CONCEPTS OF HAZARDS, DISASTERS AND HAZARD ASSESSMENT

Goals

- To instill an understanding of the concepts of hazards, multiple hazards and disaster
- To develop the capability for hazard assessment

Learning outcomes

After completing this session, you will be able to perform a hazard identification and assessment for a selected community.

Learning objectives

As you work through this session you will learn to

- ✓ Distinguish between the concepts of hazard, hazard event, secondary hazards, multiple hazards and disaster
- ✓ Classify and describe types of hazards
- ✓ Explain hazard characteristics such as magnitude, frequency, intensity and rate of onset and their importance
- ✓ Conduct hazard identification, hazard assessment and hazard mapping and explain their functional value

Keywords/phrases

Hazard

natural
man-made
technical
na-tech
human
intervention

magnitude
frequency
intensity
rate of onset

classification

identification
assessment
mapping

Multiple hazards

1. Definition of Hazard

"Those elements of the physical environment, harmful to man and caused by forces extraneous to him" (Burton et al 1978).

Standards Australia (2000) defines a hazard as

'A source of potential harm or a situation with a potential to cause loss.'

A natural event that has the potential to cause harm or loss.

-ADPC

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A **Hazard** is a threat. A future source of danger. It has the potential to cause harm to

- People - death, injury, disease and stress
- Human activity – economic, educational etc.
- Property - property damage, economic loss of
- Environment - loss fauna and flora, pollution, loss of amenities.

Some examples of hazards are earthquakes, volcanic eruptions, cyclones, floods, landslides, and other such events.

2. Hazard Event

It is the physical parameter of the **hazard event** that causes the harm.

Environmental events become hazards once they threaten to affect society and/or the environment adversely. A **physical event,** such as a volcanic eruption, that does not affect human beings is a **natural phenomenon** but not a natural hazard. A natural phenomenon that occurs in a populated area is a **hazardous event.** A hazardous event that causes unacceptably large numbers of fatalities and/or overwhelming property damage is a **natural disaster.** In areas where there are no human interests, natural phenomena do not constitute hazards nor do they result in disasters.

> For information on natural disasters, refer to: The OFM/CRED International Disaster Database at
> <http://www.cred.be/emdat/profiles/regions/sasi.htm>

Magnitude is an important characteristic for analyzing hazards since only occurrences exceeding some defined level of magnitude are considered hazardous.

The level of harm is governed by

- Magnitude of the hazard
- Frequency of hazard or recurrence
- Intensity at the impact point

2.1 Multiple hazards

When more than one hazard event impacts the same area, there arises a multiple hazard situation. These different hazard events may occur at the same time or may be spaced out in time.

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The planning process in development areas does not usually include measures to reduce hazards, and as a consequence, natural disasters cause needless human suffering and economic losses. From the early stages, planners should assess natural hazards as they prepare investment projects and should promote ways of avoiding or mitigating damage caused by hazards. Adequate planning can minimize damage from these events.

3. The Return Period

Majority of hazards have return periods on a human time-scale. Examples are five-year flood, fifty-year flood and a hundred year flood. This reflects a statistical measure of how often a hazard event of a given magnitude and intensity will occur. The frequency is measured in terms of a hazard's recurrence interval.

For example, a recurrence interval of 100 years for a flood suggests that in any year, a flood of that magnitude has a 1% chance of occurring.

Such extreme events have very low frequencies but very high magnitudes in terms of destructive capacity. This means that an event considered being a hundred year flood would cause severe damage compared to a five-year flood.

4. Classification of Hazards

4.1. Are hazards natural?

There are many different ways of classifying hazards. One is to consider the extent to which hazards are natural.

I. <u>Natural hazards</u> such as earthquakes or floods arise from purely natural processes in the environment.
II. <u>Quasi-natural hazards</u> such as smog or desertification arise through the interaction of natural processes and human activities.
III. <u>Technological (or man-made) hazards</u> such as the toxicity of pesticides to fauna, accidental release of chemicals or radiation from a nuclear plant. These arise directly as a result of human activities.

