coastal belt has not recorded many severe tsunamis in the past. Waves accompanying earthquake activity have been reported over the North Bay of Bengal.

- During an earthquake in 1881 which had its epicentre near the Andamans in the Bay of Bengal, tsunamis were reported;
- During the earthquakes of 1819 and 1845 near the Rann of Kutch, there were rapid movements of water into the sea;
- The earthquake of 1941 in Bay of Bengal caused some damage in Andaman region. This was unusual because most Tsunamis are generated by shocks which occur at or near the flanks of continental slopes;
- Further west, in the Persian Gulf, the 1945 Mekran earthquake (magnitude 8.1) generated Tsunami of 12 to 15 metres height. This caused a huge deluge, with considerable loss of life and property at Ormara and Pasi. The estimated height of Tsunami at Gulf of Kutchch was 15m but no report of damage is available;
- The Indian coastline experienced the most devastating tsunami in the recorded history on 26th December 2004. The tsunami was triggered by an earthquake of magnitude 9.0 on the Richter scale at 3.4° N, 95.7° E off the coast of Sumatra in the Indonesian Archipelago at 06:29 hrs IST (00:59 hrs GMT). These waves travelled in the Bay of Bengal and subsequently transformed into a train of catastrophic oscillations on the sea surface close to coastal zones of Sri Lanka and East coast of India.

S	Date	Remarks
1	April 12, 1762	Eq. in the Bay of Bengal generated tsunami wave of 1.8 m in coastal Bangladesh
2	August 19, 1868	Earthquake Mw 7.5 in the Bay of Bangal. Tsunami wave run-up level at Port Blair, Andaman Island 4.0 m.
3	December 31, 1881	Earthquake of magnitude Ms 7.9 in the Bay of Bangal, reported tsunami run-up level of 0.76m at Car Nicobar, 0.3m at Dublat , 0.3 m at Nagapattinam and 1.22 m at Port Blair in Andaman Island
4	1883	Karakatau, volcanic explosion in Indonessia. 1.5 m tsunami at Chennai, 0.6 m at Nagapattinam.
5	1884	Earthquake in the western part of the Bay of Bengal. Tsnamis at Port Blair & mouth of Hoogly River
6	June 26, 1941	Earthquake of magnitude MW 8.1 in the Andaman Sea at 12.9^0 N,92.5° E. Tsunamis on the east coast of India with amplitudes from 0.75 to 1.25 m. Some damage from East Coast was reported.
7	November 27, 1945	Mekran Earthquake (Magnitude Ms 8.3). 12 to 15 M wave height in Ormara, 13 m at Pasni, and 1.37 m at Karachi (Pakistan) . In Gulf off Cambay of Gujarat wave heights of 11.0 m was estimated, and 2 m at Mumbai, where boats were taken away from their moorings.
8	December 26, 2004	An earthquake of rear Magnitude (M_W9.3) generated giant tsunami waves in North Indian Ocean. Tsunmai made extensive damage to many coastal areas of Indonesia, India, Malaysia, Maldives, Srilanka and Thailand. A trans-oceanic tsunami, observed over areas beyond the Ocean limit of origin. More than 2,00,000 people lost their lives in above countries which is a record.

Source: NIDM, Ministry of Home Affair, Government of India,Tsunamis in India, 2006

PREDICTION OF TSUNAMI

Risk and vulnerability assessment is an important component of an effective End-to-End **Tsunami Early Warning System** and **Tsunami Propagation or Tracking.** Therefore, it contributes significantly to disaster risk reduction. Risk assessment is a key strategy to implement and design adequate disaster prevention and mitigation measures. The knowledge about expected tsunami hazard impacts, exposed elements, their susceptibility, coping and adaptation mechanisms is a precondition for the development of people-centred warning structures, local specific response and recovery policy planning. The developed risk assessment and its components reflect the disaster management cycle (disaster time line) and cover the early warning as well as the emergency response phase. (Post, 2009)

1) Tsunami Warning System

As warning systems that track the passage of the tsunami in the open ocean are being developed, self-help solutions can be supplemented with information on how to respond to official warnings, such as those delivered through radio, cell phone messages, or sirens. However, official warning systems can provide only part of the solution as information can never be effectively disseminated to everyone along a coastline. With only 10 to 30 minutes warning in the nearfield of major tsunamis, it is imperative that people are taught to take their own action rather than wait for official instruction.

The **Tsunami Warning System (TWS)** is projected as the only preposition for the tsunami mitigation now. As, most of the tsunamis are triggered by the submarine earthquakes, technology is not currently available to predict the earthquakes to the finest resolution of couple of hours. However, as far as India is concerned, the tsunami generic Andaman – Sumatra subduction zone lies roughly 2000 - 2500km east of the east coast of India and the Carlsberg ridge and other active faults of the Arabian sea are located again 2000 – 2500 km west of the west coast of India. As tsunamis normally travel with the maximum speed of 700-800 km/hr, it might take 2-3 hrs to reach the Indian coasts. So there is sufficient time to warn the coastal people through TWS. But the experiences of **Pacific Ocean Tsunami Warning Systems (PTWS)** show that 60 – 70 % of the forewarnings have failed. Hence, the lacunae in the Pacific ocean TWS need to be understood and rectified in the proposed tsunami warning network for India.

The following are the **Components of a Tsunami Warning System in India**:

- A Network of Land-based Seismic Stations for earthquake detection;
- Detection of Tsunami generation through a network of 10-12 bottom pressure recorders (that could detect and measure a change in water level of 1 cm at water depths of up to 6 km of water);
- Monitoring the progress of Tsunami and Storm Surges through a network of 50 real time tide gauges;
- Tsunami Modelling (addressing the inundation and amplification all along the coast and islands for different tsunami originating from different sources);
- Generating and updating a high resolution data base on bathymetry, coastal topography, coastal land use, coastal vulnerability as well as historic data base on Tsunami and Storm Surge to prepare and update Storm Surge/Tsunami hazard maps in 1:5,000 scale;
- Setting up a dedicated National Early Warning Centre (NEWC) for monitoring tsunamis and storm surges in India for operation on 24x7 basis and for generation of timely advisories; and
- Capacity building, training and education of all stakeholders on utilisation of the maps, warning and watch advisories.

As part of the Early Warning System for Tsunamis and Storm Surges in Indian Ocean set up by GoI, a 17-station Real Time Seismic Monitoring Network (RTSMN) is envisaged to be established by IMD. This network is designed to monitor and report the occurrence of earthquakes capable of generating Tsunamis from the two probable Tsunamigenic sources viz., Java-Sumatra-Andaman-Myanmar belt and the north Arabian Sea area in the least possible time. The data from the 17 Broadband seismic field stations will be transmitted simultaneously in real time through VSAT communication facilities to the Central Receiving Stations (CRS) located at IMD at New Delhi and INCOIS, Hyderabad for processing and interpretation.

2) Tsunami Propagation and Tracking

Though the tsunamis generally travel radically in all directions from the points of origin, if they are triggered by plate subductions, the waves will mostly travel orthogonally on either sides of the linear or curvilinear subduction zones and hit the maritime countries located on either side. The recent December 26, 2004 Sumatra tsunami of the Indian ocean is an example for this that due to the general N – S subduction zone, the tsunami waves travelled both towards east and west and affected the Indonesian and Thailand coasts in the east and Indian, Sri Lankan and Somalian coasts in the west whereas, the northern Bangladesh coast was not affected. Hence, this suggest for detailed **modelling on the propagation of tsunami** waves in addition to '**TWS**'. Various parameters viz: **intensity of the triggering earthquakes**, **points of origin of tsunamis, wavelength and speed of the tsunami waves, quantum of water displaced, thickness of water column, aerial extent of the ocean, seabed topography, geometry and morphology of the continental shelf and the coasts** etc., must be taken into account and tsunami models will have to be developed, so that continuous tracking of the tsunami waves can be done and also the coasts at risks can be forecast, the way cyclone tracking and forecasting is done. This must form an integral part of the proposed TWS for India.

The basic **tsunami modelling technique** used in the U.S. West Coast/Alaska Tsunami Warning Center's (WC/ATWC) **far-field prediction method** is described by Kowalik and Whitmore (1991). Initial tsunami profile is computed from **fault dislocation formulae** of Okada (1985). The methodology which utilizes models computed as described above to predict far-field tsunami amplitudes is described by Whitmore and Sokolowski (1996). To summarize, tsunami models are computed for 204 hypothetical earthquakes along the coasts of northern Honshu, Kuril Is., Kamchatka, Aleutian Is., Alaska, British Columbia, Cascadia, and Chile.

3) Tsunami Vulnerability Mapping and Risk Zonation

The tsunamis once strike the coast, the inundation of tsunami waves and the related disasters however depend on the coastal zone geology comprising lithology, active tectonics, geomorphology etc. For example, in the context of the December 26, 2004 tsunami, if the east coast of India is considered, eastern part of India is a low easterly gradient plain and hence all the rivers originated from Deccan plateau and the Eastern and Western Ghats have fully evolved life histories with youthful, mature and old stages and hence the east coast of India is characterized with vast deltas, viz: Mahanadi, Godavari, Krishna, Ponnaiyar, Cauvery, Vaigai, etc. Hence, the layered and rhythmic sedimentary sequences of the deltas along the east coast of India form the major lithology. As far as Tamil Nadu coast is concerned the Chennai area is a rocky coast by the Precambrian rocks, Pondicherry coast exposes marginally harder Tertiary sandstones and the remaining major part of the coast is of Quaternary sediments belonging to fluvial (deltas), fluvio-marine and marine origin. The South Indian coasts are said to be tectonically active with a number of alternating E – W arches and deeps from Cape Comorin in the south to Mahanadi delta in the north (Ramasamy and Balaji 1995). Further, Elliot et al (1998) have observed E – W trending set of sub-parallel active lineaments / faults in Nagore – Nagapattinam – Velanganni area of Tamil Nadu coast, which was worst affected by the recent tsunami. In addition to the deltaic sediments, the coastal zones of east coast are vested with beach ridges & swales, backwaters, creeks, estuaries, beaches, bay mouth bars, spits, etc. Such a fragile geo-system when affected by the recent tsunami of 8 – 12 m height and a speed of 40 – 50 km/hr responded differently; as absorbers, carriers, barriers etc. (Ramasamy et al 2005b). Hence, such coastal **vulnerability mapping** on the basis of geological systems are essential and the entire coast needs to be mapped and classified as high, moderate and poor risk zones to tsunami and accordingly various preventive / protective measures, rehabilitation strategies and future development are to be done.

Geographic Information System (GIS), space based **Remote Sensing** and **Global Positioning Systems (GPS)**, offer a powerful tools for Disaster Assessment, Monitoring, and Management, **Risk Zonation** etc (Herold *et. al.*, 2005). However, today none of the space based system has the capability to detect and predict natural calamities like earthquakes or Tsunami. The remote sensing and communication satellites provide the means of assessing the extent of damage and enabling the relief operators to use this data for planning the mitigation measures as well as establishing emergency communication systems. Remote sensing can be extensively used to assess damage, direct relief and rescue efforts to the areas affected by the Tsunamis. Apart from these, it can help in analyzing the geological, geomorphological changes taking place in the post disaster scenario (Nirupama and Simonovic, 2002). It can play an important role in highlighting and mapping the dramatic changes to coastlines due to the impact of Tsunamis and in understanding the extent of destruction to the mangrove swamps and coral reefs that act as protective barriers from wave erosion or Tsunamis.

TSUNAMI PRECAUTIONS

Tsunami impacts can vary greatly from one community to the next depending on their local bathymetry and topography. So to prepare for a tsunami, coastal communities should conduct hazard assessments to understand how tsunamis of different sizes and sources (location and type) might affect them. Communities can use the resulting tsunami hazard zone maps to determine where people and other important community assets (e.g., buildings, facilities, bridges, schools, and hospitals) are at risk so they can decide where to focus preparedness, response, and mitigation efforts.

The following measures will help the coastal population to prepare themselves for a Tsunami, the protective measures include:

i. Look for the alert or warning message regarding tsunami, either in local newspapers, radio or television.

ii. Observe the animals in the house for any unusual behaviour patterns as chained or tied animals may show signs of restlessness and agitation in case they feel an impending natural disaster.

iii. Keep disaster supply kits [comprising of all essential items such as medicines, drinking water, food items etc] for survival for a few days

iv. Inform all the household members (who might have gone to their work place) about the message and finalize the evacuation plans.

v. Look for the evacuation routes and possibly reach the destinations (tsunami shelters constructed on the elevated grounds) within a reasonable time.

vi. In case the time available between the announcement about the event and its actual occurrence is sufficiently large, plan for protecting the cattle and other household loose objects.

vii. If the coastal inhabitants reside in a tsunami risk area, they should be aware of the following in advance:

    a. Locations of nearest tsunami shelter, their distance and escape route from the residence to tsunami shelters, mode of travel (preferably by bicycle or moped). Residents of the village must be aware of the tsunami shelter to which they belong and this information must be pasted at the door of the *panchayat* office.

    b. Know about the ground elevation of the house, street and the area. Look for evacuation orders which normally would be based on these elevations.

    c. Conduct mock exercises and drills frequently to practice on evacuation with the disaster supply kit. This would enable the public to estimate the time required for evacuation.

d. Discuss with insurance agents and explore the possibility of insuring the lives and property in high-risk areas prone to the occurrence of a tsunami.

e. Get educated on the experience by others about past tsunamis, in case of possibility of a tsunami.

f. Keep valuables and important documents in plastic pouches in safe custody to save them from getting spoiled due to tsunamigenic sea water inundation.

viii. Education in schools, colleges and other institutions regarding tsunami must be made a part of curriculum.

ix. Each coastal village should have its own "Village Disaster Management Task Force".

MITIGATION PLAN FOR TSUNAMI

Tsunamis, like most natural disasters, are beyond human control. There are, however, a number of techniques that can minimize the harmful effects of tsunamis to the physical environment (including built structures) and to individuals and communities. Accompanied by an effective warning system, thoughtful design and strong community organization can reduce harm from Tsunamis and other natural disasters.

The following sections focus on seawalls (protective structures) and vertical evacuation structures:

- ✓ **Seawalls**: These are typically constructed along the shoreline to prevent wave overtopping. They can also serve to prevent tsunami waves from reaching the shoreline or to reduce the hydrodynamic forces that will be imposed on structures that are located within the inundation zone. Therefore, seawalls should be reinforced to resist the loading imposed by tsunamis. (Chock et al., 2013).

- ✓ **Vertical Evacuation**: During evacuation from low-lying areas to natural higher elevation provided by the surrounding terrain, there is a high probability that the population may encounter the tsunami. For this form of vertical evacuation, the evacuation should commence immediately following the earthquake motion. In such cases, the natural higher elevation should be within close proximity to inhabitants to be effective. Where this option is not available due to the topography or due to security restrictions (in industrial areas), the need for man-made vertical evacuation within the inundation zone arises. These evacuation structures can be either single-purpose or multi-purpose facility. Moreover, they should be earthquake- and tsunami resistant, and encompass sufficient space to accommodate the expected number of users. In addition, the evacuation site should be higher than the estimated tsunami inundation depth at that location. (Fraser et al., 2012).

- ✓ **Multi-purpose Shelters for Storm Surges during Tsunami:** In recent years, Multi-purpose cyclone- cum-tsunami shelters have been designed and are being constructed in storm surge prone areas. Such multi-purpose shelters can be used as schools, community halls, places of worship and other social gathering places.
- ✓ **Construction for Tsunami Safety**: It is necessary that the tsunami risk and vulnerability of the coastal areas is taken into consideration while designing buildings and other structures in tsunami and cyclone-prone coastal areas. In the design of public infrastructure like roads, schools, hospitals, multi-purpose shelters etc., prevailing risk and vulnerability has to be kept in mind.
- ✓ **Plantation along the coast:** Development of coastal forest (green belt) by planting casuarinas or coconut trees along the coastline to cover minimum of about 500m width of the beach. Establishment of mangrove plantations (as a coastal defence against Tsunami) for communities residing along the estuaries.
- ✓ **Construction of Sand Dunes:** Large scale submerged sand barriers in water depths of about 6 to 8 meters to be constructed. Development of sand dunes along the coast with sea weeds or shrubs or casuarinas trees for stabilization of the sand dunes are very effective to protect from tsunami waves.
- ✓ **Dredging:** Periodical dredging of the inlets and associated water bodies so as to absorb the influx during Tsunami.
- ✓ **Dykes:** Construction of submerged dykes (one or two rows along the stretch of the coast) so as to decrease the impact due to the incoming tsunami.

Other ways to mitigate the potential impacts of a tsunami emphasize thoughtful land-use planning and building design in tsunami hazard zones and include the following:

- Improving evacuation routes;
- Limiting new development in tsunami hazard zones;

- Designing the building structures to minimize tsunami damage;
- Adopting building codes that address tsunamis;
- Protecting and strengthening existing structures and infrastructure that if damaged would negatively affect response and recovery;
- Moving important community assets and vulnerable populations out of tsunami hazard zones;
- Planning for post-tsunami recovery etc.

To be recognized as Tsunami Ready and display this sign, a community must have implemented the activities established in the Tsunami Ready Guidelines.

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MODEL QUESTIONS:

1. What are marine hazards? Describe different types of marine hazards.
2. Give the concept and origin of tsunamis as geo-hazards.
3. Describe the characteristics of tsunami. Establish the link between earthquake and tsunamis.
4. Talk about in details the tsunamis in India.
5. Explain the techniques of prediction of tsunami.
6. Mention the components of a Tsunami Warning System in India.
7. Discuss the tsunami precautions and mitigation plan in details.

