MODULE-I

Definition of Hazard

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

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.

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.

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

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.

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.

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.

Classification of Hazard

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

I. Natural hazards such as earthquakes or floods arise from purely natural processes in the environment.

II. Quasi-natural hazards such as smog or desertification arise through the interaction of natural processes and human activities.

III. Technological (or man-made) hazards 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.

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.

• 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.

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

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.

Risk is the chance or probability that a person will be harmed or experience an adverse health effect if exposed to a hazard. It may also apply to situations with property or equipment loss, or harmful effects on the environment.

Disaster **resilience** is the ability of individuals, communities, organisations and states to adapt to and recover from **hazards**, shocks or stresses without compromising long-term prospects for development.

Vulnerability means potential to be harmed by hazard.

Exposure means how long the people, properties and other things have been exposed to atmosphere.

A **crisis** is any event that is going (or is expected) to lead to an unstable and dangerous situation affecting an individual, group, community, or whole society.

Resilience is nothing but the recovering back to original and better situation after an hazard or disaster.

Emergency is the serious, unexpected and dangerous situation when immediate action is required.

Earth system and its components

The main components of the earth system

The earth system is itself an integrated system, but it can be subdivided into four main components, sub-systems or spheres: the geosphere, atmosphere, hydrosphere and biosphere. These components are also systems in their own right and they are tightly interconnected. The four main components of the earth system may be described briefly in the following way.

- **The geosphere** - this is the part of the planet composed of rock and minerals; it includes the solid crust, the molten mantle and the liquid and solid parts of the earth's core. In many places, the geosphere develops a layer of soil in which nutrients become available to living organisms, and which thus provides an important ecological habitat and the basis of many forms of life. The surface of the geosphere is subject to processes of erosion, weathering and transport, as well as to tectonic forces and volcanic activity, which result in the formation of landforms such as mountains, hills and plateaux.
- **The atmosphere** - this is the gaseous layer surrounding the earth and held to its surface by gravity. The atmosphere receives energy from solar radiation which warms the earth's surface and is re-emitted and conducted to the atmosphere. The atmosphere also absorbs water from the earth's surface via the process of evaporation; it then acts to redistribute heat and moisture across the earth's surface. In addition, the atmosphere

contains substances that are essential for life, including carbon, nitrogen, oxygen and hydrogen.

- **The hydrosphere** - this consists of those parts of the earth system composed of water in its liquid, gaseous (vapour) and solid (ice) phases. The hydrosphere includes: the earth's oceans and seas; its ice sheets, sea ice and glaciers; its lakes, rivers and streams; its atmospheric moisture and ice crystals; and its areas of permafrost. The hydrosphere includes both saltwater and freshwater systems, and it also includes the moisture found in the soil (soil water) and within rocks (groundwater). Water is essential for the existence and maintenance of life on earth. In some classifications, the hydrosphere is sub-divided into the fluid water systems and the **cryosphere** (the ice systems).
- **The biosphere** - this contains all living organisms and it is intimately related to the other three spheres: most living organisms require gases from the atmosphere, water from the hydrosphere and nutrients and minerals from the geosphere. Living organisms also require a medium for life, and are adapted to inhabit one or more of the other three spheres. However, much of the biosphere is contained within a shallow surface layer encompassing the lower part of the atmosphere, the surface of the geosphere and approximately the upper 100 metres of the ocean. Humans are part of the biosphere, although they are increasingly responsible for the creation of systems that may be largely artificial (such as cities).

CLIMATE CHANGE

Climate is usually defined as the "average weather" in a place. It includes patterns of temperature, precipitation (rain or snow), humidity, wind and seasons. Climate patterns play a fundamental role in shaping natural ecosystems, and the human economies and cultures that depend on them. But the climate we've come to expect is not what it used to be, because the past is no longer a reliable predictor of the future. Our climate is rapidly changing with disruptive impacts, and that change is progressing faster than any seen in the last 2,000 years.