Hewitt and Burton (1971) itemized a variety of factors relating to damaging geophysical events, which were not process-specific, including

- Aerial extent of damage zone
- Intensity of impact at a point
- Duration of impact at a point
- Rate of onset of the event
- Predictability of the event.

A typology based on Hewitt and Burton (1971) would appear as follows.

1. **Atmospheric** *Single element* Excess rainfall Freezing rain (glaze) Hail Heavy snowfalls High wind speeds Extreme temperatures	**Atmospheric** *Combined elements/events* Hurricanes 'Glaze' storms Thunderstorms Blizzards Tornadoes Heat/cold stress
2. **Hydrologic** Floods – river and coastal Wave action Drought Rapid glacier advance	3. **Geologic** Mass-movement Landslides Mudslides Avalanches Earthquake Volcanic eruption Rapid sediment movement
4. **Biologic** Epidemic in humans Epidemic in plants Epidemic in animals Locusts	5. **Technologic** Transport accidents Industrial explosions and fires Accidental release of toxic chemicals Nuclear accidents Collapse of public buildings

4.2. Natural hazards and human intervention

Although humans can do little or nothing to change the incidence or intensity of most natural phenomena, they have an important role to play in ensuring that natural events are not converted into disasters by their own actions.

It is important to understand that

- **Human intervention can increase the frequency and severity of natural hazards.**
  For example, when the toe of a landslide is removed to make room for a settlement, the earth can move again and bury the settlement.

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- **Human intervention may also cause natural hazards where none existed before.**
  Volcanoes erupt periodically, but it is not until the rich soils formed on their eject are occupied by farms and human settlements that they are considered hazardous.
- **Human intervention reduces the mitigating effect of natural ecosystems.**
  Destruction of coral reefs, which removes the shore's first line of defense against ocean currents and storm surges, is a clear example of an intervention that diminishes the ability of an ecosystem to protect itself. An extreme case of destructive human intervention into an ecosystem is desertification, which, by its very definition, is a human-induced "natural" hazard. ***Quasi-natural*** *and* ***na-tech*** *are terms used to denote such hybrids.*

If human activities can cause or aggravate the destructive effects of natural phenomena, they can also eliminate or reduce them.

4.2.1. Controllable events vs. immutable events

For some types of hazards the actual dimensions of the occurrence may be altered if appropriate measures are taken. For others, no known technology can effectively alter the occurrence itself. *For example, construction of levees on both sides of a stream can reduce the extent of inundations, but nothing can moderate the ground shaking produced by an earthquake.*

5. More Hazard Terminology

5.1 Secondary hazards

These are hazards that follow as a result of other hazard events. Hazards secondary to an earthquake may be listed as follows to illustrate the concept. Primary hazard is the earthquake. Secondary hazards are

- Building collapse
- Dam failure
- Fire
- Hazardous material spill
- Interruption of power/ water supply/ communication/ transportation/ waste disposal
- Landslide
- Soil liquefaction
- Tsunami (tidal wave)
- Water pollution

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5.2. Chronic hazards

A group of hazards that do not stem from one event but arise from continuous conditions (e.g., famine, resource degradation, pollution, and large-scale toxic contamination), which accumulate over time.

5.3. Rate of onset

Include rapid-onset and slower-acting (slow onset) natural hazards. The speed of onset of a hazard is an important variable since it conditions warning time. At one extreme, earthquake, landslides, and flash floods give virtually no warning. Less extreme are tsunamis, which typically have warning periods of minutes or hours, and hurricanes and floods, where the likelihood of occurrence is known for several hours or days in advance. Volcanoes can erupt suddenly and surprisingly, but usually give indications of an eruption weeks or months in advance. (*Colombia's Volcán Ruiz gave warnings for more than a year before its destructive eruption in 1985.*)

Other hazards such as drought, desertification, and subsidence act slowly over a period of months or years. Hazards such as erosion/sedimentation have varying lead times: damage may occur suddenly as the result of a storm or may develop over many years.