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UNIT-6:

HYDROLOGICAL HAZARDS: FLASH FLOODS IN HIMALAYAN REGION AND FLOODS IN SOUTHERN PART OF WEST BENGAL

INTRODUCTION:

This chapter of the volume will discuss the hydrological hazards, types of hydrological hazards, and causes of the hydrological hazards. These hazards mainly flash floods are very common in the mountainous areas of Himalayan region where, they violently alter the water volume, landscape and affect human health as well as properties and adversely impact the entire environment. On the other hand, the floods also affect the lower catchment areas of large rivers particularly; hydrological disasters involve flooding in the southern part of West Bengal and related activities such as deposition, river scour, and landslides and droughts. This article mainly focuses on the flash flood and flood disaster, their precaution, mitigation and management.

HYDROLOGICAL HAZARDS

Hydrological hazards, or **'hydro-hazards'**, are defined as extreme events associated with the occurrence, movement and distribution of water, such as floods and droughts. Hydro-hazards usually result from a combination of compounding interacting physical processes that occur across multiple spatial and temporal scales. For example, flood hazards are the result of excess water from one or multiple sources (e.g. coastal, fluvial, or surface/sub surface water), while drought hazards arise from a deficit of river flow or precipitation over a prolonged period. Hydrological hazards are extreme and harmful changes to the quality of water on earth or in how water is distributed or moves ashore beneath the surface or in the atmosphere. It can be triggered through critical climate events. Hydrological hazards are severe events associated with water occurrence; movement, and distribution such as **flooding** and related events (e.g., **flash floods**, landslides and river scour and deposition). (https://www.usgs.gov/centers/washington-water-science-center/science/hydrologic-hazards).

Hydrological hazards and their impacts are associated with climate variability, demographic trends, land-cover change, and other causative factors and could be exasperated by global climate change. The increase in greenhouse gases in the atmosphere will continue leading to global warming and an intensification of the hydrological cycle, making hydrological extreme studies more complex and challenging. (Slavisa Trajkovic and et. al., 2016).

TYPES OF HYDROLOGICAL HAZARDS

There are several types of hydrological disasters, namely **floods**, limnic eruptions, **flash flood**, seiche, tsunami etc.

1) **Floods**

   A flood refers to an overflow of water that submerges land which is usually dry. A water body like a river or lake might have varying volumes of water in different seasons; however, the water overflow is labelled as a flood only when such overflow covers land that is otherwise used or inhabited by people or wildlife.

2) **Flash Floods**

   Floods can develop over an extended period of time or occur within a matter of minutes. That latter type is called a **Flash Flood**.

Types of Flood

There are various types of floods classified on the basis of source of floodwater, factors triggering the flood, and the area flooded. Several factors can cause floods like heavy rainfall, dam breakdown, landslides and earthquakes that change the courses of rivers, and tsunamis. Floods of large scale can cause significant property damage and deaths. For example, one of the worst floods in the history is the 1931 China floods which led to the death of more than 2,500,000 people and millions of animals.

It is a temporary inundation of large regions as a result of an increase in reservoir, or of rivers flooding their banks because of heavy rains, high winds, cyclones, storm surge along coast, tsunami, melting snow cloud bursts or dam failure. The categories are:

- River Floods: Such floods are caused by precipitation over large catchment's areas. These floods normally build up slowly or seasonally and may continue for days or weeks as compared to flash floods
- Flash Floods: It is defined as floods occurs within six hours of the beginning of heavy rainfall, and are usually associated with cloud bursts, storms and cyclones requiring rapid localized warning and immediate response if damage is to be mitigated. In case of flash floods, warning for timely evacuation may not always be possible. (WeatherEye, 2007)
- Coastal Floods: Some floods are associated with the cyclonic activities like Hurricanes, tropical cyclone etc. Catastrophic flooding is often aggravated by wind-induced storm surges along the coast.

FLASH FLOOD: CONCEPTS AND IMPACT

Flash Floods can be caused by a number of things, but is most often due to extremely heavy rainfall from thunderstorms that begins within 6 hours, and often within 3 hours, of the heavy rainfall. This type of flood also can occur due to Dam or Levee Failure, and/or Mudslides (Debris Flow) etc. Human activities can also cause flash floods to occur. When dams fail, a large quantity of water can be released and destroy everything in its path. (National Weather Service Forecast Office Morristown, Tennessee, 2006). The intensity of the rainfall, the location and distribution of the rainfall, the land use and topography, vegetation types and growth/density, soil type, and soil water-content - all these factors determine just how quickly the Flash Flooding may occur, and its impact. Urban Areas are also prone to flooding in short time-spans and, sometimes, rainfall (from the same storm) over an urban area will cause flooding faster and more-severe than in the suburbs or countryside. These are known as urban flash flood.

Flash floods are distinguished from regular floods by having a timescale of fewer than six hours between rainfall and the onset of flooding. (National Weather Service, 2017)

Impacts of Flash Flood

Flash floods induce severe impacts in both the built and the natural environment. The effects of flash floods can be catastrophic and show extensive diversity, ranging from damages in buildings and infrastructure to impacts on vegetation, human lives and livestock. Analysis of flash floods in the United States between 2006 and 2012 shows that injuries and fatalities are most likely in small, rural catchments, that the shortest events are also the most dangerous, that the hazards are greatest after nightfall, and that a very high fraction of injuries and fatalities involve vehicles.

Depending on the affected elements, the flood effects are grouped into 4 categories:

(i) Impacts on built environment

(ii) Impacts on man-made mobile objects,

(iii) Impacts on the natural environment (including vegetation, agriculture, geomorphology, and pollution) and

(iv) Impacts on the human population (entrapments, injuries, fatalities). The scale was proposed as a tool on prevention planning, as the resulting maps offer insights on future impacts, highlighting the high severity areas. (Diakakis, M. et. al 2020)

FLASH FLOODS IN HIMALAYAN REGION

The Himalayas are one of the youngest mountain ranges on earth and represent a high energy environment very much prone to natural disasters. High relief, steep slopes, complex geological structures with active tectonic processes and continued seismic activities, and a climate characterised by great seasonality in rainfall, all combine to make natural disasters, especially water-induced hazards, common phenomena.

Flash floods are among the more devastating types of hazard as they occur rapidly with little lead time for warning, and transport tremendous amounts of water and debris at high velocity. Flash floods affect thousands of people in the Himalayan region every year – their lives, homes, and livelihoods – along with expensive infrastructure. There are several different types of flash flood. The most common include

i. **Intense Rainfall Floods (IRF)**;

ii. **Landslide Dam Outburst Floods (LDOF);**

iii. **Glacial Lake Outburst Floods (GLOFs)**; and

iv. **Flash Floods** caused by **Rapid Snow Melt (RSM)** and

Failure of Dams and other hydraulic structures can also lead to flash floods.

i) **Intense Rainfall Floods (IRF):** Intense rainfall is the most common cause of flash floods in the Himalayan region. These events may last from several minutes to several days. Such events may happen anywhere but are more common to mountain catchments. The main meteorological phenomenon causing intense rainfalls in the region are cloudbursts, stationary of monsoon trough and monsoon depressions.

ii) **Landslide Dam Outburst Floods (LDOF):** Debris from a landslide can temporarily block the flow of a river creating a reservoir in the upstream reach. The landslide dam can breach due to overtopping and cause huge floods known as landslide dam outburst floods (LDOF).

iii) **Glacial Lake Outburst Floods (GLOFs):** The glaciers in the Himalayas are mostly retreating, and as they retreat lakes can form from melt water held in exposed terminal moraine acting as a dam. If the dam breaks the water can be released suddenly resulting in a glacial lake outburst flood. (International Centre for Integrated Mountain Development, 2006).

Impact of Flash Floods

Impact of climate change Intense Rainfall Floods and landslide dam outburst floods are directly related to the hydro-meteorological conditions and likely to be affected by climate change. Climate models project an increase in monsoon precipitation in the region. Similarly the frequency and magnitude of extreme rainfall events are also anticipated to. GLOFs are related to glacial retreat which in turn is mainly due to climatic warming. It is therefore very likely that flash floods due to intense rainfall, landslide dam outbursts, and glacial lake outbursts will increase in the future. (International Centre for Integrated Mountain Development, 2006).

CASE STUDIES RELATED TO FLASH FLOODS IN HIMALAYAN REGION

The Himalayan region too is prone to rain-induced hazards that occur in the form of flash floods, cloudburst and glacial lake outburst. Among them, the flash floods and cloudbursts are very common (Joshi & Kumar 2006).

- **Uttarakhand Disaster:** From 10pm on Friday, 3rd August 2012 to 3am on Saturday, 4th August 2012, intense heavy rains (cloudburst) were reported in the Asi Gnaga Valley and Sawari Gad of Bhatwari Tehsil in Uttarkashi district of Uttarakhand State. The cloudburst led to formation of transient lakes at some places in the Upper Catchment areas where it gathered a huge amount debris and water for some time. At night, these lakes bursted and created flash floods in the above said valleys as well as the major river Bhagirathi in this region. The voluminous water and debris resulted in numerous landslides along the river banks and damages /destruction to the various elements along its way in Sangam Chatti, Bhatwari and Uttarkashi areas. The affected villages are situated on both the sides of Assi Ganga and Bhagirathi. Heart-wrenching scenes were witnessed at Gangori where the maximum numbers of deaths were reported so far. About 700 pilgrims were stuck and efforts were made to move them to the safer place on foot, as the roads were totally damaged, and the hostile weather was not allowing airlifting of the people. According to the government data,, 31 deaths and 5 people missing so far. However, according to informal sources and local prediction the missing number is more than 500. (https://en.wikipedia.org/wiki/2012_Himalayan_flash_floods)
- **Flood in Himachal Pradesh:** Flash floods hit the Palchan region in Himachal Pradesh. Two bridges and a road which connects Manali to Rohtang were washed away on the night of 4 August 2012. About 120 people have been evacuated from the affected areas. A government school, an under construction hydropower project and many electricity poles were also washed away.

  (https://web.archive.org/web/20120806080410/http://ibnlive.in.com/news/flash-floods-hit-uttarakhand-hp-jk-30-dead/278619-3-245.html)
- **Chamoli Disaster:** Recently, the glacial burst in the Chamoli district of Uttarakhand is an eye-opener to the ongoing disruption of the ecological balance. Disaster struck Uttarakhand’s Chamoli District on 7 February 2021, when a massive flash flood ravaged through the valleys of the Rishi Ganga, Dhauliganga and Alaknanda rivers. More than 70 people have been confirmed dead and another 134 people reported missing. The flood swept away the unfinished Tapovan Vishnugad Hydropower Project and inflicted substantial damage on the Rishi Ganga Hydropower Project. A glacial lake outburst flood (GLOF) was suggested as the reason for the flood, but there is enough data to suggest that

climate change is responsible for the increasing number of severe flash floods due to glacial melt. The flood was triggered by a massive rockslide just below Ronti peak, of ~22 mio m3 of rock mixed with ice and snow. The energy of the fall melted the ice creating the source of flood. This remobilized the debris and ice on the valley floor deposited by previous events, pushed the stream water and created an excessive flood wave.

- **Kedarnath Incidence:** During 16–17 June 2013, about a 600-km-long central segment of the Himalayan ranges witnessed unprecedented rainfall followed by flash floods in about 25 major snow-fed rivers and their tributaries, causing destruction on a scale not recorded ever before. These floods occurred in the period when Hindus all over India and neighbouring countries visit the four pilgrimages in Garhwal Himalaya. In this calamity thousands of people were killed due to massive landslides and flash flood triggered by very heavy monsoon rain and cloud burst. The entire region around Kedarnath shrine was washed away in Kedarnath valley due to very heavy monsoon rain (appx. 400 mm) precipitation in entire Uttarakhand. Flash flood damaged the buildings, temples, bridges, hydropower projects in Bhagirathi, Mandakini, and Alaknanda river valleys. (NIDM, 2018)
- **Leh floods** of 6 August 2010 occurred due to the torrential rains delivered to the region by a succession of meso-scale convective systems (MCSs; Houze 2004) moving over the region triggered extensive flash flooding and mudslides. Fatalities numbered 193, hundreds of persons were left missing, thousands were rendered homeless, and property and infrastructure experienced severe damage throughout the region. The average August rainfall for the city of Leh is 15.4 mm with record rain accumulation in 24 h set in 1933 at 51.3 mm (Indian Meteorological Department 2010). During the Leh flood event, various sources reported a 1½-h rain accumulation of 12.8 mm2 and 100 mm h–1 rain rates (http://blogs.wsj.com/indiarealtime/2010/08/06/lehs-flashfloods- how-much-did-it-rain/).

The causes of these disasters are related to mostly glacial lake outburst flood resulted from climate change issues. However, apart from climate change, the sudden spurt of environmentally-unfriendly development activities is responsible for the frequent occurrence of the disaster due to flash floods.

Prediction of Flash Flood

Flash floods represent different forecast and detection challenges because they are not always caused by meteorological phenomena. Flash floods result when favourable meteorologic and hydrologic conditions exist together. Although heavy rainfall is often necessary, a given amount and duration of rainfall may or may not result in a flash flood, depending on the hydrologic characteristics of the watershed where it is raining. Variables include:

- how quickly the storm is moving
- how intense are the rainfall rates
- whether storms are redeveloping and repeatedly impacting the same area (also known as “training echoes,” because the line of storms looks like a line of railroad cars moving over the same area, one after another)
- how much rainfall becomes surface runoff (and where it drains to)
- how porous the soil is and how much water it already holds
- the amount and type of vegetation covering the soil
- how much of the land surface is paved and won’t absorb water
- whether there are storm drains to effectively convey water out of the area
- how steep the terrain is
- whether the land has been impacted by recent wildfire
- depth and condition of snowpack

Forecasters can usually tell in advance when conditions are right for flash floods to occur, but there is often little lead-time for an actual warning. (By contrast, flooding on large rivers can sometimes be predicted days ahead). Scientists are working to understand the types of storms that have high precipitation rates and long duration, and to determine what factors can be used in forecast models and in forecast operations to help forecast floods. In order to evaluate the forecasting tools, scientists need observations of flash flooding. They assembled flash flood observations from USGS automated discharge measurements, trained spotter reports from the NWS, and from NSSL’s Severe Hazards Analysis and Verification Experiment (SHAVE). This database is available for community research purposes.

The MRMS Hydro-meteorological Tested Experiment (HMT-Hydro) is an ongoing summer experiment that began in 2014. The in-house experiment provides an opportunity to test out new approaches in flash flood forecasting. For a period of approximately 4 weeks, several National Weather Service forecasters participate during the week by using the experimental products in a real-time setting. They issue experimental flash flood watches and warnings throughout the day, and the research team and the forecasters subjectively evaluate the products the following day. The HMT-Hydro experiment has been successful in garnering essential feedbacks from eventual end-users, thus enabling the researchers to refine and optimize the products. The experiment also provides a rich environment for collaborations and forecaster training.

During the MRMS Hydro-meteorological Tested Experiment, researchers are investigating ways to increase flash flood lead times using ensemble rain forecasts from the Warn-on-Forecast system as inputs to FLASH. This will represent the world's first coupled atmospheric-hydrologic modelling system that explicitly forecasts the precipitation and concomitant hydrologic response down to minutes at flash flood scale. Another major paradigm change is being explored. Through the use of ensemble precipitation forecasts, researchers are also advancing the FLASH system forecasts from being deterministic to fully probabilistic. (https://www.nssl.noaa.gov/education/svrwx101/floods/forecasting/)

FLOOD: CONCEPTS AND DEFINITIONS

A flood (in Old English flood, a word common to Teutonic languages; compare German Flut, Dutch *vloed* from the same root as seen in flow, float) is an overflow of water, an expanse of water submerging land, a deluge. In the sense of 'flowing water', the world is applied to inflow of the tide, as opposed to the outflow or 'ebb'. Floodplains are, in general, those lands most subject to recurring floods situated adjacent to rivers and streams. Floodplains are therefore "flood-prone" and hazardous to development activities if the vulnerability of those activities exceeds an acceptable level.

Flooding is a natural and recurring event for river or stream. Statistically streams will equal or exceed the mean annual flood once every 2.33 years (Leopold, et.at 1964). Flooding is the result of heavy and continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of rivers, streams and coastal areas. This causes a watercourse to overflow its banks on adjacent lands. V. T. Chow defined flood as "a relatively high flow which overtakes the natural channel provided for run-off" Ward (1978) defined flood as "a body of water which rises to overflow land which is not normally submerged". Flooding involves spilling over of water in motion in the stream channel. Periodic spilling is not only normal for a stream but it is also a very welcome process. A river in flood distributes a large part of its suspended sediment load into the adjacent flood plains, thereby enhancing its fertility. A part of the sediment load also settles down on the banks of the river building up embankments called natural levees. A river will also flood when excessive siltation within the channel decreases its effective capacity to hold water.