According to the report, Preparing for a Changing Climate, rising levels of carbon dioxide and other heat-trapping gases in the atmosphere have warmed the Earth and are causing wide-ranging impacts, including rising sea levels; melting snow and ice; more extreme heat events, fires and drought; and more extreme storms, rainfall and floods. Scientists project that these trends will continue and in some cases accelerate, posing significant risks to human health, our forests, agriculture, freshwater supplies, coastlines, and other natural resources that are vital to economy, environment, and our quality of life.

Because so many systems are tied to climate, a change in climate can affect many related aspects of where and how people, plants and animals live, such as food production, availability and use of water, and health risks. For example, a change in the usual timing of rains or temperatures can affect when plants bloom and set fruit, when insects hatch or when streams are their fullest. This can affect historically synchronized pollination of crops, food for migrating birds, spawning of fish, water supplies for drinking and irrigation, forest health, and more.Some short-term climate variation is normal, but longer-term trends now indicate a changing climate.Our state and societies around the globe need to reduce human-caused greenhouse gas emissions to avoid worsening climate impacts and reduce the risk of creating changes beyond our ability to respond and adapt.

According to the **U.S. Environmental Protection Agency**, the term climate change is often used interchangeably with the term global warming, but according to the National Academy of Sciences, "the phrase 'climate change' is growing in preferred use to 'global warming' because it helps to convey that there are other changes in addition to rising temperatures." Climate change refers to any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer).

Climate change is a significant change in earth's overall conditions, which can be measured by major changes in the distribution of weather patterns – such as temperature or precipitation, among other effects – that occur over several decades or longer. Climate change is mainly caused by global warming due to increasing concentrations of greenhouse gases in our atmosphere.The consequences of climate change vary across the globe. We are already seeing significant impacts to the coastline due to rising sea levels. We are also seeing increased precipitation, increased air and ocean temperatures, more flooding, higher storm surge, more intense storms, and more.

Causes of climate change:

The general state of the Earth's climate is dependent upon the amount of energy stored by the **climate system,** and in particular the balance between the amount of energy the Earth receives from the Sun, in the form of light and ultraviolet radiation, and the amount of energy the Earth releases back to space, in the form of infrared heat energy. Causes of climate change involve any process that can alter this **global energy balance.** Scientists call this as "**climate forcing".** Climate forcing "forces" the climate to change.

There are many climate forcing processes, but broadly speaking, they can be separated into internal and external types. External processes operate outside planet Earth, and include changes in the global energy balance due to variations in the Earth's around the Sun, and changes in the amount of energy received from the Sun. Internal processes operate from within the Earth's climate system, and include changes in the global energy balance due to changes in ocean circulation or changes in the composition of the atmosphere. Other climate forcing processes include the impacts of **large volcanic eruptions** and collisions with comets or meteorites.

Luckily, the Earth is not hit by large **comets or meteorites** very often, perhaps every 20 to 30 million years or so, and therefore their associated climate changes occur rarely throughout Earth History. However, other causes of climate change influence the Earth on much shorter time scales, with changes sometimes occurring within a single generation. Indeed, our present pollution of the atmosphere with greenhouse gases may be causing the global climate to change. This man-made climate change has become known as global warming.

The earth's climate is dynamic and always changing through a natural cycle. What the world is more worried about is that the changes that are occurring today have been speeded up because of man's activities. These changes are being studied by scientists all over the world who are finding evidence from tree rings, pollen samples, ice cores, and sea sediments. The causes of climate change can be divided into two categories - those that are due to natural causes and those that are created by man.

Natural causes:

There are a number of natural factors responsible for climate change. Some of the more prominent ones are continental drift, volcanoes, ocean currents, the earth's tilt, solar variations etc. Let's look at them in a little detail.