5.4. Spatial dispersion

This refers to the pattern of distribution of a hazard over the geographic area in which the hazard can occur.

5.5. Temporal spacing

Refers to the sequencing and seasonality of events. Some events are quite random (volcanoes) while others have seasons (hurricanes, tropical cyclones, river floods).

5.6. Hazardscape

It is the landscape of many hazards. The interaction among nature, society, and technology at a variety of spatial scales creates a mosaic of risks that affect places and the people who live there. The term is normally used in reference to a specific place or region.

6. Hazard Identification and Assessment

If you are living in an area exposed to multiple hazards, for each hazard, ask yourself the following questions and try to answer them. The answers are usually based on past experience of hazard events. They may be recorded or may be gathered through interviews. They could give you a reasonable indication of the threat posed by the hazard for the area you live in.

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- Could this hazard affect the area you live in?
- Is this hazard a significant threat there?
- How often does it pose a threat? E.g. Once every 5 years? 10 years?
- What is a close estimate of the population size that could be affected by this hazard event? Give a rating. Very high? High? Medium? Low?
- What is the expected duration of the hazard?
- What is the expected damage from the hazard event? Give a rating. Very high? High? Medium? Low?
- What is the expected intensity of impact expected? Give a rating.
- Very high? High? Medium? Low?
- How predictable is the threat?
- Can the effect of the event be reduced?

Keywords/phrases

Location
Probability
Severity
Manageability
Event parameter
Site parameter

6.1. **Hazard Assessment** is sometimes called **Hazard Evaluation** or **Hazard Analysis** (UNDRO, 1991). There seems to be a lack of consistency in the use of this terminology.

> *Hazard Assessment is the process of estimating, for defined areas, the probabilities of the occurrence of potentially-damaging phenomenon of given magnitude within a specified period of time.*
>
> UNDRO

Governments mostly carry out hazard reduction measures without much enthusiasm and within economic constraints. In order to compete for limited expenditure and resources hazard reduction proposals must find justification. This is facilitated by the collection of information about

- Local hazards - **Location & Probability**
- The extent to which they threaten local populations - **Severity**
- Ease with which their effects can be averted - **Manageability**

The severity of a natural hazard is quantified in terms of the magnitude of occurrence, which is an **event parameter**. It can also be done in terms of the effect of the occurrence at a particular location. This is called a **site parameter**. Both parameters may be combined in certain situations. Parameters for selected hazards are listed below.

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Event and Site Parameters of Selected Hazards		
Natural Hazard	**Event Parameter**	**Site Parameter**
Cyclone	Wind speed - km/h	Area affected
Earthquake	Magnitude – Richter Scale	Intensity – Modified Mercalli Scale
Flood	Area flooded – km^2 Volume of water – m^3 Speed	Depth of flood water - meters
Landslide	Volume of material dislodged Area affected	Ground displacement - meters
Tsunami	Height of wave crest	Depth of flood water
Volcano	Eruption size and duration	Ash fall – meter Lava flow - area

6.2. Hazard assessment approaches

The process of collecting this information is called hazard assessment.

These studies rely heavily on

I. Available scientific information, including geologic, geomorphic, and soil maps; climate and hydrological data; and topographic maps, aerial photographs, and satellite imagery.
II. Historical information, both written reports and oral accounts from long-term residents. These may include myths and legends.

For assessment of most natural phenomenon, one cannot expect complete data required to carry out a comprehensive assessment. Depending on the situation, various methods are used with obvious variations in the degree of accuracy.

6.2.1 Quantitative approach

Here mathematical functions are used to denote relationships between variable considered to quantify the hazard. Numerical data can be fed in to assess the impact of the hazard event.

An example is the probable flood that a particular rainfall could cause within a watershed area. Flood dimensions such as depth of flood and area of inundation would depend on the volume of water that flows into the stream. Surface run-off, soil permeability, vegetation cover etc would determine this. The empirical data collected from historical records as well as theoretical data from basic principles of physics are used to derive the relationship between variables.

The mathematical expression so derived could be used to forecast future events.