FLOOD CHARACTERISTICS IN SOUTHERN PART OF WEST BENGAL

The rivers of the south-eastern part of the West Bengal are monsoonal in nature. Within Southern part of West Bengal, several distributary streams, of which the Bhagirathi-Hooghly is the most important, carry the water of the Ganga into the sea. Several tributaries, Pagla, Bansloi, Brahmani, Dwarka, Maurakshi, and Ajoy join the Bhagirathi from the west. The Damodar used to flow directly into the Bhagirathi-Hooghly channel in the past. At present, it flows into the tidal basin of the Rupnarayan. Other rivers joining the tidal basin are the Dwarkeswar, Silabati (Silai) and Kangsabati (Kasai). The rivers are subjected to severe floods during the monsoon season. In the last few decades, several large-magnitude floods have been recorded. In general, floods caused by precipitation from Bay of Bengal depressions include the peak flood of record. Comparative analyses of the systematic, historical, and palaeo-flood records indicate that, in recent decades, the frequency of high-magnitude floods has increased significantly. Floods in this region are responsible for colossal loss of human life, crops, and property. To understand flood hazards and environmental change it is imperative that engineers and hydrologists utilize historical and paleo-flood records to improve risk analyses as well as to estimate probable maximum flood on rivers such as these in a highly flood-prone region (Kron, 2005) of West Bengal.

Two factors are responsible for frequent flooding of the Bhagirathi and its associated stream channels. 1) Firstly, the catchment area of the Ganga, lying within the territories of India and Nepal, is exceptionally large (about a million square kilometers). All the major distributaries of this large catchment, however, lie within the Bengal delta, which is not more than 59,000 square kilometers in area. This large ratio is a major factor responsible for flooding of the rivers within the Bengal delta. 2) Another problem responsible for flooding is excessive siltation within the distributary channels. The average suspended silt content in the Bhagirathi is about 0.42 gm/litre. During rainy seasons, it may go up about 1.70 gm/litre in places. To add to the problem a large part of the silt accumulated at the mouth of the Bengal estuary is driven into the Hooghly channel by tidal current. The flow velocity during the ebb being less than that of the tide, a large part of this silt settles down within the Hooghly channel thereby reducing its effective cross-section.

Flood Prone Districts of Southern Part of West Bengal

West Bengal, a part of the Ganga delta has a long recorded history of flood. It is because the major part of land of the state is formed by the Ganga- Padma river system through the delta building process. Flood is an adjunct being the main carrier of sediments, the bulk of fluvial deposit, in huge volumes. At present 42.3% of the total area of the state is susceptible to flood spread over110 blocks in 18 districts. Among those districts which are very significantly flood prone can be shown as follows—

Significant Flood Prone Disctricts in West Bengal

Name of the flood prone districts	Area (Hectors)
Burdwan	1,70,000
Birbhum	3,82,500
Murshidabad	5,34,100
Nadia	3,90,000
Hooghly	2.54,900
Midnapore	78,000

Source: Paschimbanga, flood –2000: Information and Broadcasting Division, W.B

Among the mostly affected districts, Murshidabad is most prominent due to its vulnerability and location. Almost each and every year this district suffers from flood and creates landforms common to flood prone regions.

Impact of Flood of the Southern Part of West Bengal

In the state only five years could be identified as flood free years within last fifty years (1959 to 2009), when only less than 500sq.km of area were inundated. After last

1959 major flood, the state suffered consecutively in 1978, 1985, 1998, 1999 and 2000. In terms of loss of property and life, the 2000 flood was almost comparable to 1978 flood. Seventy two hours of continuous and concentrated rainfall over the western river basin areas of Bhagirathi viz. from the Pagla-Bansloi to the Ajoy, generated so huge flood volume that all embankments on the eastern side of the Bhagirathi were almost washed away and the whole of Nadia and larger part of Murshidabad were flooded and remained under water for a long period. In this trans-basin transfer of flood people were caught unaware and all sorts of speculative ideas was propagated (Chandan Roy, 2000).

Records of Large Floods in West Bengal

PERIOD	DESCRIPTION
1978	Major Flood
1986	Flooding due to heavy rains in some areas of Kolkata, Hooghly, Howrah, Parganas and Midnapore
1988	Monsoonal rains caused flooding in areas of Balurghat and Dinajpur lying under the purview of the Ganges and Churani rivers
1991	Flash floods caused damage 35,000 houses
1995	Flooding triggered by heavy rains caused erosion, severe agricultural damage and outbreak of diseases
1998	Monsoon rains caused flooding of the Ganges River
1999	Tropical cyclones caused destruction of an estimated number of 1500 villages. Floods due to brief torrential rains affected areas of Kolkata, Burdwan and Birbhum
2000	Besides flash floods triggered by incessant torrential rains, disaster is also accredited to the opening of sluice gates of dams. The fatalities counted to the tune of 1262, besides affecting millions of people.
2002	Flooding in Jalpaiguri, Cooch Behar and Jalpaiguri in north Bengal due to monsoonal rains. Flash floods swamped ten villages, causing four deaths and 11,000 displacements
2003	Monsoonal rains caused floods affecting the regions of Darjeeling, Jalpaiguri, Malda and Murshidabad

2004	Heavy monsoonal rains affected several districts
2005	Heavy rains caused floods in many areas. About 3000 coastal villages were inundated and 60,000 huts and many roads washed away.
2005	Heavy rains caused floods in many areas. About 3000 coastal villages were inundated and 60,000 huts and many roads washed away. Heavy monsoon rains triggered flash floods and landslides
2006	The regions of Birbhum, Burdwan and Murshidabad were affected mainly from continuous monsoonal downpour Monsoonal rains and tropical cyclone-driven storms in the Bay of Bengal hit India and Bangladesh. West Bengal recorded 50 deaths, 300 were injured and 30,000 mud houses destroyed. Heavy rains left large parts of Kolkata city under water; subsequently 2000 people were evacuated from the city.
2007	Heavy rain from tropical depression in the Bay of Bengal caused flooding leading to 51 deaths, and affecting 3.2 million people.
2013	Heavy rainfall & water release from various dams by DVC led to widespread flooding in the districts of Paschim & Purba Medinipur, Howrah, Hooghly, Bardhaman and Bankura Causing 17 deaths, 8790 villages affected, and affecting 2.1 miillion people

Source: West Bengal Disaster Management Department (WBDMD)

MANAGEMENT AND MITIGATION OF FLOODS AND FLASH FLOODS

According to the 'Climate change and India: A 4X4 assessment a sectoral and regional analysis for 2030s floods report', temperature rise in India would increase the frequency of flood events in India during the end of the 21st century (2071-2100). Further, the Himalayan belt is also projected to witness a significant rise in temperature up to 2.6 degrees Celsius. By the 2030s, the intensity is expected to increase by 2-12%. The report further stated that the temperature rise will result in multiplication of flash flood incidents leading to extensive landslides, which would bring extreme damage to the agricultural area thereby threatening the food security of the country. (https://newsonair.com/2022/10/06/flash-floods-the-causes-prevention-and-future/).

Sustainable Management of Flood

Flood is such a natural phenomenon that is uncontrolled and to some extent unpredictable. Man has been toiling for ages to control flood but all in vain. Geologically southern part of West Bengal is a part and parcel of Ganga-Brahmaputra delta, prone to flood almost each and every year. Flood damages all the geonomic aspects of the state and led to get poverty, illiteracy, starvation death and migration etc. In this state flood can be managed sustainably by different physical and socio-economic measures amongst which river channel improvement, proper and scientific reservoir control, construction of new barrages, lock gates, embankments, removal of human encroachment along the river side, flood warning and forecasting, stoking of essential services along with proper flood plain planning are indispensable. West Bengal floodplain is one of the most destructive floodplain in India. Owing to be the part of Ganga-Brahmaputra River's delta, the southern part of West Bengal is frequently affected by flood with unmanageable discharge. So proper and scientific management of flood and floodplains of West Bengal can reduce the damage of the state and can give the relief for human civilization.

Management of Flash Flood and Related Developments

In general the capacity to manage the risk of flash floods is low. ICIMOD has undertaken several initiatives targeted towards mitigation of the impact of flash floods including development of an inventory of glaciers and glacial lakes for a part of the Hindu Kush-Himalayan region. ICIMOD will continue to work in flash flood management in the region particularly in raising awareness towards flash flood, increasing capacity to manage the risk, and linking flash flood risk management with climate change adaptation. (https://lib.icimod.org/record/27767)

Most flash flood events take place in remote, isolated catchments where the central government's reach is limited or non-existent. When flash floods strike, external help may take several days to reach affected communities, during which time they are left to cope on their own. Technological advances and institutional arrangements for disaster risk management are gradually improving, but this process takes time. In areas where flash floods can be expected, it is essential to build the capacity of communities to manage the risks from disaster by themselves. Individual households usually have strategies in place, but the effectiveness of these individual efforts can be enhanced many-fold if they are coordinated.

1) Community risk management committee

A forum like a community flash flood risk management committee is a good mechanism for uniting the efforts of community members and local authorities. The use of local and indigenous knowledge can be an important part of community-based flash flood risk management.

2) Structural and non-structural measures

It is difficult to predict the exact location, magnitude, and extent of most flash floods, thus it is rarely useful to carry out **large-scale structural measures** like building of embankments, dams, and levees. But there are many **non-structural measures** that can help to reduce the impact of floods, ranging from land use planning, construction codes, and soil management and acquisition policies, through insurance, awareness raising, public information, and emergency systems, to post-catastrophe recovery plans. Such non-structural measures are generally sustainable and less expensive. **Small-scale structural measures** like check dams, small-scale levees using local materials, and sand bag embankments can also be useful. The best solution is usually a combination of small-scale structural and non-structural measures.

Structural and non-structural measures for flash flood risk management

Structural measures			Catchment-wide interventions (agriculture and forestry actions and water control work)
			River training
			Other flood control measures (passive control, water retention basins and river corridor enhancement, rehabilitation and restoration)
Non-structural measures	Risk acceptance	Tolerence strategies	Tolerance
			Emergency response system
			Insurance
	Risk reduction	Prevention strategies	Delimitation of flood areas and securing flood plains
			Implementation of flood areas regulations
			Application of financial measures
		Mitigation Strategies	Reduction of discharge through natural retention
			Emergency action based on monitoring, warning, and response systems (MWRS)
			Public information and education

Source: Colombo et al. (2002)

Roles of different groups in flash flood risk management

Central administration	River basin organisers	Provincial administration	Local adminstation	Household
• Develop national strategy • Create legal framework • Create financial mechanisms	• Long-term planning taking into account basin-wide conditions, development, and climate change scenarios • Create hazard/risk maps • Forecasting and dissemination of warnings	• Planning at provincial level • Implementing mitigation measures • Linkage between national and local (basin and catchment) levels	• Formation of community-based flash flood management organisation • Coordination with community-based organisations • Post-flash flood preparedness • Local level early warning system	• Securing household from flooding • Organising life at home • Preparing family for evacuation
Professionals/scientists	**Natl meteorological & hydrological services**	**Regional organisations**	**Private sector**	**Crisis management services**
• Support central administration in planning and strategy building • Prepare guidelines and practical solutions • Advice to government and academia • Capacity building at policy level	• Create early warning and dissemination system • Research	• Knowledge transfer • Capacity building • Transboundary dialogue • Cooperation facilitation	• Prepare action plan for damage minimisation • Ensure safety of equipment and structures • Insurance • Implementation of financial mechanisms	• Coordinate warning systems • Identify vulnerable groups and their needs • Planning response mechanisms • Post-flash flood activities
Spatial planners	**Academia**	**NGOs**	**Media**	
• Create spatial planning • Land zoning • Support regulation	• Flood education • Research support • Advice to government	• Awareness raising • Capacity building • Pressurise higher level • Post-event support	• Awareness raising • Exert pressure • Early warning • Post-event support and information dessemination	

Source: Adapted from APFM (2007)

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MODEL QUESTIONS:

1. What do you mean by 'hydro-hazards'? How many types of hydrological hazards are there? Give examples.
2. Discuss different types of Flood.
3. What is flash flood? Give a short note on the impacts of Flash Flood.
4. Describe the flash flood types found in Himalayan Region, its impact.
5. Give account of some major flash flood events occurred in Himalayan region.
6. How the prediction of flash flood is prepared in the Himalayan region?
7. Define flood. Illustrate the flood characteristics in southern part of West Bengal.
8. Discuss the management and mitigation measures of floods and flash floods.

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UNIT-7:

MOUNTAIN HAZARDS: LANDSLIDE AND AVALANCHE

INTRODUCTION:

Mountains and high ground occupy about 20% of the land, and approximately 10% of the Earth's population live in mountains. Great differences in altitude and significant energy potential of gravity, along with the important role of water in both liquid and solid phases, means that natural disasters are common phenomena in mountains. First of all, there are landfalls (faults) and landslides, mudflows and snow avalanches, glacier surges and floods. Landfalls and landslides are genetically and spatially interconnected.

The present module will discuss about the concept and types of mountain hazards, specially the landslides and avalanches, its causes and impact, prediction, mitigation and management etc.

MOUNTAIN HAZARDS

Natural hazards in the mountains are generally recognized as **Mountain Hazards** include large-scale hazards such as landslides, earthquake, avalanches, flash flood, mud flow, debris fall rock fall etc. A **geomorphic hazard** results from any landform or landscape change that adversely affects the geomorphic stability of a site or drainage basin (Schumm, 1988) and that intersects the human use system with adverse socio-economic impacts (White, 1974).

Frequent occurrences of hazards such as **landslides, snow avalanche**, floods and other types of mass wasting are becoming common features in mountainous regions. If there are no people affected, there is no hazard and if the landform or landscape is unchanged there is no geomorphic hazard. Barsch and Caine (1984) have described the distinctive relief typologies of major mountain systems. **Mountain geosystems** are not exceptionally fragile but they show a greater range of vulnerability to disturbance than many landscapes (Körner and Ohsawa, 2005) and their recovery rate after disturbance is often slow. During the past three decades, the world's population has doubled, the mountain regions' population has more than tripled and stresses on the physical and biological systems of mountain regions have intensified many fold. The combination of extreme geophysical events with exceptional population growth and land use modifications underlines the urgency of better understanding of these interactions and working out the implications for adaptation to and mitigation of the effects of drivers of change on landforms and landscapes. **Geomorphic or Mountain hazards** intensify and risks multiply accordingly.

TYPES OF MOUNTAIN HAZARDS

Hazards identification in high mountain areas involved intensive and lengthy fieldwork and mapping with the interpretation of landforms and its related hazards, compulsion of increasing intensity of land-use and careless application of technology leading to further land degradation. **Mountain Hazards** can be termed as **natural** (caused by natural occurrence) and **man-made** (caused by an individual, such as lack of preparation, carelessness, improper diet, equipment misuse). There are two kinds of hazards people face while operating in the mountains ie **Subjective and Objective**.

i. Subjective Hazards: Subjective hazards are created by human being themselves; for example, choice of route, companions, over exertion, dehydration, climbing above one's ability, and poor judgment-

a) Falling: Falling can be caused by carelessness, over-fatigue, heavy equipment, bad weather, over estimating one's ability, a hold breaking away, or other reasons.

b) Camp Site: Bivouac sites must be protected from rock fall, wind, lightning, avalanche run-out zones, and flooding (especially in gullies). If the possibility of falling exists, rope in, the tent and all equipment may have to be tied down.

(c) Equipment: Ropes are not total security; they can be cut on a sharp edge or break due to poor maintenance, vintage, or excessive use. You should always pack emergency and bivouac equipment even if the weather situation, tour, or a short climb is seemingly low of dangers.

ii. **Objective Hazards:** Objective hazards are caused by the mountain and weather and cannot be influenced by a person operating in mountains. Objective hazards are further classified as:-

(**a**) **Snow Group Hazards:** The difficulties offered by snow in snow bound and glaciated areas are called snow group hazards. Different snow group hazards are as follows:-

(i) Avalanche. Avalanche is a massive mass of unstable snow and / or ice that can come hurtling down a slope and brings with it snow, ice, rocks, soil, trees etc.

Avalanche is a dangerous and life threatening hazard in mountains, the chances of survival of an avalanche victim are estimated at 85% percent, if rescued within 15 minutes, 50% within 30 minutes, 20% within one hour.

(ii) Soft Snow. Excessive snow fall makes movement very difficult.

Movement on soft snow is very slow and tiring. Trugger shoes or skis can be used to move easily on soft snow.

(iii) Glaciers. Movement on glaciers is difficult especially while climbing the slopes. Ice axe and crampons are used to move in glaciers.

(iv) Crevasses. Crevasses are formed when a glacier moves over a slope and makes a bend, or when a glacier separates from the rock walls that enclose it. They can be very wide and deep making movement very difficult on glaciers. Crevasses can be crossed by constructing rope bridges or by launching a ladder.

(**b**) **Weather Hazards**:

i. Storm – Snow storm with powder snow can be deadly, it can choke life out of living being as he/she cant breathe in it. Can reduce the temperature rapidly.

ii. Temperature – Changes quickly, adequate and dry clothing required.

iii. Cloud –Visibility depleted, accidents can occur, loss of direction can happen in white out.

iv. Ultra-violate – Even on a cloudy day, wear goggles.

v. Wind chill factor – (Icy wind, need to keep soft parts / nose/ear/finger covered.

(c) Rock Group Hazards:

1. **Rock gap –** Gap between two rocks but not visible because of snow.
2. **Scree or Loose Slate –** dislodging one rock may lead to "scree chute" where one dislodged small stone dislodges other stones beneath it, the process continues, and heaps of stones/loose slate falls down the slope with massive momentum, leading to destruction.
3. **Verglass –** Thin layer of ice on rock surface generally at the early hours.
4. **Rockfall** (due to snowfall, melting of snow, earthquake or by animal) (https://jawaharinstitutepahalgam.com/mtn_hazards.php)

Tough these classifications, the foremost type of hazards which are very common phenomena in the mountains are none other than landslides and avalanches.