Continental drift:
We may have noticed something peculiar about South America and Africa on a map of the world - don't they seem to fit into each other like pieces in a jigsaw puzzle?
About 200 million years ago they were joined together. Scientists believe that back then, the earth was not as we see it today, but the continents were all part of one large landmass. Proof of this comes from the similarity between plant and animal fossils and broad belts of rocks found on the eastern coastline of South America and western coastline of Africa, which are now widely separated by the Atlantic Ocean. The discovery of fossils of tropical plants (in the form of coal deposits) in Antarctica has led to the conclusion that this frozen land at some time in the past, must have been situated closer to the equator, where the climate was tropical, with swamps and plenty of lush vegetation.

The continents that we are familiar with today were formed when the landmass began gradually drifting apart, millions of years back. This drift also had an impact on the climate because it changed the physical features of the landmass, their position and the position of water bodies. The separation of the landmasses changed the flow of ocean currents and winds, which affected the climate. This drift of the continents continues even today; the Himalayan range is rising by about 1 mm (millimeter) every year because the Indian land mass is moving towards the Asian land mass, slowly but steadily.

Volcanoes:
When a volcano erupts it throws out large volumes of sulphur dioxide (SO_2), water vapour, dust, and ash into the atmosphere. Although the volcanic activity may last only a few days, yet the large volumes of gases and ash can influence climatic patterns for years. Millions of tonnes of sulphur dioxide gas can reach the upper levels of the atmosphere (called the stratosphere) from a major eruption. The gases and dust particles partially block the incoming rays of the sun, leading to cooling. Sulphur dioxide combines with water to form tiny droplets of sulphuric acid. These droplets are so small that many of them can stay aloft for several years. They are efficient reflectors of sunlight, and screen the ground from some of the energy that it would ordinarily receive from the sun. Winds in the upper levels of the atmopshere, called the stratosphere, carry the aerosols rapidly around the globe in either an easterly or westerly direction. Movement of aerosols north and south is always much slower. This should give us some idea of the ways by which cooling can be brought about for a few years after a major volcanic eruption.

The earth's tilt:
The earth makes one full orbit around the sun each year. It is tilted at an angle of 23.5° to the perpendicular plane of its orbital path. For one half of the year when it is summer, the northern hemisphere tilts towards the sun. In the other half when it is winter, the earth is tilted away from the sun. If there was no tilt we would not have experienced seasons. Changes in the tilt of the earth can affect the severity of the seasons - more tilt means warmer summers

and colder winters; less tilt means cooler summers and milder winters.

Ocean currents:
The oceans are a major component of the climate system. They cover about 71% of the Earth and absorb about twice as much of the sun's radiation as the atmosphere or the land surface. Ocean currents move vast amounts of heat across the planet - roughly the same amount as the atmosphere does. But the oceans are surrounded by land masses, so heat transport through the water is through channels.

Winds push horizontally against the sea surface and drive ocean current patterns.
Certain parts of the world are influenced by ocean currents more than others. The coast of Peru and other adjoining regions are directly influenced by the Humboldt current that flows along the coastline of Peru. The El Niño event in the Pacific Ocean can affect climatic conditions all over the world.

Ocean currents have been known to change direction or slow down. Much of the heat that escapes from the oceans is in the form of water vapour, the most abundant greenhouse gas on Earth. Yet, water vapor also contributes to the formation of clouds, which shade the surface and have a net cooling effect.

Solar variations:

Sun is the source of energy for the Earth’s climate system. Although the Sun’ energy output appears constant from an everyday point of view, small changes over an extended period of time can lead to climate changes. Some scientists suspect that a portion of the warming in the first half of 20th century was due to an increase in the output of solar energy. As the sun is the fundamental source of energy that is instrumental in our climate system, it would be reasonable to assume that changes in the Sun’s energy output would cause the climate to change. Scientific studies demonstrate that solar variations have performed a role in past climate changes. For instance a decrease in solar activity was thought to have triggered the little Ice Age between approximately 1650 and 1850, when Greenland was largely cut off by ice from 1410 to the 1720s and glaciers advanced in the Alps.