However, quantitative assessment may not be possible for all hazard events.

6.2.2. Qualitative approach

This method uses ranking such as 'high', 'moderate' and 'low 'to assess a hazard event. Where there is a lack of sufficient data for quantitative evaluation, or where certain variables cannot be expressed numerically, this qualitative ranking may be appropriate to take hazard mitigation decisions.

6.2.3. Deterministic approach

A past event is selected and associated characteristics and the consequences are described. Past impact data can be combined with current conditions and possible exposure levels and impact. This would be adequate to visualize the recurrence of an event for community awareness but leaves room for inaccuracies.

6.2.4. Probabilistic approach

After identifying the hazards that affect the planning area and assessment of the impacts from those hazards, a probability analysis is undertaken. It provides an estimate of the probability of each hazard affecting an area or region.

Probability for each hazard may be categorized as 'high', 'moderate' or 'low'.

Probability of occurrence can be calculated through research on past events.

7. The Outcome

The outcome is natural hazards information, which denotes the presence and effect of natural phenomena.

Hazard assessment is the first step for hazard mitigation planning. It prioritizes hazards so that a community or a government may use discretion to plan and implement hazard mitigation action.

This information should ideally include the location, severity, frequency, and probability of occurrence of a hazardous event. Location is the easiest for planners to find; the rest can often be obtained from sectoral agencies, natural hazard research and monitoring centers and integrated development planning studies.

It could have information on natural ecosystems (e.g., slopes and slope stability, river flow capacity, vegetation cover), which provides

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the basis for estimating the effect natural hazards can have on these systems. Change in the ecosystem may create, modify, accelerate, and/or retard the occurrence of a natural event.

Large-scale data describing lifeline infrastructure and human settlements for example, are critical elements for preparing vulnerability assessments and for initiating disaster preparedness and response activities.

8. Hazard Mapping

> *This is the process of establishing geographically where and to what extent particular phenomenon is likely to pose a threat to people, property, infrastructure and economic activities.*
>
> -UNDRO

Probability of hazard occurrence varies from place to place.

The use of mapping to synthesize data on natural hazards and to combine these with socioeconomic data facilitates analysis. It improves communications among participants in the hazard management process and between planners and decision-makers. Two important techniques in use are

- Multiple hazard mapping and
- Critical facilities mapping

8.1. Multiple Hazard Mapping (MHM)

This is usually carried out with new development in mind. Valuable information on individual natural hazards in a study area may appear on maps with varying scales, coverage, and detail, but these maps are difficult to use in risk analyses due to the inability to conveniently overlay them on each other for study. Information from several of them can be combined in a single map to give a composite picture of the magnitude, frequency, and area of effect of all the natural hazards.

- Regional scale hazard mapping uses **1:100,000** to **1:250,000**. These are useful during planning stages of regional development.

- Urban land use planners may need medium scale hazard maps of **1: 10,000** to **1:25,000**.

- Site investigation for infrastructure projects may require large-scale hazard maps of **1:1,000** to **1:5,000**.

The multiple hazard map (MHM; also called a composite, synthesis, or overlay map) is an excellent tool for fomenting an awareness of natural hazards and for analyzing vulnerability and risk, especially

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when combined with the mapping of critical facilities. Its benefits include the following:

- Characteristics of the natural phenomena and their possible impacts can be synthesized from different sources and placed on a single map.

- It can call attention to hazards that may trigger others (as earthquakes or volcanic eruptions trigger landslides) or exacerbate their effects.

- A more precise view of the effects of natural phenomena on a particular area can be obtained. Common mitigation techniques can be recommended for the same portion of the study area.

- Sub-areas requiring more information, additional assessments, or specific hazard-reduction techniques can be identified.

- Land-use decisions can be based on all hazard considerations simultaneously.

The use of a multiple hazard map also has several implications in emergency preparedness planning:

- It provides a more equitable basis for allocating disaster-planning funds.

- It stimulates the use of more efficient, integrated emergency preparedness response and recovery procedures.