LANDSLIDES: CONCEPT AND CHARACTERISTICS

The word "landslide" (like the word "avalanche") means both the process leading to the event as well as the event itself. A landslide is a displacement of some of the rock on a slope, down to a lower level in a form of sliding motion, generally without loss of contact between moving and motionless rocks. A landslide starts as a result of breakdown of the slope stability and lasts until a new state of equilibrium has been reached. Any landslide process is irreversible. After the displacement a slope assumes new geometry and internal structure, and any repetition of a landslide cycle takes place in other rock mass in a new place.

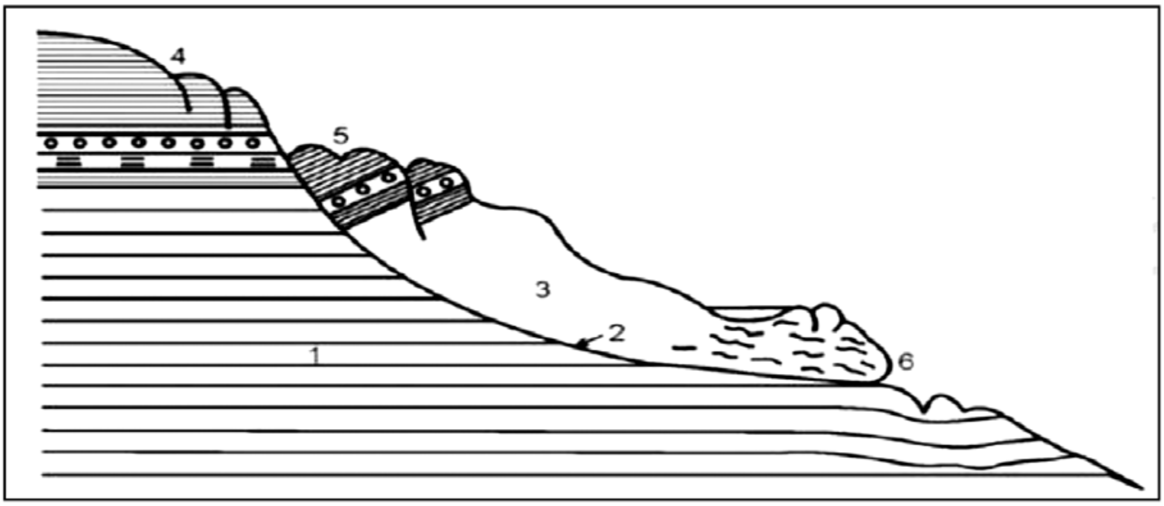
Origin of a Landslide

The progress of landslides and other gravitational processes, including stone falls, is conditioned by the relationship of slope steepness to thickness and composition of the weathering crust and other covering structures on the slope. The stability of slopes of homogeneous geological structure depends on the strength and density of the rocks, the height of the slope and its geometry, in particular, by its steepness.

Landslides occur on part of a slope due to disturbance of the rock equilibrium, caused by increase of slope steepness, resulting from water wash-down, weakening of the rock strength by weathering or over-moistening with rains and underground waters, effect of seismic shocks, building and economic activity carried out without taking into account the geologic structure of the region. Most often, landslides occur on slopes composed of alternating layers of clayey and water-bearing rocks. The landslide progress is also exacerbated by an arrangement of strata where the layers lie with their inclination towards the slope, or they are cut across by crevasses in the same direction. In strongly wetted clayey rocks, a landslide takes a form of a torrent.

Segments of a Landslide

Mountain rocks underlying the sliding surface of a landslide as well as the resulting relief are called the landslide “bed”. The lower part of a landslide body, adjacent to the sliding surface, as well as the surface limiting it from below is called the landslide “foot”. Isolated parts of a landslide have different names: the “head” is the upper part of a landslide body; the “tongue” is part of the sliding mass moving over a surface of separation, generally in the lower part of the landslide body.

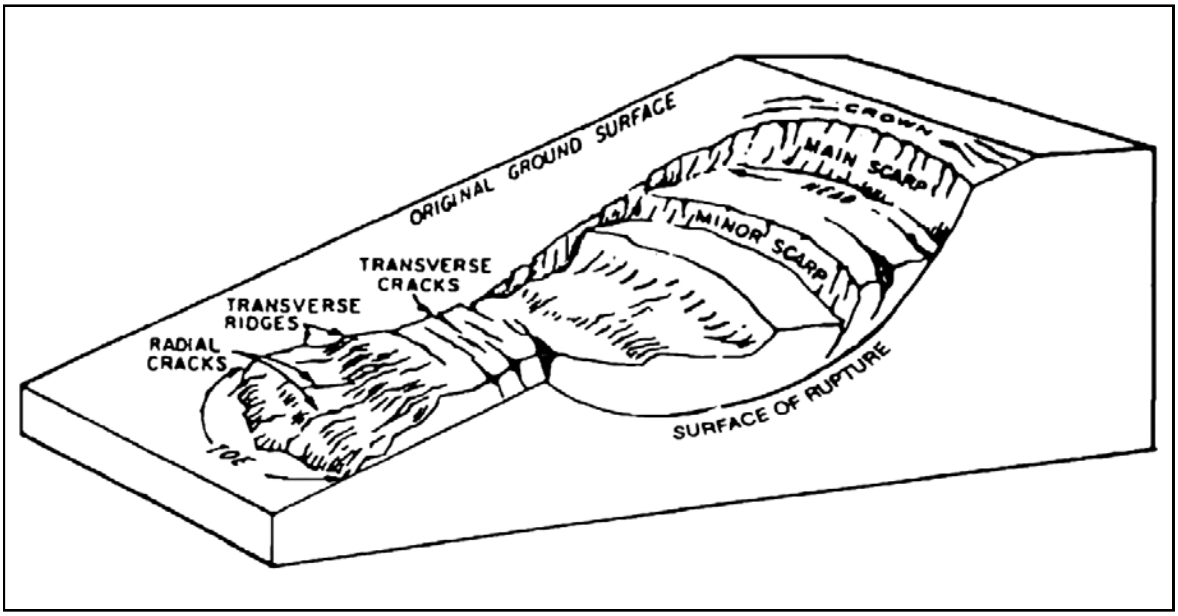


Longitudinal cross-section of a landslide: 1 is a bedrock massif; 2 is the landslide bed; 3 is the landslide body; 4 is edge (crest) of a separation; 5 is the head; 6 is the tongue; 7 is the foot

According to Nilson and Brabb (1972), landslide deposits are commonly characterized by one or more of the following features:

1. Small, isolated ponds, lakes, or other closed depressions;
2. Abundant natural springs;
3. Abrupt and irregular changes in slope and drainage pattern;
4. Hummocky irregular surfaces;

5. Smaller landslide deposits that are commonly younger and form within older and larger landslide deposits (in other words, if an area has slid ill the past, it is subject to both small and large renewed slides);
6. Steep, arcuate scarps at the upper edge;
7. Irregular soil and vegetation patterns;
8. Disturbed vegetation;
9. Abundant flat areas.



Parts of a complex (slump-earth flow) landslide (Nilsen and Brabb, 1972)
(https://people.wou.edu/~taylors/g473/Exercise_8_Landslides_and_Avalanches.pdf)

Classification of landslides

The classification is based on types of mountain rock movements. These are landfalls, overturn, landslides of slipping, extrusion, and streams (flows):

- under **landfalls**, a quantity of rock, of any size, is broken off from a steep slope or a scarp and falls down, bumping and jumping;
- **overturn** is the detaching, inclination and rotation of a rock block under the effect of gravity or the effect of water where there is a steep bedding of layers; their center of rotation is located below that of the center of gravity;

- **landslides** of slipping are characterized by shearing deformations and dislocations along one or several surfaces, and within the limits of a relatively low-power zone. The massif dislocated can be moved outside the limits of the initial surface of the break into the relief elements which become the boundary of the landslide foot;
- in **landslide-extrusions** a loosening, caused by a shear and cracks of expansion, takes place. As a result, various movements take place in a general spreading but no visible and well-pronounced basic surface of the displacement or zone of plastic deformations is observed. Overlying blocks of compact rocks can subside, slide, rotate, and break down, and become transformed into landslide flows under water encroachment;
- **Landslide-flows** in solid rocks are deformations scattered among many large and small cracks, or even micro-crevasses without a concentration of the displacement along one extensive break. These movements proceed extremely slowly and, obviously, at more or less the same speed. Landslide-flows can form folds, bends and other manifestations of plastic deformations. The speed distribution reminds a flow of a viscous liquid.

Continuous transition from sliding to avalanching of fragments takes place as the movement accelerates, being caused by the decrease of cohesion or increase of the water content and steepness of slopes. Landslides of fragmental mass sliding, and more rarely fragmental avalanches, can contain rotating landslide blocks in their frontal parts. When the fragmental masses slide down to the slope foot, the landslide separates into smaller parts, and the movement itself usually remains slow. In fragmental avalanches the progressing movement is fast, the displacing masses are diluted, and, at the least, they are partially transformed into a flow which rushes down a creek channel and can spread far from the slope foot.

Difference between Landslides and Avalanches

The main difference between landslide and avalanche is that landslides occur on land whereas avalanches occur on snow. Both landslide and avalanche refer to the movement of a large stationary mass under the force of gravity. These are very dangerous processes that can cause many damages and deaths.

Landslides Avalanches	
i. **A landslide is a form of mass wasting that includes the movement of a large area of land under the force of gravity**	i. An avalanche is a type of landslide that occurs in the snowy regions
ii. **Made of soil, rocks or mud**	ii. Made of snow and air
iii. **It occurs in land with steep slopes**	iii. it occurs in snowy regions where snow packs are weekly held with snow layers

Source: Landslide.” National Geographic Society, 9 Oct. 2012

In past years, there have been some serious and fatal landslides in India. Here is a list of worst landslides:

- **Guwahati landslide, Assam:** The landslide took place on September 18, 1948 due to heavy rains. Over 500 people died in the landslide and according to the reports, the landslide buried an entire village.
- **Darjeeling landslide, West Bengal:** The landslide happened around October 4, 1968. The landslide was triggered by floods and the 60 km long highway was cut in 91 parts. As per reports, thousands of people died in the landslide.
- **Malpa landslide, Uttarakhand:** Consecutives landslides occurred between August 11 and August 17 in 1998 in the village of Malpa where over 380 people died as the entire village washed away in the landslide. The landslide is one of the worst landslides in India.
- **Mumbai landslide, Maharashtra:** The landslide was caused in July 2000. The landslide took place in the suburbs of Mumbai due heavy rains which was followed by land erosion. As per reports around 67 people died and the local trains were also stricken.
- **Amboori landslide, Kerala:** The landslide was known as the worst landslide in Kerala’s history. The landslide occurred on November 9, 2001 due to heavy rains and around 40 people died in the incident.
- **Kedarnath landslide, Uttarakhand:** The landslide took place on June 16, 2013 and was the result of Uttarakhand floods. Over 5700 were reported dead and over 4,200 villages had been affected by the floods and post-floods landslide.

- **Malin landslide, Maharashtra:** The landslide occurred on July 30, 2014, in a village in Malin. The landslide occurred due to heavy rainfall and around 151 people died and 100 people went missing after the disaster.

AVALANCHES: CONCEPT AND CHARACTERISTICS

An **avalanche** is a rapid flow of snow down a slope, such as a hill or mountain. **Avalanche** is a type of landslide that occurs in snowy regions. Therefore, we can call it a snow-slide. Avalanches can be set off spontaneously, by such factors as increased precipitation or snowpack weakening, or by external means such as humans, animals, and earthquakes. Primarily composed of flowing snow and air, large avalanches have the capability to capture and move ice, rocks, and trees. This type of landslide occurs when a cohesive slab of snow that is lying upon a weaker layer of snow fractures and slides down a steep slope. Moreover, when an avalanche moves very fast, some of the snow mixes with air and forms a powder snow avalanche. It is a type of gravity current. (NIDSC).

Origin of an Avalanche

Primarily, an avalanche is composed of snow and air. But, upon the rapid growth of the snowpack, it has the ability to entrain trees, ice, rocks, etc. on the way.

The main cause of avalanche initiation is loss of snow stability on a slope due to overload of the slope following heavy snowfalls and snowstorms, and formation of weakened horizons within the snow thickness. Avalanches move with a speed of 40-50 *m*Å”*s*-1. Powder avalanches which are mixtures of dry snow and air of very low density are particularly dangerous as they are often accompanied by a destructive air wave. The distance travelled by an avalanche outburst varies from just tens of meters to 10-20 *km*.

In a zone of avalanche deposition, snow deposits of from 5 to 30 *m* thick may be formed. Great effort is expended in preventing and combating avalanches, and predicting avalanches.

The formation of the initial snowpack may occur due to the weakening of the snowpack on a snow layer or increased load due to precipitation. These avalanches are called spontaneous avalanches. In addition, an avalanche can also be initiated due to human activities and biological activities (natural reasons).

Types of Avalanches:

Avalanches occur in three general forms, the types of avalanches include **i) Slab Avalanche, ii) Loose Snow Avalanche and iii) Wet Snow Avalanche** etc. **Slab Avalanches** are made of tightly packed snow, triggered by a collapse of an underlying weak snow layer, and **Loose Snow Avalanches** made of looser snow. After being set off, avalanches usually accelerate rapidly and grow in mass and volume as they capture more snow. If an avalanche moves fast enough, some of the snow may mix with the air, forming a powder **Snow Avalanche**. (Louchet, 2021).

i) **Slab avalanche:** A slab avalanche occurs when a cohesive plate of snow (the slab) breaks away from its anchorage on the mountain and slides under the force of gravity. Typically, the slab will reach speeds quicker than fastest speed of the average skier within a few seconds and eventually travel at up to 80m/h, so it's very difficult to outrun. As the slab moves, it tends to break up into progressively smaller pieces of different sizes, ending up as a flow of jumbled fragments and debris.

ii) **Loose snow avalanches ("*sluffs*"):** As the name suggests, these are made up of loose snow that hasn't bonded into a slab or a cohesive layer. A Snow Avalanche is a snow mass rushing down with great velocity. Avalanches can arise in every place where the average thickness of snow cover exceeds 30-40 cm on slopes with steepness greater than 15° and a relative height differential greater than 40-50 m.

iii) **Wet snow avalanches.** These tend to occur in spring or in mild temperatures or after rain, and happen when water permeates the snowpack, causing the bonds between snow crystals to weaken. They tend to move more slowly than the dry slab avalanches mentioned above, and typically might reach speeds of up to 30mph. Due to the weight of snow and water involved they can be very destructive. A particular type of wet snow slide that is often seen late season in the Alps is the glide avalanche, where the whole depth of snowpack gradually slides downhill.

EFFECTS OF LANDSLIDES AND AVALANCHES

i. **Impact on the Economy:** Landslide and avalanches causes destruction of the property. Its rehabilitation and rebuilding cost millions.

ii. **Damages to infrastructure:** The force flow of mud, debris, and rocks as a result can cause serious damage to personal property and other significant infrastructures such as roads, railways, leisure destinations, buildings, and communication systems.

iii. **Loss of life:** Communities living at the foot of hills and mountains are at greater risk of these extreme events. Most of the disaster-prone areas are highly populated which makes lives more miserable.

iv. **Affects the beauty of landscapes:** The flow of mud, rock, and debris disturbs the natural sight or beauty of a place.

v. **Decline river ecosystems:** The substances landslide and avalanches carries with themselves block or hinder their natural flow. It causes a serious impact on many river habitats like fish as they can die due to interference with the natural flow of water.

vi. **Trigger Flood:** It can lead to the diversion of river water that can lead to flood in areas and loss of properties as well.

vii. **Impact on Livelihood:** Communities depending on the river water or coasts for household activities, livelihood, and irrigation will suffer from it.

viii. **Affect Development:** Landslides and avalanches make the development and other infrastructural projects risky as well as costly, which, in turn, adversely affect the developmental activities in these areas.

PREDICTION, PREPAREDNESS AND MITIGATION

In India, landslides occur frequently in the regions of Himalayas, Western Ghats, Eastern Ghats and other hill ranges like Vindhyas. The vulnerability to landslide hazards is a function of a site's location (topography, geology, and drainage), type of activity, and frequency of past landslides. The effects of landslides on people and structures can be lessened by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard zone activity.