Human causes:
The Industrial Revolution in the 19th century saw the large-scale use of fossil fuels for industrial activities. These industries created jobs and over the years, people moved from rural areas to the cities. This trend is continuing even today. More and more land that was covered with vegetation has been cleared to make way for houses. Natural resources are being used extensively for construction, industries, transport, and consumption. Consumerism (our increasing want for material things) has increased by leaps and bounds, creating mountains of waste. Also, our population has increased to an incredible extent.

All this has contributed to a rise in greenhouse gases in the atmosphere. Fossil fuels such as oil, coal and natural gas supply most of the energy needed to run vehicles generate electricity for industries, households, etc. The energy sector is responsible for about ¾ of the carbon dioxide emissions, 1/5 of the methane emissions and a large quantity of nitrous oxide. It also produces nitrogen oxides (NOx) and carbon monoxide (CO) which are not greenhouse gases but do have an influence on the chemical cycles in the atmosphere that produce or destroy greenhouse gases.

Greenhouse gases and their sources:
Carbon dioxide is undoubtedly, the most important greenhouse gas in the atmosphere. Changes in land use pattern, deforestation, land clearing, agriculture, and other activities have all led to a rise in the emission of carbon dioxide.

Methane is another important greenhouse gas in the atmosphere. About ¼ of all methane emissions are said to come from domesticated animals such as dairy cows, goats, pigs, buffaloes, camels, horses, and sheep. These animals produce methane during the cud-chewing process. Methane is also released from rice or paddy fields that are flooded during the sowing and maturing periods. When soil is covered with water it becomes anaerobic or lacking in oxygen. Under such conditions, methane-producing bacteria and other organisms decompose organic matter in the soil to form methane. Nearly 90% of the paddy-growing area in the world is found in Asia, as rice is the staple food there. China and India, between them, have 80-90% of the world's rice-growing areas.

Methane is also emitted from landfills and other waste dumps. If the waste is put into an **incinerator** or burnt in the open, carbon dioxide is emitted. Methane is also emitted during the process of oil drilling, coal mining and also from leaking gas pipelines (due to accidents and poor maintenance of sites).
A large amount of nitrous oxide emission has been attributed to fertilizer application. This in turn depends on the type of fertilizer that is used, how and when it is used and the methods of tilling that are followed. Contributions are also made by leguminous plants, such as beans and pulses that add nitrogen to the soil.

All of us in our daily lives contribute our bit to this change in the climate. Give these points a good, serious thought:

- Electricity is the main source of power in urban areas. All our gadgets run on electricity generated mainly from thermal power plants. These thermal power plants are run on fossil fuels (mostly coal) and are responsible for the emission of huge amounts of greenhouse gases and other pollutants.
- Cars, buses, and trucks are the principal ways by which goods and people are transported in most of our cities. These are run mainly on petrol or diesel, both fossil fuels.
- We generate large quantities of waste in the form of plastics that remain in the environment for many years and cause damage.
- We use a huge quantity of paper in our work at schools and in offices. Have we ever thought about the number of trees that we use in a day?
- Timber is used in large quantities for construction of houses, which means that large areas of forest have to be cut down.
- A growing population has meant more and more mouths to feed. Because the land area available for agriculture is limited (and in fact, is actually shrinking as a result of ecological degradation), high-yielding varieties of crop are being grown to increase the agricultural output from a given area of land. However, such high-yielding varieties of crops require large quantities of fertilizers; and more fertilizer means more emissions of nitrous oxide, both from the field into which it is put and the fertilizer industry that makes it. Pollution also results from the run-off of fertilizer into water bodies

Effects of climate change:

Over 100 years ago, people worldwide began burning more coal and oil for homes, factories, and transportation. Burning these fossil fuels releases carbon dioxide and other greenhouse gases into the atmosphere. These added greenhouses gases have caused Earth to warm more quickly than it has in the past.