- It promotes the creation of cooperative agreements to involve all relevant agencies and interested groups.

The base map upon which to place all the information is the first consideration. It is usually selected during the preliminary mission. If at all possible, it is best to use an existing map or controlled photograph rather than go through the difficult and time-consuming process of creating a base map from scratch.

The scale used for an MHM depends on the hazard information to be shown, availability of funds and the scale of the base map. If a choice of scales is available, then the following factors should be considered:

- Number of hazards to be shown.
- Hazard elements to be shown
- Range of relative severity of hazards to be shown.
- Area to be covered.
- Proposed uses of the map.

Much hazard information will be in forms other than maps, and not readily understandable by laymen. It must be "translated" for planners and decision-makers and placed on maps. The information should explain how a hazard may adversely affect life, property, or socioeconomic activities, and must therefore include location, likelihood of occurrence (return period), and severity. If some of this information is missing, the planning team must decide whether it is feasible to fill the gaps. Development and investment decisions made in the absence of these data should be noted.

Despite the importance of multiple hazard maps in the integrated development planning process, planners and decision-makers must remember that the credibility, accuracy, and content of an MHM are no better than the individual hazard information from which it was compiled. Furthermore, since it contains no new information - it is merely a clearer presentation of information previously compiled - the clarity and simplicity of the map is the key to its utility.

8.2. **Critical Facilities Mapping** (CFM)

This is carried out for development within existing infrastructure in mind. The term "critical facilities" means all man-made structures or other improvements whose function, size, service area, or uniqueness gives them the potential to cause serious bodily harm, extensive property damage, or disruption of vital socioeconomic activities if they are destroyed or damaged or if their services are repeatedly interrupted.

The primary purpose of a critical facilities map (CFM) is to convey clearly and accurately to planners and decision-makers the location, capacity, and service area of critical facilities. An extensive number of such facilities can be presented at the same time. Also, when combined with a multiple hazard map, a CFM can show which areas require more information, which ones require different hazard reduction techniques, and which need immediate attention when a hazardous event occurs. Some of the benefits of a CFM are:

- The uniqueness of service of facilities in the area (or lack of it) is made clear.
- Facilities that may require upgrading and expansion are identified.
- The impact of potential development on existing infrastructure can be assessed before a project is implemented.
- Any need for more (or better) hazard assessment becomes apparent

8.3. Combining critical facilities maps and multiple hazard maps

There are many advantages in combining a CFM, with a MHM, and integrating both into the development planning process. For example, if a critical facility is found to be in a hazardous area, planners and decision-makers are alerted to the fact that in the future it may confront serious problems. Its equipment, use and condition can then be analyzed to evaluate its vulnerability.

If appropriate techniques to reduce any vulnerability are incorporated into each stage of the planning process, social and economic disasters can be avoided or substantially lessened. Avoiding hazardous areas, designing for resistance, or operating with minimal exposure, can make new critical facilities less vulnerable.

Mitigation strategies for existing critical facilities include relocation, strengthening, retrofitting, adding redundancy, revising operations, and adopting emergency preparedness, response, and recovery programs.

The benefits obtained by combining a CFM and an MHM include:

- Project planners and decision-makers are made aware of hazards to existing and proposed critical facilities prior to project implementation.

- The extent to which new development can be affected by the failure or disruption of existing critical facilities as a consequence of a natural event can be determined.

- More realistic benefit-cost ratios for new development are possible.

- Sub-areas requiring different assessments, emergency preparedness, immediate recovery, or specific vulnerability reduction techniques can be identified.

8.4. Mapping techniques and tools

8.4.1. Community knowledge

A simple mapping of local experience can be achieved using local knowledge. Tools used in rural development activities such as

Participatory Rural Appraisal (PRA)
Rapid Rural Appraisal (RRA)

can be very useful in this work. The method is cost effective and the outcome reflects the local perception of hazard. The information can overlay local contour maps.

8.4.2. Surveys on historic events

There may be reports compiled on historic events, which may focus on varying issues depending on its original purpose. However they may contain useful information.