In order to reduce fatalities and to protect villages and roads in mountains the attempt to **predict and prevent** avalanches is evident. Accurate avalanche prediction requires an experienced avalanche forecaster who often works both in the field to gather snowpack information and in the office with sophisticated tools such as remotely accessed weather data, detailed historical weather and avalanche databases, weather models, and avalanche-forecasting models. Avalanche forecasters combine their historical knowledge of past conditions with their knowledge of the affected terrain, current weather, and current snowpack conditions to predict when and where avalanches are most likely to occur. Such forecasting work typically takes place along mountain highways, adjacent to potentially affected villages. (https://ndma.gov.in/about-us/division/Mitigation)

The **preparedness** actions to deal with the disasters of landslides and snow avalanches are as follows:

i) Community Education and Awareness

ii) Preparation of Hazard Zonation Maps

iii) Relocating highly vulnerable settlements

iv) Strengthening of weak structures

v) Removal of likely blockages

vi) Creating adequate drainage

vii) Monitoring and Warning

viii) Community cooperation and vigilance

In addition to predicting avalanches, the procurement of a variety of techniques to reduce avalanche danger is required for the **mitigation**. Explosives are used to trigger avalanches on potentially unstable slopes so that the avalanches will occur when people are not endangered. Such avalanche control is particularly effective for vulnerable areas and highway corridors. In some areas prone to avalanches, particularly near villages and fixed structures, devices such as avalanche rakes (large reinforced fencing) are used on slopes to hold snow in place, and diversion structures such as dams or wedges are used at the base of the slope to stop, split, or deflect the snow in an avalanche. Though expensive, these defensive measures are common throughout the Alps, where numerous villages are found in areas known for dangerous avalanches. Instrumental monitoring to detect movement and the rate of movement is a major method to be implemented. The disrupted drainage pathways should be restored or reengineered to prevent future water build-up in the slide mass. It is necessary to establish proper grading and engineering of slopes, wherever possible. This will reduce the hazard considerably. Construction of retaining walls at the toe may be effective to slow or deflect the moving soil. (Sekhri, Simran et. al., 2020)

The following are the mitigation measures in brief points:

i. **Area-Specific Measures:** It is always advisable to adopt area-specific measures to deal with landslides and avalanches.

ii. **Restriction on the Construction in Certain Areas:** Restriction on the construction and other developmental activities such as roads and dams, limiting agriculture to valleys and areas with moderate slopes, and control on the development of large settlements in the high vulnerability zones, should be enforced.

iii. **Hazard Maps:** Hazard mapping to locate areas prone to landslides and avalanches. Hence, such areas can be avoided for building settlements.

iv. **Afforestation**: Some positive actions like promoting large-scale afforestation programs and the construction of bunds to reduce water flow.

v. **Terrace Farming:** Terrace farming should be encouraged in the north-eastern hill states where *Jhumming* (Slash and Burn/Shifting Cultivation) is still prevalent.

vi. **Landslide Monitoring and Early Warning System:** To warn people residing in landslide-prone areas in advance.

vii. **Scientific Technique Advancement:** Advancement in scientific techniques will empower us to understand what factors cause landslides and avalanches as well as how to manage them. (Gan, Binrui et. al., 2018)

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MODEL QUESTIONS:

1. What are the mountain hazards? Give some examples of mountain hazards.
2. Classify and discuss the types of mountain hazards.
3. What do you mean by landslides? Describe the characteristics of the landslides.
4. What are the segments of an ideal landslide discuss with figure.
5. Classify landslides and discuss. Differentiate landslide and avalanches.
6. Discuss the origin and types of avalanches.
7. State the effects of landslides and avalanches.
8. Mention the strategies for preparedness and mitigation of mountain hazards.

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UNIT-8:

NUCLEAR HAZARDS AND RADIO-ACTIVE CONTAMINATION

INTRODUCTION

Among the various other types of pollution, radioactive pollution is one of the most serious pollution in the earth. Nuclear hazards are threat posed by the invisible and odourless contamination of the environment by the presence of these volatile radioactive materials such as radio-nuclides in air water or soil.

This article is going to explore the concept of nuclear hazards and radio-active contamination in details. The module also will discuss the causes, effects, sources, prevention and management of radio – active contamination in addition to the nuclear hazards. The chapter will examine how radioactive pollution impacts human life as well as its repercussions on the environment.

RADIO-ACTIVE CONTAMINATION AND NUCLEAR HAZARDS

Radioactive or Nuclear pollution can be defined as the release of radioactive substances or high-energy particles into the air, water or earth mostly as a result of human activity, either by accident or by design. Sometimes natural sources of radioactivity, such as radon gas emitted from beneath the ground, are considered pollutants when they become a threat to human health.

A nuclear and radioactive contamination is defined by the **International Atomic Energy Agency (IAEA)** as "an event that has led to significant consequences to people, the environment or the facility. Examples include lethal effects to individuals, large radioactivity release to the environment, reactor core melt."

Radioactive contamination, also called radiological pollution, is the deposition of, or presence of radioactive substances on surfaces or within solids, liquids, or gases (including the human body), where their presence is unintended or undesirable (from the International Atomic Energy Agency (IAEA) definition). Such contamination presents a hazard because the radioactive decay of the contaminants produces ionizing radiation (namely alpha, beta, gamma rays and free neutrons). The degree of hazard is determined by the concentration of the contaminants, the energy of the radiation being emitted, the type of radiation, and the proximity of the contamination to organs of the body. It is important to be clear that the contamination gives rise to the radiation hazard, and the terms "radiation" and "contamination" are not interchangeable.

Radio-nuclides occur naturally in our environment. They are even found in human bodies and every day we ingest or inhale these radio-nuclides through air, water or food. Out of the known 450 radioisotopes only some are of environmental concern like strontium 90, tritium, plutonium 239, argon 41, cobalt 60, cesium 137, iodine 131, krypton 85 etc. These can be both beneficial and harmful, depending on the way in which they are used.

SOURCES OF NUCLEAR HAZARDS OR RADIOACTIVE POLLUTION

The sources of nuclear pollution include both natural and manmade sources. The human environment has always been radioactive and accounts for up to 85% of the annual human radiation dose. Radiation arising from human activities typically accounts for up to 15% of the public's exposure every year.

1. **Natural Sources:** Most radiation exposure is from natural sources. These include: radioactivity in rocks and soil of the earth's crust; radon, a radioactive gas given out by many volcanic rocks and uranium ore, cosmic radiations etc.

   a. **Cosmic rays from outer space-** The quantity depend on altitude and latitude; it is more at higher latitudes and high altitudes.

   b. **Emissions from radioactive materials in the Earth Crust** i.e. Rocks, Marine sediments etc.

2. **Man-Made Sources**: These sources involve any process that emanates radiation in the environment. While there are many causes of radiation pollution such as including research and medical procedures and wastes, nuclear power plants etc.

a. **Nuclear waste handling and disposal**: It may generate low to medium radiation over long period of times. The radioactivity may contaminate and propagate through air, water, and soil as well. Thus, their effects may not be easily distinguishable and are hard to predict. The main issue with the radiation waste is the fact that it cannot be degraded or treated chemically or biologically. Thus, the only options are to contain the waste by storing it in tightly closed containers shielded with radiation-protective materials (such as Pb) or, if containing is not possible, to dilute it. The waste may also be contained by storage in remote areas with little or no life (such as remote caves or abandoned salt mines). However, in time, the shields (natural or artificial) may be damaged. Additionally, the past waste disposal practices may not have used appropriate measures to isolate the radiation. Thus, such areas need to be carefully identified and access restrictions promptly imposed.

b. **Use of radioactive materials in Defence weapon production**: Nuclear weapon production may also release radiations from the handled radioactive materials (usually of high health risks). However, unless accident occurs, the current standards will not allow the release of any significant amount of radiation.

c. **Mining and processing of radioactive ores:** It involves the crushing and processing of radioactive ores and generates radioactive by-products. Mining of other ores may also generate radioactive wastes (such as mining of phosphate ores).

d. **Nuclear accidents:** explosion at Three Mile Island 1979 and Chernobyl 1986 nuclear-power plant accidents are the classic examples of radiation pollution from this type of source. Even accidents from handling medical nuclear materials/wastes could have radiation health effects on workers.

e. **Use of radioactive isotopes in medical, industrial and research applications:** The greatest exposure to human beings comes from the diagnostic use of X-rays, radioactive isotopes used as tracers and treatment of cancer and other ailments. (USNRC, 2017).

EXAMPLES OF NUCLEAR HAZARDS

The following is a list of major nuclear disasters of the world:

- **Chernobyl, Russia – 1986(INES Level 7):** The Chernobyl disaster is the worst nuclear power plant accident ever in terms of death toll and cost. The only other Level 7 accident happened on 26 April 1986 when a steam explosion destroyed reactor number four at the Ukrainian plant. Resulting fires spread huge amounts of radioactive waste across Western Europe, killing around 30 people from acute radiation poisoning in the immediate aftermath and raising long-term fears of increased instances of thyroid cancer. The World Nuclear Association says...”The nuclear disaster was the product of a flawed Soviet reactor design coupled with serious mistakes made by the plant operators.”
- **Fukushima, Japan – 2011(INES Level 7):** On Friday 11 March 2011 the Great East Japan Earthquake, which measured 9.0 on the Richter scale, caused a 15-metre tsunami that disabled the power supply and prompted three reactor meltdowns at the Fukushima Daiichi plant. Official figures suggest that more than 1,000 deaths occurred as a result of an evacuation process that displaced more than 100,000 people. Subsequent investigations have suggested that the infrastructure and risk forecasting were inadequate for such a devastating natural disaster. It was only the second accident in history to receive the most severe Level 7 rating.
- **Kyshtym Nuclear Disaster, Russia – 1957 (INES Level 6):** The third most serious nuclear accident in history happened at the secretive Mayak plant, near the Russian town of Kyshtym – part of the Soviet Union’s attempt to match the US for weapons-grade plutonium production. After a faulty cooling system was left to disrepair, rising temperatures resulted in an explosion with the equivalent force of 70-100 tons of TNT. Nuclear fallout reached more than 300 kilometres away and, due to the classified nature of the plant, it was only a week later that 10,000 locals were evacuated from the area.
- **Three Mile Island, US – 1979 (INES Level 5):** The Three Mile Island Unit 2 (TMI-2) reactor, near Middletown, Pennsylvania, suffered a partial melt down on March 28, 1979. The most serious accident in U.S. nuclear power

plant history was caused by a relief valve failure, after an unplanned shutdown, causing severe damage to the core. Better instrumentation, training programs and public information would have vastly improved matters but luckily there were no injuries or discernible health impacts. (Shellenberger, Michael. 2020)

- **Windscale Fire Nuclear Disaster, Sellafield, UK – 1957 (INES Level 5):** On 10 October 1957 a raging inferno swept through the core of Unit 1 nuclear reactor at Windscale, Cumberland (now Sellafield, Cumbria) for three days. The Level 5 accident dumped radioactive contamination across Europe and it is thought that traces of isotope iodine-131 may have caused several hundred cancer diagnoses. Windscale's two piles had been hastily built during the British atomic bomb project. It was the UK's worst ever nuclear accident. (International Atomic Energy Agency, 2005).

EFFECTS OF NUCLEAR HAZARDS OR RADIOACTIVE POLLUTION

Radioactive substances when released into the environment are either dispersed or become concentrated in living organisms through the food chain. Other than naturally occurring radioisotopes, significant amounts are generated by human activity, including the operation of nuclear power plants, the manufacture of nuclear weapons, and atomic bomb testing. Typically these effects can be of two types:

1. **Somatic effects:** Somatic affects the function of cells and organs of the individual exposed. It causes damages to cell membranes, mitochondria and cell nuclei resulting in abnormal cell functions, cell division, growth and death.
2. **Genetic effects:** Radiations can cause mutations, which are changes in genetic makeup of cells and effects the future generations also. These effects are mainly due to the damages to DNA molecules. People suffer from blood cancer and bone cancer if exposed to higher doses around 100 to 1000 roentgens. (Frank N. And Von Hippel. 2011)

These adverse health effects can range from mild effects, such as skin reddening, to serious effects such as cancer and death, depending on the amount of radiation absorbed by the body, the type of radiation, the route of exposure, and the length of time a person is exposed. Exposure to very large doses of radiation may cause death within a few days or months. Exposure to lower doses of radiation may lead to an increased risk of developing cancer or other adverse health effects. (Andrew C. Revkin, 2012)

Nuclear hazard effects on health can be either initial or residual.

A. **Initial effects** occur in the immediate area of explosion and are hazardous immediately after the explosion. The principal initial effects are **blast and radiation**.

   i) **Blast** causes damage to lungs, ruptures eardrums, collapses structures and causes immediate death or injury.

   ii) Thermal **Radiation** is the heat and light radiation, which a nuclear explosion's fireball emits producing extensive fires, skin burns, and flash blindness. Nuclear radiation consists of intense gamma rays and neutrons produced during the first minute after the explosion. This radiation causes extensive damage to cells throughout the body. Radiation damage may cause headaches, nausea, vomiting, diarrhoea, and even death, depending on the radiation dose received. (Report of UNSCEAR, 2008),

B. The **Residual Effects** can last for days or years and may lead to death.

All organisms are affected from radiation pollution, and the effects can vary from mild to extremely dangerous depending upon the various factors such as dose, duration and type of radiation. Some of the possible human health effects are listed as under:

   a. **Effects on DNA and Mutations:** Radiations may break chemical bonds, such as DNA in cells and cause mutations. This affects the genetic make-up and control mechanisms. The effects can be instantaneous, prolonged or delayed types. Even it could be carried to future generations.

   b. **General Physiological Effects:** Exposure at low doses of radiations (100-250 rads), men do not die but begin to suffer from fatigue, nausea, vomiting and loss of hair.

   c. **Effects on Immunity:** Exposure at higher doses (400-500 rads), the bone marrow is affected, blood cells are reduced, natural resistance and fighting capacity against germs is reduced, blood fails to clot, and the irradiated person soon dies of infection and bleeding.

d. **Effects on Tissues of Vital Organs:** Higher radiation doses (10,000 rads) kill the organisms by damaging the tissues of heart, brain, etc. **Hypothyroidism** may also be a radiation cause due to the destruction of thyroid gland by radioactive accumulated iodine.

e. **Occupational Diseases**: Few occupations that involve radioactive exposures are uranium mineworkers, radium watch dial painters, technical staff at nuclear power plants, etc. Exposure to radioactive and nuclear hazards has been clinically proven to cause cancer, mutations and ***teratogenesis*** (a prenatal toxicity characterized by structural or functional defects in the developing embryo or foetus).

f. **Effects through biomagnifications:** Through food chain also, radioactivity effects are experienced by man. E.g. Strontium 90 behaves like calcium and is easily deposited and replaces calcium in the bone tissues. It could be passed to human beings through ingestion of strontium-contaminated milk.

g. **Cancers:** Cancer generation is the most typical **health effect of radiation exposure**, especially when high or moderate amounts of radiation are involved (in general regardless of the exposure period). **Lung cancer** is a typical example of the effect of exposure to radon, which is the second leading cause of lung cancer in the U.S. Hasegawa, (Hasegawa, Arifumi. et al., 2015)

CONTROL OF NUCLEAR HAZARDS, PREVENTION AND MANAGEMENT:

Peaceful uses of radioactive materials are so wide and effective but also there is no cure for radiation damage. Thus the only option against nuclear hazards is to check and prevent radioactive pollution. Following are the ways to prevent or control these hazards:

a. Nuclear devices should never be exploded in air. If these activities are extremely necessary they should be exploded underground.

b. Leakages from nuclear reactors, careless handling, transport and use of radioactive fuels, fission products and radioactive isotopes have to be totally stopped.

c. Safety measures should be enforced strictly and strengthened against nuclear accidents.

d. There should be regular monitoring and quantitative analysis through frequent sampling in the risk areas.

e. Preventive measures should be followed so that background radiation levels do not exceed the permissible limits.

f. Appropriate steps should be taken against occupational exposure. Workers should wear protective garme nts and glass spectacles should be screened from radiation.

g. Waste disposal must be careful, efficient and effective. (Hugh, Gusterson. 2011)

☛ **Disposal of nuclear wastes**

Since nuclear waste can be extremely dangerous and, therefore, the way in which they are to be disposed of is strictly controlled by international agreement. Since 1983, by international agreement, the disposal in the Atlantic Ocean and into the atmosphere has been banned.

After processing, to recover usable material and reducing the radioactivity of the waste, disposal is made in solid form where possible. The nuclear wastes are usually classified into three categories:

a. **High Level Wastes (HLW):** High level wastes have a very high-radioactivity per unit volume. E.g. spent nuclear fuel. HLWs have to be cooled and are, therefore, stored for several decades by its producer before disposal. Since these wastes are too dangerous to be released anywhere in the biosphere, therefore, they must be contained either by converting them into inert solids (ceramics) and then buried deep into earth or are stored in deep salt mines.

b. **Medium level wastes (MLW):** Medium level wastes (e.g., filters, reactor components, etc.,) are solidified and are mixed with concrete in steel drums before being buried in deep mines or below the sea bed in concrete chambers.

c. **Low liquid wastes (LLW):** Low liquid wastes (e.g., solids or liquids contaminated with traces of radioactivity) are disposed of in steel drums in concrete-lined trenches in designated sites. (Jacobson, Mark Z. & Delucchi, Mark A. 2010)

In India, a Waste Immobilization Plant (WIP) was commissioned in 1985 at Tarapore. It verifies HLWs. The main objective in managing and disposing of radioactive (or other) waste is to protect people and the environment. This means isolating or diluting the waste so that the rate or concentration of any radio-nuclides returned to the biosphere is harmless. To achieve this for the more dangerous wastes, the preferred technology to date has been deep and secure burial. Transmutation, long-term retrievable storage, and removal to space have also been suggested.

- **Precautions after the disposal of nuclear waste:**

The careful, efficient and effective treatment/disposal of radioactive waste, just do not complete the task. A regular supervision of the disposal sites is must. The essential precautions, at the disposal sites, that have to be taken include:

i. Monitoring radioactivity around the disposal sites.

ii. Prevention of erosion of radioactive waste disposal sites.

iii. Prevention of any drilling activity in and around the waste disposal site.

iv. Periodic and long-term monitoring of such disposal sites and areas of naturally occurring uranium rich rocks.

(https://rcet.org.in/uploads/academics/rohini_27389077475.pdf)

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MODEL QUESTIONS:

1. State the radio-active contamination and nuclear hazards.
2. Discuss the sources of nuclear hazards.
3. Portray some major nuclear disasters of the world with level and occurrences.
4. Discuss in details the harmful effects of nuclear hazards on human health and the environment.
5. Mention the controlling measures of nuclear hazard prevention and management.
6. Illustrate the methods of disposal of nuclear wastes and precautions after the disposal of nuclear waste.