Scientists from around the world with the Intergovernmental Panel on Climate Change (IPCC) tell us that during the past 100 years, the world's surface air temperature increased an average of 0.6° Celsius (1.1°F). This may not sound like very much change, but even one degree can affect the Earth. Below are some effects of climate change that we see happening now.

- **Sea level is rising**. During the 20th century, sea level rose about 15 cm (6 inches) due to melting glacier ice and expansion of warmer seawater. Models predict that sea level may rise as much as 59 cm (23 inches) during the 21st Century, threatening coastal communities, wetlands, and coral reefs.
- **Arctic sea ice is melting**. The summer thickness of sea ice is about half of what it was in 1950. Melting ice may lead to changes in ocean circulation. Plus melting sea ice is speeding up warming in the Arctic.
- **Glaciers and permafrost are melting.** Over the past 100 years, mountain glaciers in all areas of the world have decreased in size and so has the amount of permafrost in the Arctic. Greenland's ice sheet is melting faster too.
- **Sea-surface temperatures are warming**. Warmer waters in the shallow oceans have contributed to the death of about a quarter of the world's coral reefs in the last few decades. Many of the coral animals died after weakened by bleaching, a process tied to warmed waters.
- **The temperatures of large lakes are warming**. The temperatures of large lakes world-wide have risen dramatically. Temperature rises have increased algal blooms in lakes, favor invasive species, increase stratification in lakes and lower lake levels.
- **Heavier rainfall cause flooding in many regions.** Warmer temperatures have led to more intense rainfall events in some areas. This can cause flooding.
- **Extreme drought is increasing**. Higher temperatures cause a higher rate of evaporation and more drought in some areas of the world.
- **Crops are withering**. Increased temperatures and extreme drought are causing a decline in crop productivity around the world. Decreased crop productivity can mean food shortages which have many social implications.
- **Ecosystems are changing**. As temperatures warm, species may either move to a cooler habitat or die. Species that are particularly vulnerable include endangered species, coral reefs, and polar animals. Warming has also caused changes in the timing of spring events and the length of the growing season.
- **Hurricanes have changed in frequency and strength.** There is evidence that the number of intense hurricanes has increased in the Atlantic since 1970. Scientists continue to study whether climate is the cause.
- **More frequent heat waves.** It is likely that heat waves have become more common in more areas of the world.
- **Warmer temperatures affect human health.** There have been more deaths due to heat waves and more allergy attacks as the pollen season grows longer. There have also been some changes in the ranges of animals that carry disease like mosquitoes.

- **Seawater is becoming more acidic.** Carbon dioxide dissolving into the oceans is making seawater more acidic. There could be impacts on coral reefs and other marine life.

Climate change control measures:

1. Plant native, drought-resistant trees and shrubs around our home and outdoor air conditioning unit.

2. Use an electric or push mower instead of a gasoline-powered mower to cut our lawn.

3. Replace our current home appliances (refrigerator, washing machine, dish washer) with high-efficiency models.

4. Buy food and other products with reusable or recyclable packaging instead of those in non-recyclable packaging.

5. Replace incandescent light bulbs with compact fluorescent bulbs.

6. Install a solar heated system to provide your hot water.

7. Recycle our home's waste newsprint, cardboard, glass and metal.

8. Leave our car at home (walk, bike or take mass transit instead).

9. Insulate our home, clean our air conditioning filters and install energy efficient showerheads.

10. Purchase a fuel-efficient car (rated at 32 mpg or more) to replace our most frequently used automobile.

GLOBAL WARMING

Global warming can be defined as an increase in the earth's atmospheric, oceanic temperatures and an overall change in earth's atmosphere including a rise in sea levels and variability of snow falls. Climate change and associated impacts vary from region to region around the globe. Due to increase in the greenhouse effect resulting especially from pollution and other activities such as, greenhouse gas emissions produced by human activities mainly industrial processes and transportation.