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UNIT-9:

PLASTIC HAZARDS

INTRODUCTION

Plastics are polymers i.e. large molecules consisting of repeating units called monomers. In the case of plastic bags, the repeating units are ethylene. When ethylene molecules are polymerized to form polyethylene, they form long chains of carbon atoms in which each carbon is also bonded to two hydrogen atoms. Plastic bags are made from one of the three basic types of polymers – polyethylene - High Density polyethylene (HDPE), Low Density Polyethylene (LDPE), or Linear Low-Density Polyethylene (LLDPE). Grocery bags are generally of HDPE, and bags from the dry cleaner are LDPE. The major difference between these materials is the degree of branching of the polymer chain. HDPE and LLDPE are composed of linear, un-branched chains, while LDPE chains are branched. The problem created by the use of plastics bags is primarily due to shortcomings in the waste management system. Indiscriminate chemical additives pose environmental problems including choking open drains, ground water contamination, etc.

The present chapter will deal with the types of plastics, plastic pollution or hazard, its causes, impact and strategies for the plastic waste management. The module also will discuss about the plastic wastes generated in India along with the Plastic Waste Management Rules (2016) in India.

TYPES OF PLASTICS

According to different studies the plastics are categorised in the following types (Abioye, O.P. et. al. 2018):

1.1. Natural plastics

They are natural substances which are classified as plastics due their property which permits them to be molten, moulded and shaped easily when subjected to heat. For instance, amber is a fossil pine tree resin that is commonly used in the production of jewellery.

1.2. Semi synthetic plastics

These are plastics obtained from the combination of natural materials with other substances. For instance, cellulose acetate is the product of reacting cellulose fibre with acetic acid which is widely applied in cinema film production.

1.3. Synthetic plastics

These types of plastics are obtained when the molecular structure of carbon-based materials such as coal, crude oil or gas undergoes decomposition or 'cracking' process. This process which involves the subjection of such materials to pressure and heat forms the basic procedure used in petrochemical refineries for manufacturing most of the plastics commonly found around today. There are two other categories of synthetic and semi-synthetic plastics. These are classified based on the manner or way a standard plastic material will react after heating.

1.4. Thermoplastics

The thermoplastics plastic materials, whose property allows to get soft and melt under heat and to be shaped or reshaped by taking the shape of a desired designed and mould when cooled. The most distinguishing property of thermoplastics is that when reheated they can molten again. Styrene's and acrylics are the most common and perhaps the largest occurring examples of thermoplastics which were discovered in school workshops.

1.5. Thermosetting plastics

Unlike thermoplastics, thermosetting plastics cannot be softened or molten when reheated, although at the first instance they will mellow and melt under high temperature. When molten they can be moulded into shapes into which they were placed before cooling but afterwards they become permanent in the shapes into which they were set and any attempt to further subject them to heat will only make them brittle or burn. The commonest examples of these plastics include polyester resins which are used largely for glass reinforced plastics work and those mostly employed in the manufacture of Formica for kitchen work surfaces such as melamine formaldehyde.

The Society of the Plastics Industry, Inc. (SPI) introduced its resin identification coding system in 1988 at the urging of recyclers around India. The seven types of plastic include:

1. Polyethylene Terephthalate (PETE or PET)
2. High-Density Polyethylene (HDPE)

3. Polyvinyl Chloride (PVC)
4. Low-Density Polyethylene (LDPE)
5. Polypropylene (PP)
6. Polystyrene or Styrofoam (PS)
7. Miscellaneous plastics (includes: polycarbonate, polylactide, acrylic, acrylonitrile butadiene, styrene, fiberglass, and nylon)

   (http://cpcb.nic.in/Plastic_waste.php)

PLASTIC WASTE GENERATED IN INDIA

According to the reports for year 2017-18, Central Pollution Control Board (CPCB) has estimated that India generates approximately 9.4 Million tonnes per annum plastic waste, (which amounts to 26,000 tonnes of waste per day), and out of this approximately 5.6 Million tonnes per annum plastic waste is recycled (i.e. 15,600 tonnes of waste per day) and 3.8 Million tonnes per annum plastic waste is left uncollected or littered (9,400 tonnes of waste per day). Out of the 60% of recycled plastic:

- 70% is recycled at registered facilities
- 20% is recycled by Unorganized Sector
- 10% of the plastic is recycled at home.

While these statistics are 38% higher than the global average of 20% there is no comprehensive methods in place for plastic waste management. Additionally, there is a constant increase in plastics waste generation. One of the major reasons for this is that 50% of plastic is discarded as waste after single use. This also adds to increase in the carbon footprint since single use of plastic products increase the demand for virgin plastic products. (http://cpcb.nic.in/Plastic_waste.php/)

PLASTIC POLLUTION

Plastic pollution is caused by the accumulation of plastic waste in the environment. It can be categorized in primary plastics, such as cigarette butts and bottle caps, or secondary plastics, resulting from the degradation of the primary ones. It can also be defined by its size, from microplastics - small particles (<5 mm) of plastic dispersed in the environment - to macroplastics.

Plastic pollution can take different forms including:

- The accumulation of waste
- The accumulation of marine litter, fragments or microparticles of plastics and non-biodegradable fishing nets, which continue to trap wildlife and waste
- Waste causing the death of animals by ingestion of plastic objects
- The arrival of microplastics and microbeads of plastics from cosmetic and body care products.

Globally, plastics demand rose from over 320 million tons in 2015 to more than 330 million tons in 2016 alone (Plastics Europe, 2017). Globally, plastic production was estimated to be 380 million tonnes in 2018. Since 1950 to 2018, plastics of about 6.3 billion tonnes have been produced worldwide, 9% and 12% of which have been recycled and incinerated, respectively. (www.wikipedia.com). Plastic waste is rapidly increasing its damage on all ecological systems and life (Kaza, S. Yao, L. and Bhada, P, 2018). Invariably, plastics have affected man’s daily living and its continued usage and production especially in most low-income nations is now worrisome, since they may not be able meet up with the advanced techniques of plastic waste management (Uwaegbulam, C. Et. al. 2018). Moreover, the qualities of plastics and durability that make them so unique have in turn become a disposal problem. For instance, when used plastic products are trashed into the environment, they endure for long time in the surrounding due to the fact that they are durable, while those thrown into water bodies continue to float on the surface because they are of low density (Hopewell, J. Et. al. 2009). Thus, the damage these wastes are getting to life and the ecosystem is increasing thereby causing severe environmental hazards such as water pollution, soil pollution and air pollution.

CAUSES OF PLASTIC POLLUTION

Since its commercial development in the 1950s, plastic has been a real success. Its global production is growing exponentially. Its success comes from its remarkable qualities: ease of shaping, low cost, mechanical resistance, etc. Being the ideal material for packaging, plastic is basically everywhere.

Negligence is the main cause. In fact, it is estimated that 80% of marine litter comes from land. This pollution comes mainly from household waste, which is poorly recycled, dumped in landfills or abandoned in nature. This waste is carried by the winds, pushed by the rains into sewers, streams, rivers, and finally in the oceans. Natural disasters such as floods must be considered as other causes of plastic pollution as well.

(http://cpcb.nic.in/Plastic_waste.php)

i. **Plastic is everywhere**, even on those items it may not expect it to be. Milk cartons are lined with plastic, water bottles are handed out everywhere, and some products may even contain tiny plastic beads. Every time one of these items gets thrown away or washed down a sink, the toxic pollutants have more of a chance to enter the environment and do harm. Trash dumps and landfills are unfortunate major problems, as they allow pollutants to enter the ground and affect wildlife and groundwater for years to come.

ii. **Plastic is Overused**, as plastic is less expensive, it is one of the most widely available and overused items in the world today. Rapid urbanization and population growth increase the demand of cheap plastics. Since it is an affordable and durable material, it is utilized in every other way possible, from packaging materials to plastic bottles and containers, straws to plastic carry bags. Also because they're so cheap, we have a disposable mentality. We don't value them to hang on to individual items. When disposed of, it does not decompose easily and pollutes the land or air nearby when burned in the open air.

iii. **Plastic takes 400 years and even more to decompose**. The chemical bonds that make-up plastics are strong and made to last. The decomposition rate of plastic typically ranges from 500 to 600 years, depending on the type. According to the EPA (Environmental Protection Agency), in the US, every bit of plastic that ever made and sent to landfills or dumped in the environment still exists.

iv. **Burning plastic is incredibly toxic** and can lead to harmful atmospheric conditions and deadly illnesses. Therefore, if it is in a landfill, it will never stop releasing toxins in that area. Even recycling doesn't cut down on plastic, as it essentially uses the existing plastic, albeit in a new form. The process of recycling plastic can also lead to plastic irritants being released in a number of ways.

Many a time waste is transported by the winds. Plastic, which is very light, even gets blown away in gentle winds and carried away by the rains into sewers, streams, rivers, and finally, in the oceans. Besides, natural disasters such as floods should also be considered as other causes of plastic pollution.

IMPACT OF PLASTIC HAZARD

The WHO published shocking research in 2018 that exposed the presence of micro-plastics in 90% of bottled water, the test of which revealed only 17 were free of plastics out of 259. We absorb plastic through our clothes, 70% of which are synthetic and worst fabric for the skin. (Report of WHO, 2018). Plastic carry bags are manufactured using organic and inorganic additives like colourants and pigments, plasticizers, antioxidants, stabilizers and metals.

- **Colourants and pigments** are industrial azodyes which are used to give bright colour to plastic carry bags. Some of these are carcinogenic and likely to contaminate food stuffs, if packed in these carry bags. Heavy metals such as Cadmium contained in pigments can also reach out and prove to be a health hazard.
- **Plasticizers** are organic esters of low volatile nature. They can migrate to food stuffs as a result of leaching. Plasticizers are also carcinogenic.
- **Antioxidants** and Stabilizers are inorganic and organic chemicals to protect against thermal decomposition during manufacturing process.
- **Toxic metals** like cadmium and lead when used in manufacturing of plastic bags also leach out and contaminate the food stuffs. Cadmium when absorbed in the low doses can cause vomiting and heart enlargement. Lead exposure in long term may cause degeneration of brain tissues.

Plastic bags if not disposed properly may BE fatal for the environment:

i) It May find their way into the drainage system resulting into choking of drains, creating unhygienic environment causing water borne diseases and water pollution.

ii) Recycled /coloured plastic bags may contain certain chemicals, which can leach to the ground and contaminate soil and sub-soil water and soil pollution.

iii) Units not equipped with environmentally sound techniques for recycling may create environmental problems due to toxic fumes generated during reprocessing and affect the air quality.

iv) Some of the plastic bags which contain leftover food or which get mixed up with other garbage are eaten by animals resulting in harmful effects and disturb the ecological structure.

v) Because of the non-biodegradable and impervious nature of plastics, if disposed in the soil, they could arrest the recharging of ground water aquifers and increase water scarcity.

vi) Burning plastic is incredibly toxic and can lead to harmful atmospheric conditions and air pollution.

Further, to improve the properties of plastic products and to inhibit degradation reactions, additives and plasticisers, fillers, flame retardants and pigments are generally used, these may have health impacts.

STRATEGIES FOR PLASTICS WASTE MANAGEMENT

The reality is that the only way this problem can be addressed is by individuals and companies around the world, agreeing to implement practices that reduce waste on every level.

i. Thin plastic bags have little value and their segregation is difficult. If the thickness of plastic bags is increased, it would make plastic bags expensive and check their usage.

ii. The plastic Manufacture Association and rag pickers could also be involved in the waste collection and disposal system.

iii. Littering of Plastic carry bags, water bottles, plastic pouches have been a challenge for municipal solid waste management.

iv. Instead of plastic bags everyone should carry reusable bags, many of which fold up compactly to be portable and eco-friendly. Therefore, to carry a bag and always reuse plastic bags as much as possible is an important regular practice for everyone today.

v. People should reduce the use of plastic water bottles as these are only recommended for single-use as these are made from polyethylene terephthalate (Pet) it takes over 400 years to decompose naturally. The best practice is to carry a reusable metal bottle in bag for daily use.

Plastic Waste Management Rules (2016) in India

In India, 17 States / Union Territories have imposed complete ban on manufacture, stock, sale and use of plastic carry-bags, through directions/notifications and executive orders. Further, use of plastic carry bags has been partially banned in some pilgrimage centres, tourist and historical places which are located in the States of Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Gujarat, Karnataka, Odisha, Tamil Nadu, West Bengal, Uttar Pradesh and Uttarakhand etc.

The Government has notified Plastic Waste Management Rules, 2016, which regulate manufacture, sale, distribution and use of plastic carry bags including carry bags of compostable plastic, and plastic sheets for packaging or wrapping applications. The use of carry bags made from conventional plastic with thickness less than 50 micron is prohibited. The use of plastic for packaging *gutkha*, tobacco and *pan masala* is also prohibited.

As per the provisions of Plastic Waste Management Rules, 2016, the generators of waste have been mandated to take steps to minimize generation of plastic waste, not to litter the plastic waste, ensure segregated storage of waste at source and handover segregated waste to local bodies or agencies authorised by the local bodies. The Rules also mandate the responsibilities of local bodies, gram *panchayats*, waste generators, retailers and street vendors to manage the plastic waste. The rules mandate the producers, importers and brand owners to work out modalities for waste collection system based on Extended Producer Responsibility. The Bureau of Indian Standards (BIS) has notified 10 standards on biodegradable plastics. Alternatives to Plastic is the use of jute or cloth bag as alternatives to plastic paper bag should be popularized and prompted through fiscal incentives; however, it needs to be noted that paper bag involve cutting of trees and their use is limited. Ideally bio-degradable plastic bags alone should be used and research work is going on to develop biodegradable plastics. (https://pib.gov.in/newsite/erelease.aspx?relid=58057).

To reduce and ban the plastic use in day to day life, the Govt. and NGOs also should adopt policies and programmes to raise the awareness among the citizens. Proper campaigning and implementing regulations against the use of harmful plastics only can check the overuse. The following steps are very important:

- **a.** **Reduce**: To efficiently reduce plastic pollution, there is an evident need of reducing our usage of plastic. It means changing our everyday behaviours of not using plastic.
- **b.** **Reuse**: Plastic may cause pollution when poorly managed but it has lots of advantages too, such as being resistant. Many plastic items can therefore be reused or used for different purposes. Before throwing plastic items, it is important to consider how they can be reused.
- **c.** **Recycle**: Plastic recycling consists of collecting plastic waste and reprocessing it into new products, to reduce the amount of plastic in the waste stream.
- **d.** **Educate**: Another crucial solution is education in order to increase awareness and behavioural change.

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MODEL QUESTIONS:

1. How many types of plastics are found in general? Why the plastics are hazardous to the nature?
2. Give a short note on plastic pollution and its causes and increase in the world.
3. Describe the impact of plastic hazard on human health and the environment.
4. Discuss the strategies for plastics waste management with special reference to India.

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UNIT-10:

ARSENIC CONTAMINATIONS IN DELTAIC BENGAL

INTRODUCTION

Arsenic contamination in groundwater in the *Ganga- Brahmaputra* fluvial plains in India and *Padma-Meghna* fluvial plains in Bangladesh and its consequences to the human health have been reported as one of the world's biggest natural groundwater calamities to the mankind. (http://cgwb.gov.in/documents/papers/incidpapers/Paper%208%20-%20Ghosh.pd).

Arsenic toxicity in groundwater affecting major parts of the southern West Bengal is a stupendous environmental problem. Arsenic is a naturally occurring trace element in the environment, because of its geogenic origin and causes a natural disaster (Biswas et al., 2019). This calamity is well known as "the largest poisoning of a population in history" by the World Health Organization (WHO) (Bhattacharya et al., 2010; Smith et al., 2000).

This chapter will represent arsenic contamination, causes, effects and status of this contamination in deltaic Bengal. Further it will discuss about the mitigation and management strategies.

ARSENIC CONTAMINATION

Arsenic is a metalloid and its compounds exist in four forms, that is, crystalline, powder, amorphous and vitreous (Dhillon, 2020; Gomez-Caminero et al., 2001). Arsenic is a natural element of the Earth's crust and exists at usual levels of 2 mg per kg of earth's crust. [In comparison Iron levels in earth's crust is 4.09 grams/100 grams of crust] (Dhillon, 2020; Gomez-Caminero et al., 2001).

Arsenic is usually found in trace amounts in rock, air, water and soil. Though, in a few zones, arsenic can be found in toxic levels because of natural circumstances and anthropogenic actions (Dhillon, 2020; Tchounwou et al., 2012). It is highly toxic in its inorganic form. Arsenic (As) is introduced into soil and groundwater during weathering of rocks and minerals followed by subsequent leaching and runoff. It can also be introduced into soil and groundwater from anthropogenic sources. People are exposed to elevated levels of inorganic arsenic through drinking contaminated water, using contaminated water in food preparation and irrigation of food crops, industrial processes, eating contaminated food and smoking tobacco. Long-term exposure to inorganic arsenic, mainly through drinking-water and food, can lead to chronic arsenic poisoning. Skin lesions and skin cancer are the most characteristic effects. (https://www.who.int/news-room/fact-sheets/detail/arsenic#)

The World Health Organization recommends limiting arsenic concentrations in water is up to 10 ìg/L, although this is often an unattainable goal for many problem areas due to the difficult nature of removing arsenic from water sources. (www.who.int.).

Sources of Arsenic Exposure

i) Drinking-water and food: The greatest threat to public health from arsenic originates from contaminated groundwater. Inorganic arsenic is naturally present at high levels in the groundwater of a number of countries, including Argentina, **Bangladesh**, Cambodia, Chile, China, **India**, Mexico, Pakistan, the United States of America and Viet Nam. Drinking-water, crops irrigated with contaminated water and food prepared with contaminated water are the sources of exposure.

Fish, shellfish, meat, poultry, dairy products and cereals can also be dietary sources of arsenic, although exposure from these foods is generally much lower compared to exposure through contaminated groundwater.

ii) Industrial processes: Arsenic is used industrially as an alloying agent, as well as in the processing of glass, pigments, textiles, paper, metal adhesives, wood preservatives and ammunition. Arsenic is also used in the hide tanning process and, to a limited extent, in pesticides, feed additives and pharmaceuticals.

iii) Tobacco: People who smoke tobacco can also be exposed to the natural inorganic arsenic content of tobacco because tobacco plants can take up arsenic naturally present in the soil. The potential for elevated arsenic exposure was much greater in the past when tobacco plants were treated with lead arsenate insecticide.

SOURCES OR CAUSES OF ARSENIC CONTAMINATION

The arsenic contamination can be classified into two broad classes:

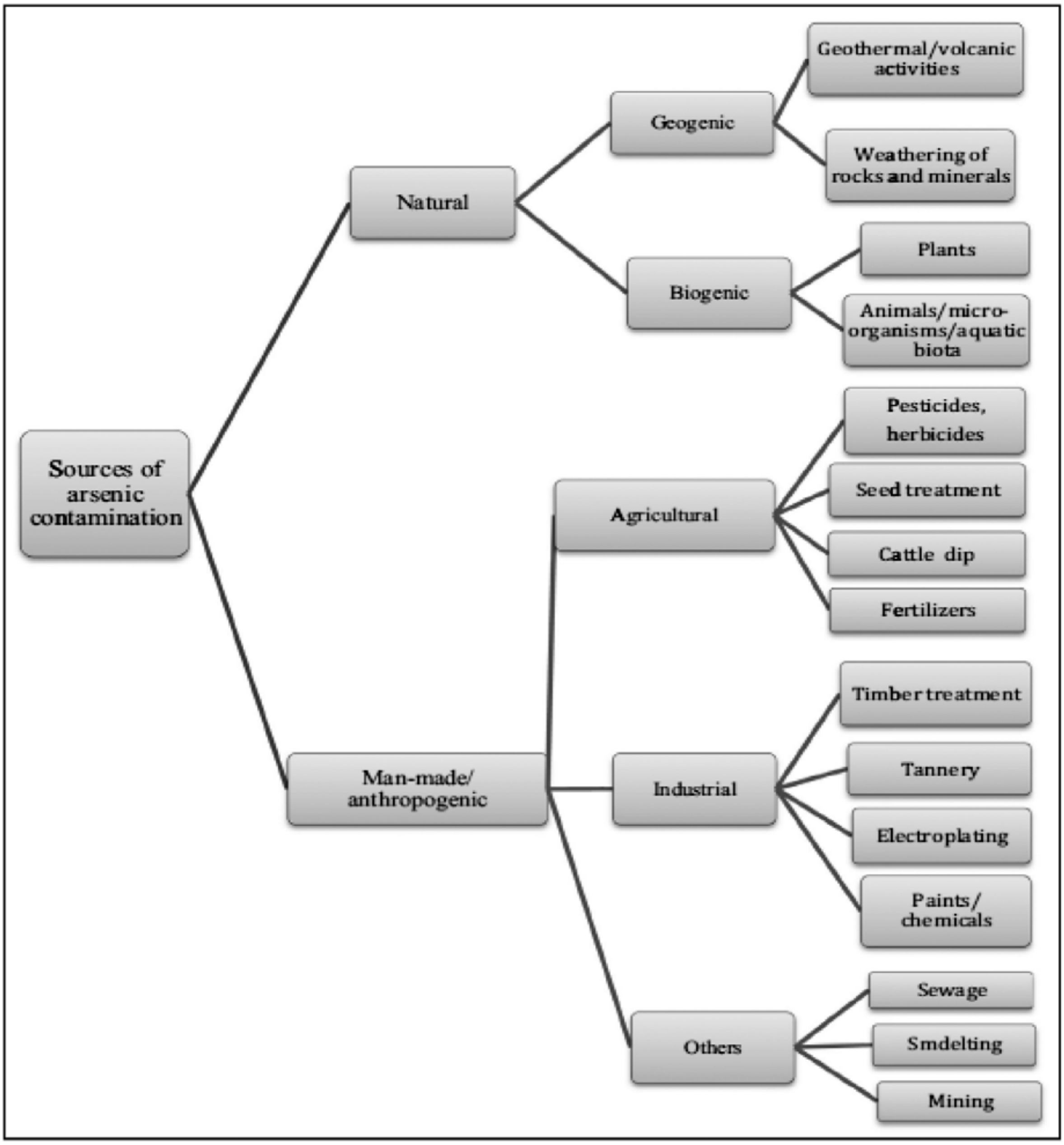
a. Natural Sources and

b. Man Made Sources

a) According to DPHE, BGS (2000), the **Natural Sources of Arsenic Pollution** are sulfide and oxide minerals. Transportation of sediments and pyrite oxidation has been recognized to be the cause of release of sulfates and arsenic in this region. However, sulphates are rapidly lost in the sea, in the form of salt, and arsenic is ingurgitated by iron oxides, which has increased over the years in the delta region. The alluvial deposits beneath the floodplains of four major rivers, namely, *Ganga, Brahmaputra, Meghna,* and *Tista,* are the worst-affected aquifers (Hossain, 2006). Hydrogeochemistry and arsenic contamination of groundwater in *Haor* basin, Bangladesh was studied by Tanvir et al. (2012). According to this report, arsenic is released into groundwater through dissolution and is facilitated by microbial degradation of organic matter. Bhattacharya et al. (1997) had reported the same findings, where arsenic was released by desorption from ferric hydroxide minerals in the aquifer sediments under reducing conditions.

b) There are two main hypotheses suggested by scientists about the **Man Made Sources**, according to Chakraborti et al. (2013), about the origin of arsenic in groundwater in the Bengal delta (Bagla and Kaiser, 1996). In the first hypothesis, arsenic is derived from the oxidation of arsenic-rich pyrite in shallow aquifers, as a result of lowering of the water table due to over abstraction of groundwater for irrigation (Mallick and Rajgopal, 1996).

The second hypothesis clarifies the “reduction hypothesis,” in which the reduction of arsenic-rich iron-oxides results from increased oxygen demand possibly related to human disturbances or buried compost (McArthur et al., 2001). Numerous industrial practices release arsenic into the environment, such as metal mining, steel production, coal combustion, manufacturing of paints and varnishes, cement production, pharmaceutical industries, etc. (Hossain, 2006).



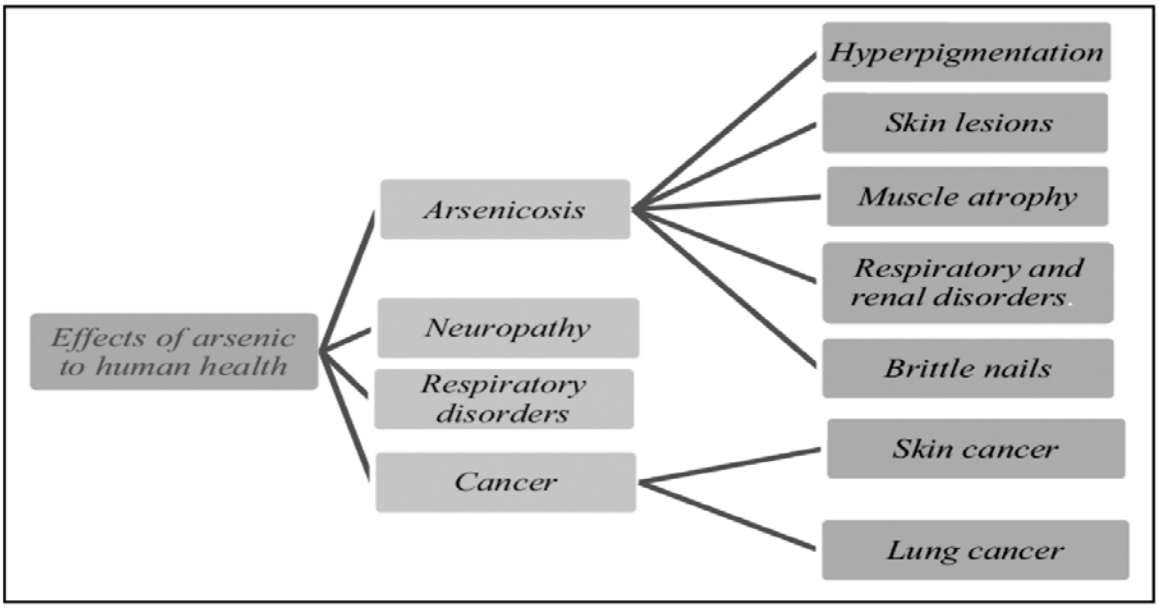
Causes of Arsenic Contamination

ARSENIC CONTAMINATION IN DELTAIC BENGAL

It was reported by Roychowdhury (2008) that one of the severest natural disasters of the world is arsenic pollution, which has been recognized in the Bengal delta. The Bengal basin is located along the Indo-Bangladesh border and encompasses major parts of Bangladesh and some parts of eastern and north-eastern India (comprising states such as West Bengal, Tripura, and Assam). The Bengal basin is well known as the largest fluvial-deltaic region of the world (Alam et al., 2003). This region is surrounded by the world's largest origin, the Himalayas to the north and the world's largest submarine fan, the Bengal fan to the south.

The Bengal basin is drained by the *Ganges*, *Brahmaputra*, and *Meghna* river systems and is thus also known as the *GangesBrahmaputraMeghna* (GBM) plain with an expansion of 569,749 km2 and a population of over 500 million. These residents are being exposed to toxic levels of arsenic through their drinking water and daily dietary intake. The state of the Bengal delta is extremely poor, with more than 100 million inhabitants living in areas with arsenic levels exceeding 0.05 mg/L (Roychowdhury, 2008; Chowdhury et al., 2000; Chakraborti et al., 2002). Over 50 districts in Bangladesh and 9 districts in West Bengal, 85 blocks, and nearly 3500 villages have been well documented as having groundwater arsenic levels exceeding 0.05 mg/L (Roychowdhury, 2008; Chakraborti et al., 2002; Rahman et al., 2005). Tube wells installed for potable water are free of waterborne diseases but have toxic levels of arsenic contamination.

During 1980's some cases of skin disorder in the districts of North 24 Parganas, South 24 Parganas, Nadia, Murshidabad and Burdwan were report from where it is



(https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Programs/DWEHD/Water-Well-Construction/Arsenic-in-Well-Water.pdf) known that the disease is due to use of arsenic contaminated groundwater. Out of the twenty districts in West Bengal, 9 districts Malda, Murshidabad, Nadia, North-24-Parganas, South-24-Parganas, Bardhaman, Howrah, Hoogly and Kolkata are affectedby arsenic contaminated groundwater (Fig. 1). Ground water having higher concentration of arsenic generally occurs within 20 – 80 M depth zone (Das, D., 1996). In West Bengal more than 26 millions of people are potentially at risk for drinking arsenic contaminated water.

CONSEQUENCES OF ARSENIC CONTAMINATION

The way arsenic affects our bodies is not fully understood. **Long-term exposure** to low levels of inorganic arsenic in drinking water is known to cause human health problems including: cancer, thickening and discoloration of the skin, problems with blood vessels, high blood pressure, heart disease, and nerve effects including numbness and/or pain, and interference with some important cell functions.

Short-term exposure to very high levels of arsenic may cause stomach pain, nausea, vomiting, diarrhea, headaches, weakness, and even death. There is some evidence that suggests that long-term exposure to low levels (e”0.005 milligrams/liter (mg/L)) of arsenic from drinking water may result in lower IQ scores in children. A urine test will indicate if anyone has been exposed to arsenic at levels of concern.

Arsenic groundwater contamination has far-reaching consequences including its ingestion through food chain which are in the form of social disorders, health hazards and socio-economic dissolution besides its sprawling with movement, and exploitation of groundwater.

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MODEL QUESTIONS:

1. What do you mean by the arsenic contamination in ground water?
2. What are the sources of arsenic exposure? Mention the sources or causes of the arsenic contamination.
3. Describe the status of arsenic contamination in deltaic Bengal.
4. Discuss the long-term and short-term impact of arsenic exposure.

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UNIT-11:

FLUORIDE CONTAMINATIONS IN WESTERN PART OF WEST BENGAL

INTRODUCTION:

Fluoride (F) becomes toxic when it occurs in drinking water beyond the maximum permissible limit of 1.5 ppm. (WHO, 1984) Chronic exposure to fluoridated ground or drinking water creates a health problem not only in human beings (Choubisa SL., 2012) but also in diverse species of domestic animals in the form of osteo-dental *fluorosis* (Choubisa SL., 2013). Recently, bio-indicators of endemic *fluorotoxicosis* due to fluoridated ground water have been reported.

The following chapter will throw some light on the issues related to the fluoride contaminations in western part of West Bengal, its occurrence, factors control high fluoride concentration in ground water,

OCCURRENCE AND DEVELOPMENT

In India, several states are endemic for *hydrofluorosis* due to the high F content in drinking water. It is well known that F contamination is present in the ground water in the western part of West Bengal (Birbhum, particularly Nalhati, Bankura, Purulia, parts of Midnapore, and Bardhaman districts). (Gupta S et. al., 2006)

The occurrence and development of endemic *fluorosis* have its roots in the high fluoride content in water, air, and soil of which, water is perhaps the major contributor (Gupta et al., 2005). The World Health Organization (WHO) has recommended an upper limit at 1.50 mg/L for fluoride in the potable water (WHO, 2011), whereas, the Bureau of Indian Standards (BIS, 1992) suggested the permissible limit of fluoride in drinking water has to be 1mg/L. However, in India, the *fluorosis* is observed at the concentration of more than 1.20mg/L and dental caries at the concentration of less than 0.60 mg/L in the drinking water (ISI, 1983). Due to larger societal implication and major human concern, it is therefore crucial to understand the origin and distribution of fluoride in groundwater. Fluoride is important for tooth and bone formation.

The main source of fluoride for human body is usually drinking water while, other sources are food and air. Research has shown that a concentration of 1mg/litre of fluoride in drinking water reduce tooth decay. But oral intake of fluoride more than 1.5 mg/litre results in different types of diseases. According to BIS (Bureau of Indian Standards, 1991) and ICMR (Indian Council of Medical Research, 1975), the highest desirable limit of fluoride is specified at 1.0 mg/l and the maximum permissible limit is 1.5 mg/l. Fluoride pollution in drinking water is a public health problem. Fluoride is known to cause diseases like dental *fluorosis*, skeletal *fluorosis*, Alzheimer's disease, dementia, abnormal thyroid function and other hormonal disturbances.

FACTORS OF FLUORIDE CONCENTRATION

Three key factors control high fluoride concentration in groundwater, viz. (i) paleoclimatic: increased dry deposition during the arid climatic regime and weaker monsoon, (ii) geogenic: high fluoride content in aquifer matrix, evaporation of stagnant water and its subsequent infiltration to underground, and (iii) anthropogenic: brick kilns, industries, fertilizers and aquifer leakage due to groundwater extraction, etc. (Todd, 1980; Handa, 1975; Bardsen et al., 1996; Gosselin et al., 1999).

Moreover, the characteristics of aquifers, like porosity and acidity of soils and rocks, temperature (Abu Rukah and Alsonkhny, 2004; Jacks et al., 2005), groundwater age, well depth, hydrologic condition, residence time (Kim and Jeong, 2005), low calcium concentration and high sodium and bicarbonate concentrations (Handa, 1975; Rao et al., 1993; Kundu et al., 2001; Smedley et al., 2002; Edmunds and Smedley, 2005; Vithanage and Bhattacharya, 2015) may also controls the fluoride concentration in groundwater. In addition, the fluoride enrichment in shallow groundwater may also linked with the influence of contaminated river in the region (Li et al., 2016a,b). Therefore, among all these factors, the climatic/geographic location of an area is one of the critical factors thatmay affect the fluoride concentration in groundwater. As a matter of fact, most of the regions affected by endemic fluorosis geographically correspond to warm, arid/semi-arid climate. For example, the dry region in the western part (Rajasthan and Gujarat) and the interior part of southern India witnessed high fluoride concentration in groundwater (Gupta et al., 2005).

FLUORIDE FACTS IN WEST BENGAL

In West Bengal, excess fluoride in groundwater has been detected so far in 43 blocks spread over seven districts, viz. Purulia, Birbhum, Bankura, Malda, South

Dinajpur, North Dinajpur and South 24-Parganas. Fluoride-contaminated groundwater was first detected in West Bengal in 1997. Exceedances were noted in the Nasipur area of Nalhati I block in the district of Birbhum, after which the government took rapid action to provide an alternative water supply based on river-bed tube wells from River Tripita.

The Geological Survey of India (GSI) undertook a follow-up study during 1999–2000 covering an area of some 600 sq. km of West Bengal in order to determine the scale and cause of contamination. Fluoride problems were found to be mostly associated with tube wells abstracting from basaltic rocks of the Rajmahal Traps (http://www.wbphed.gov.in). Shear zones in Precambrian rocks were also found to be associated with high-fluoride groundwater in parts of Purulia and Bankura districts. Dug wells, ponds, and shallow tube wells tapping alluvium had low fluoride concentrations (<1.5 mg/L). (PHED, 2008)

A fluoride committee constituted by PHED with the involvement of several organizations, instigated a rapid assessment of fluoride in groundwater sources across West Bengal in 2003. The survey covered 107 blocks in 12 districts and found fluoride concentrations exceeding 1.5 mg/L in groundwater from 43 blocks in seven districts (PHED, 2013). Subsequent testing of all hand-pumped tube wells in the 43 blocks found 3.88% exceeding the acceptable government standard.