According to, IPCC(Intergovernmental Panel on Climate change) "Greenhouse gases effectively absorb thermal infra-red radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the **Greenhouse effect**".

In 1998, the Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), to cope with the threat that global warming presents to the world.

2.9.1 Causes of global warming:

1. Increase in co2 concentration: The CO2 concentrations in the atmosphere by about thirty percent, due to Human beings have increased, the increase is proportional to increases in fossil fuel combustion for electricity generation, transportation, and heating, and also the manufacture of cement (human caused) emissions. It is predicted that we'll soon reach carbon dioxide concentrations that haven't been seen on Earth in the last 50 million years, which is eventually leading to changes in the Earth's average surface temperature, which is really proving fatal to human lives.

2. Ozone Depletion: Increase in ozone levels in the stratosphere over Antarctica, are the result of complex chemical processes. The return of the Sun at the end of winter triggers photochemical reactions that lead to the destruction of ozone in the stratosphere. As reported Over the Arctic the gradual development of an annual decline during the 1990s, has been observed. The Protection of the Ozone Layer amendments has been issued to eliminate certain CFCs from industrial production, the substantial destruction of ozone in the stratosphere over Antarctica, has not seen any improvement till date.

3. Deforestation: The use of forests for fuel (both wood, for charcoal and other necessary lifestyle products) is one cause of deforestation. In order satiate ourselves, for wood and other products, mainly habitat and to build farms we are chopping forests which is not a good sign and has also leads to decrease in rainfalls. Forests are very human friendly, they clean the air as they act as natural filters remove and store carbon dioxide from the atmosphere, and this deforestation releases large amounts of carbon, as well as reducing the amount of carbon gas capture on the earth.

4. Methane and Nitrous oxide emissions from agriculture, Arctic sea beds and factories: Methane is one of the greenhouse gases, which causes global warming. When organic matter is broken down by bacteria under oxygen-starved conditions as in agricultural fields, methane is produced. The process also takes place in the intestines of herbivorous animals, and with the increase in the amount of concentrated livestock production, the levels of methane released into the atmosphere is increasing. Another source of methane is methane clathrate, a compound in large amounts of methane trapped in the crystal structure of ice. As methane escapes from the Arctic seabed, the rate of global warming increases, accordingly.

5. Aerosols present in the Atmosphere: Atmospheric aerosols are able to alter the climate in two important ways.

- They scatter and absorb solar and infra-red radiation
- They may change the micro-physical and chemical properties of clouds and possibly their lifetime and extent.

This can be explained as, scattering of solar radiation acts to cool the planet, while the absorption of solar radiation by aerosols warms the air directly instead of absorption of sunlight from the surface of the Earth.The human contribution to the amount of aerosols in the atmosphere takes many forms, such as:

- Biomass burning produces a combination of organic droplets.
- Exhaust emissions from transport generate pollutants that are either aerosols from the outset, or are converted by chemical reactions in the atmosphere to form aerosols.

The concentrations of condensation nuclei are about three times higher in the Northern Hemisphere than in the Southern Hemisphere. This higher concentration is estimated to result in radiation forcing that is only about 50 percent higher in the Northern Hemisphere as reported.

6. Rise in sea levels: Increase in sea levels is the result of melting of two massive ice sheets in Antarctica and Greenland as researched by scientists. However, many nations around the world will experience the effects of rising sea levels, which could displace millions of people. The Maldives a country is already looking for a new home due to rising sea levels. Majority of Americans living in coastal states, are facing large impacts due to global warming. Seawater expands, takes more space in the ocean and causes a surplus rise in water level and also the melting of ice over land, which then adds water to the ocean.

7. Plankton boom due to warming seas: Some of the sea lions, sea urchins, kelp beds, and fish populations, appears to have extinct due to loss of plankton, decrease in population of sea lions, leading orcas to eat too many sea otters, leading to urchin explosions, leading to loss of various fish populations.