Blocks in West Bengal Affected by Fluoride at Concentrations >1.5 mg/L

District	Fluoride-affected blocks	No. blocks
Bankura	Bankura II, Barjora, Chhatna, Gangajalghati, Hirbandh, Indpur, Raipur,Saltora, Simlapal, Taldangra	10
Birbhum	Khoyrasol, Mayureswar I,Nalhati I, Rajnagar, Rampurhat I, Sainthia, Suri II	7
Dakshin Dinajpur	Bansihari, Gangarampur, Kumarganj, Kushmundi, Tapan	5
Malda	Bamangola, Ratua II	2
Purulia	Arsha, Bagmundi, Balarampur, Barabazar, Hura, Jaipur, Jhalda I, Kashipur, Manbazar I, Neturia, Para, Puncha, Purulia I, Purulia II, Raghunathpur I, Raghunathpur II, Santuri	17
S 24 Parganas	Baruipur	1
Uttar Dinajpur	Itahar	1
Total		**43**

Source: Government of West Bengal, Public Health Engineering Department 2013.

Data from the PHED shows that as of August 2016, an estimated 615,000 people in the state were affected by fluoride >1.5 mg/L. Interventions by PHED to reduce fluoride exposure in the affected districts have resulted in the provision of piped water supplies in Birbhum, Dakshin Dinajpur, and Purulia. (PHED, 2016)

District	No. habitations	Total population	Affected habitation	Affected population	% population affected
Bankura	6,638	3,403,362	43	30,570	0.90
Birbhum	4,335	3,416,742	51	55,671	1.60
Dakshin Dinajpur	4,788	1,480,800	701	251,917	17.00
Maldah	7,787	5,717,269	4	2,110	<0.05
Purulia	4,363	2,802,601	229	245,900	8.80
Uttar Dinajpur	3,687	2,672,341	18	28,985	1.10
Total	**31,598**	**19,493,115**	**1046**	**615,153**	**3.20**

Source: Government of West Bengal, Public Health Engineering Department. Integrated Management Information System (IMIS). August 2016 data.

A high degree of seasonal variability has been observed in fluoride concentrations. In 40% of the groundwater samples, fluoride concentrations higher than the WHO-prescribed permissible limit for drinking water have been detected during pre-monsoon season. However, the fluoride concentration in all samples remains within the WHO-prescribed limit during post-monsoon season.

Prominent seasonal variation in fluoride concentration may result in categorizing a well as “contaminated” if sampled during pre-monsoon and “uncontaminated” if sampled during post-monsoon. Thus, a systematic seasonal sampling is required before marking a well as contaminated or uncontaminated and declaring an area as affected, unaffected, or severely affected. The decrease in fluoride concentration during post-monsoon season is attributed to dilution of groundwater with the percolating rainwater.

MITIGATION AND MANAGEMENT

In order to mitigate the rising problem of *fluorosis*, fluoride free, safe drinking water to the rural communities of Western part of West Bengal, is to be ensured. Along with fluoride free water, nutritional supplement should be added. The following action plan is suggested as a holistic alternative to mitigate the rising *fluorosis* problem:

- ☐ Household treatment of excess fluoride by using fluoride removal filter
- ☐ River water based piped water supply from Kangsabati river and other small streams
- ☐ Rainwater harvesting
- ☐ Use of traditional water sources (bunds/ponds) after treatment
- ☐ Extensive water quality monitoring programme
- ☐ Diagnosis and treatment of fluorosis
- ☐ Nutritional supplement of calcium, vitamin C, E and D
- ☐ Changes of food habit adding calcium, vitamin C, D rich food avoiding of chewing supari, gutka etc
- ☐ Awareness, motivation and training of the community

Since the average annual rainfall in the area is around 1400 mm, rain water harvesting for conservation and through artificial recharge to ground water may be attempted for augmentation of ground water. Sites for artificial recharge structures through *nullah bunding*, gully plugging, and renovation of tanks / ponds, abandoned dug wells etc., can be selected. Roof top rainwater harvesting technique may also be adopted in some schools on experimental basis.

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MODEL QUESTIONS:

1. What do you mean by fluoride contamination? State the occurrence and development of the fluoride contamination in West Bengal.

2. Identify the key factors controlling high fluoride concentration in ground water and give details.

3. Mention the names of the districts of West Bengal affected by the fluoride contamination. Give the present status of the contamination in West Bengal.

4. Discuss the measures for the mitigation of rising *fluorosis* problem.

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UNIT-12:

ROLE OF NATIONAL DISASTER MITIGATION AGENCY FOR MANAGEMENT OF HAZARDS AND DISASTERS

INTRODUCTION

National Disaster Management Authority (NDMA) is an organization of Government of India, with an authorization to set down policies for disaster management. NDMA was established through the Disaster Management Act enacted by the Government of India on 23 December 2005. NDMA is responsible for framing policies, laying down guidelines and best-practices for coordinating with the State Disaster Management Authorities (SDMAs) to ensure a holistic and distributed approach to disaster management (NDMA, 2006).

EVOLUTION OF NDMA

Emergence of an organization is always through an evolutionary process. NDMA has also gone through the same stages. The Government of India (GOI), in recognition of the importance of Disaster Management as a national priority, set up a High-Powered Committee (HPC) in August 1999 and a National Committee after the Gujarat earthquake, for making recommendations on the preparation of Disaster Management plans and suggesting effective mitigation mechanisms. The Tenth Five-Year Plan document also had, for the first time, a detailed chapter on Disaster Management. The Twelfth Finance Commission was also mandated to review the financial arrangements for Disaster Management.

On 23 December 2005, the Government of India enacted the Disaster Management Act, which envisaged the creation of National Disaster Management Authority (NDMA), headed by the Prime Minister, and State Disaster Management Authorities (SDMAs) headed by respective Chief Ministers, to spearhead and implement a holistic and integrated approach to Disaster Management in India.

The National Disaster Management Authority (NDMA), headed by the Prime Minister of India, is the apex body for Disaster Management in India. Setting up of NDMA and the creation of an enabling environment for institutional mechanisms at the State and District levels is mandated by the Disaster Management Act, 2005.

India envisions the development of an ethos of Prevention, Mitigation and Preparedness. The Indian government strives to promote a national resolve to mitigate the damage and destruction caused by natural and man-made disasters, through sustained and collective efforts of all Government agencies, Non-Governmental Organizations and People's participation. This is planned to be accomplished by adopting a Technology-Driven, Pro-Active, Multi-Hazard and Multi-Sectoral strategy for building a Safer, Disaster Resilient and Dynamic India.

VISION OF NDMA

The vision of NDMA is "To build a safer and disaster resilient India by a holistic, pro-active, technology driven and sustainable development strategy that involves all stakeholders and fosters a culture of prevention, preparedness and mitigation."

ORGANISATION STRUCTURE

The National Disaster Management Authority has been constituted under the Disaster Management Act 2005, with the Prime Minister of India as its Chairman-; a Vice Chairman with the status of Cabinet Minister, and eight members with the status of Ministers of State. With well-defined functional domains for each of its members and concern to carry out the mandated functions, NDMA has evolved into a lean and professional organization which is IT-enabled and knowledge based. Skills and expertise of the specialists are extensively used to address disaster related issues. A functional and operational infrastructure has been built, which is appropriate for disaster management involving uncertainties coupled with desired plans of action.

Conceptually, the organization is based on a 'disaster divisions-cum-secretariat' system. Each member of the Authority heads disaster-specific divisions for specific disaster and functional domains. Each member has also been given the responsibility of specified states and UTs for close interaction and coordination.

The NDMA Secretariat, headed by a Secretary, is responsible for providing secretarial support and continuity. The Secretariat deals with mitigation, preparedness, plans, reconstruction, community awareness and financial and administrative aspects.

NDMA also has the National Disaster Management Operations Centre which will be equipped with a state-of-the-art resilient and redundant communication systems, NDMA also carries out the tasks of capacity development, training and knowledge management. (https://www.drishtiias.com/printpdf/national-disaster-management-authority-ndma-)

FUNCTIONS AND RESPONSIBILITIES

NDMA is mandated to lay down the policies, plans and guidelines for Disaster Management to ensure timely and effective response to disasters. Towards this, it has the following responsibilities:-

- Lay down policies on disaster management;
- Approve the National Plan;
- Approve plans prepared by the Ministries or Departments of the Government of India in accordance with the National Plan;
- Lay down guidelines to be followed by the State Authorities in drawing up the State Plan;
- Lay down guidelines to be followed by the different Ministries or Departments of the Government of India for the Purpose of integrating the measures for prevention of disaster or the mitigation of its effects in their development plans and projects;
- Coordinate the enforcement and implementation of the policy and plans for disaster management;
- Recommend provision of funds for the purpose of mitigation;
- Provide such support to other countries affected by major disasters as may be determined by the Central Government;
- Take such other measures for the prevention of disaster, or the mitigation, or preparedness and capacity building for dealing with threatening disaster situations or disasters as it may consider necessary;

- Lay down broad policies and guidelines for the functioning of the National Institute of Disaster Management.

POLICY

The National Policy framework has been prepared after due deliberation and keeping in view the National Vision to build a safe and disaster-resilient India by developing a holistic, proactive, multi-disaster and technology-driven strategy for DM. This will be achieved through a culture of prevention, mitigation and preparedness to generate a prompt and efficient response during disasters. The entire process will centre-stage the community and will be provided momentum and sustenance through the collective efforts of all government agencies and Non-Governmental Organizations.

In order to translate this vision into policy and plans, the NDMA has adopted a mission-mode approach involving a number of initiatives with the help of various institutions operating at the national, state and local levels. Central ministries, States and other stakeholders have been involved in the participatory and consultative process of evolving policies and guidelines.

This Policy framework is also in conformity with the International Strategy for Disaster Reduction, the Rio Declaration, the Millennium Development Goals and the Hyogo Framework 2005-2015. The themes that underpin this policy are:-

- ✓ Community-based disaster management, including last mile integration of the policy, plans and execution.
- ✓ Capacity development in all related areas.
- ✓ Consolidation of past initiatives and best practices.
- ✓ Cooperation with agencies at the national, regional and international levels.
- ✓ Compliance and coordination to generate a multi-sectoral synergy.

NDMA (National Disaster Management Authority) runs various programs for mitigation and responsiveness for specific situations. These include the National Cyclone Risk Management Project, School Safety Project, Decision Support System and others. India Disaster Response Summit held on 9 November 2017 held at New Delhi. This Summit was jointly organised by the National Disaster Management Authority (NDMA) and social networking site *Facebook*. India has become the first country to partner with *Facebook* on disaster response.

ORGANISATIONS FOR DISASTER MANAGEMENT IN INDIA

- **National Disaster Management Authority (NDMA):-**The National Disaster Management Authority, or the NDMA, is an apex body for disaster management, headed by the Prime Minister of India. It is responsible for the supervision, direction and control of the National Disaster Response Force (NDRF).
- **National Executive Committee (NEC):-**The NEC is composed of high profile ministerial members from the government of India that include the Union Home Secretary as Chairperson, and the Secretaries to the Government of India (GoI)like Ministries/Departments of Agriculture, Atomic Energy, Defence, Drinking Water Supply, Environment and Forests etc. The NEC prepares the National Plan for Disaster Management as per the National Policy on Disaster Management.
- **State Disaster Management Authority (SDMA):-**The Chief Minister of the respective state is the head of the SDMA.The State Government has a State Executive Committee (SEC) which assists the State Disaster Management Authority (SDMA) on Disaster Management.
- **District Disaster Management Authority (DDMA):-** The DDMA is headed by the District Collector, Deputy Commissioner or District Magistrate depending on the situation, with the elected representatives of the local authority as the Co-Chairperson. The DDMA ensures that the guidelines framed by the NDMA and the SDMA are followed by all the departments of the State Government at the District level and the local authorities in the District.
- **Local Authorities:-**Local authorities would include Panchayati Raj Institutions (PRI), Municipalities, District and Cantonment 11 Institutional and Legal Arrangements Boards, and Town Planning Authorities which control and manage civic services.

(https://www.drishtiias.com/printpdf/national-disaster-management-authority-ndma-)

CONCLUSION

The National Disaster Management Authority (NDMA) appears to be an apex agency of the Indian government in charge of disaster management policy formulation. NDMA is in charge of developing framing policies (the national framing policies were developed following extensive consideration and by the National Vision to establish a comprehensive, proactively, multi-disaster, or technology-driven strategy for DM to build a safe and disaster-resilient India.), standards, and best practices for working with State Disaster Management Authorities (SDMAs) to guarantee a comprehensive and dispersed disaster response.

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MODEL QUESTIONS:

5. What is the full form of NDMA? Discuss the evolution of NDMA.
6. Describe the structure, functions and responsibilities of NDMA as an active organization.
7. What are the policies taken by NDMA in the Rio Declaration, the Millennium Development Goals?
8. Mention the names of some organisations for disaster management in India

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SELF ASSESSMENT TESTS

1. Distinguish between natural and man-made disasters.
2. Classify the disasters and discuss the types. Give examples of disasters in India.
3. Classify different types of hazards and discuss. Give the Truncated WHO Classification of hazards.
4. Find out the relationship between capacity, resilience, resistance and sensitivity.
5. Differentiate social and physical vulnerability. Give a short note on social vulnerability.
6. Discuss the different approaches and methods of risk and vulnerability assessment in disaster management.
7. What is disaster risk management cycle? Evaluate the disaster risk management framework according to UNISDR.
8. Give a short note on Indian cyclones with the description of cyclone prone states of India.
9. What is climate refugee? Describe the tropical cyclone forecast system in India.
10. Describe the characteristics of tsunami. Establish the link between earthquake and tsunamis.
11. Mention the components of a Tsunami Warning System in India. Discuss the tsunami precautions and mitigation plan in details.
12. What is flash flood? Describe the flash flood types found in Himalayan Region. Give an account of some major flash flood events occurred in Himalayan region.
13. Discuss the management and mitigation measures of floods and flash floods.
14. Classify landslides and discuss. Differentiate landslide and avalanches. Discuss the origin and types of avalanches.
15. Discuss the sources of nuclear hazards. Portray some major nuclear disasters of the world with level and occurrences.

16. Illustrate the methods of disposal of nuclear wastes and precautions after the disposal of nuclear waste.
17. Describe the impact of plastic hazard on human health and the environment. Discuss the strategies for plastics waste management with special reference to India.
18. Describe the status of arsenic contamination in deltaic Bengal. Discuss the long-term and short-term impact of arsenic exposure.
19. What do you mean by fluoride contamination? Mention the names of the districts of West Bengal affected by the fluoride contamination. Give the present status of the contamination in West Bengal.
20. Mention the names of some organisations for disaster management in India Describe the structure, functions and responsibilities of NDMA as an active organization.

SUMMARIES AND KEY POINTS

The entire volume may be summaries with emphasising some important key points:

i. The concepts and definition of the disaster and hazards along with the minute differences in between natural and manmade disasters have been discussed ;

ii. The concept of risk and vulnerability, the types of vulnerability, different terminologies of disaster such as capacity, resilience, resistance and sensitivity etc. along with their interlinkages have been analysed ;

iii. The concept of risk reduction, hazard reduction, disaster risk reduction, disaster risk management, analyses of risk and vulnerability, types of disaster risk management, disaster risk management vs. disaster management, different aspects of disaster risk management cycle as a part of disaster risk management framework have been illustrated with suitable diagrams;

iv. Concept of climatic hazards, types and causes are studied in chapter four. Specially the tropical cyclone, it's formation, characteristics, classification, naming, cyclone hazard in India, tropical cyclone forecast or prediction system along with cyclone warning system have been covered here.

v. Marine hazards are classified into several types, although most important marine hazard is known as tsunamis. The origin, causes of generation and characteristics of tsunami is discussed here with suitable figure. The linkage between tsunami-earthquake has been encountered, tsunamis in India along with prediction, precaution and mitigation strategies are key points illustrated in the chapter five.

vi. Chapter six emphasizes the hydrological hazards and their types among which the flash flood and flood are most significant. The concept, occurrences and impact of flash flood in the Himalayan Region is the thrust area of this part. The floods in the southern part of West Bengal, it's stretch, impact and mitigation approaches have been taken into consideration.

vii. The mountain hazards are of several types in the high altitudes. Here the landslides and avalanches, origin, Classification, different segments of landslides, difference between landslides and avalanches, prediction, preparedness and mitigation strategies have been analysed.

viii. Chapter eight deals with nuclear hazards, its harmful effects, the sources of nuclear hazards or radioactive pollution and finally the control of nuclear hazards, prevention and management.

ix. The chapter nine deals with the plastic hazards, different types, and plastic waste generated in India causes of plastic pollution, impact and strategies for plastics waste management.

x. Arsenic pollution in deltaic West Bengal is now-a-days a matter of concern. The sources of arsenic exposure, fatalities and causes behind the pollution are the key points of discussion in this part.

xi. Fluoride contamination is also widespread phenomenon in the regime of ground water. It is localised in the western part of West Bengal. Factors of Fluoride concentration, its occurrence and development is studies in details with emphasis on the management and mitigation steps.

xii. The agency involved in the mitigation of natural disaster as well as manmade disasters in India is NDMA. The vision, structure, functions and responsibilities of NDMA is considered and well interpreted. Other organisations also play important role in management and mitigation of disasters at different levels.

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