8. Water Vapour: Water vapour is increasing in the atmosphere due to carbon dioxide-induced warming. Two-thirds of the heat trapped by greenhouse gases is contained in water vapor, and as the average temperature on the planet to raises, the amount of water vapour rises in turn, leading to untimely rainfall which may further cause other natural calamities such as floods.

9. Sunspots: Sunspots are dark patches on the sun’s surface that block hot solar plasma. Increase in solar activities changes the Earth’s solar radiation levels, thereby causing short-term warming cycles. Surrounding sunspots are bright patches known as faculae. These patches give off greater than normal radiation, and they are more powerful than the darker, cooler patches. This means that the total average energy over a 30-day solar rotation increases, which gives way to many other after effects

10. Burning of Fossil Fuels: Each time a fossil fuel burn, carbon dioxide levels in the atmosphere increase. As we know carbon dioxide absorbs infra-red energy emitted from the earth’s surface, preventing it from returning to space. Auto mobile’s Carbon emissions are from the burning of gasoline to power cars, trucks, and other methods of transportation. Electricity generation requires coal which is the largest producer of carbon dioxide emissions, Therefore countries across the world want to switch to nuclear power plants.

11. Mining activities: Mining oil, coal and other mineral products underlying in deep beds allow methane, a greenhouse gas, to escape from the earth. Disturbing the soil, stored gases make their way into the environment.

12. Population Increase: As the population on Earth increases, food and housing demands along with other basic necessities also increase. Manure from cattle, contributes to methane gas levels. The cutting down of forests to make space for housing and other buildings accounts for close to 11-12 % of carbon emissions.

Effects of global warming:

Global Warming is already affecting the human kind, plant and animals in number of ways through increased ocean levels, droughts and changed weather patterns. It is well recognized by scientists around the world as a serious public health and environmental concern. **Here are 22 effects of global warming on the environment:**

1. Melting of Glaciers: The melting of glaciers will create plethora of problems for human kind and the animals living on the **earth.** Due to increased global warming, the level of the sea will rise which will lead to flooding and this will in turn create havoc in human life. Apart from raising the sea levels, it will also **endanger several species** of animals and thus will hamper the balance of the ecosystem.Areas in the Arctic are diminishing away and flowing into major oceans. Rising temperatures create a much accelerated threat to wildlife and whole ecosystems in these regions. With glaciers melting at vast rates, a chain of events is being set into motion that cannot be reversed.

2. Climate Change: Irregular weather patterns have already started showing results. Increased precipitations in the form of rain have already been noticed in polar and sub-polar regions. More global warming will lead to more evaporation which will cause more rains. Animals and plants cannot easily adapt to increased rainfall. Plants may die and animals may migrate to other areas, which can cause entire ecosystem out of balance.

3. Droughts: While it may be flooding in Savannah, severe drought is happening elsewhere in the world. As temperatures warm, the presence of drought has increased. Add on top of that heat waves and no precipitation, whole forests have begun to disappear including tens of millions of trees.Large scale evaporation will be the major cause of droughts in many places particularly Africa. Although, it is reeling under the huge pressure of water crisis, increased global warming would further make the situation worse and will cause malnutrition.

4. Diseases: As the temperature becomes warmer, it can affect the health of humans and the diseases they are exposed to. With the increase in the rainfall, water borne diseases are likely to spread like malaria. The earth will become warmer and as a result heat waves are likely to increase that can cause a major blow to the people.

5. Hurricanes Frequency: As the temperature of the oceans rises, hurricanes and other storms are likely to become stronger. With the increase in the global warming, the water in the ocean warms up and it heats up the surrounding air, creating hurricanes.

6. Rise of Sea Levels: The melting of polar ice-caps and less water evaporating into the atmosphere are causing increased sea levels. Quaint coastal towns and cities near the U.S. east coast and Gulf of Mexico are just a few areas where devastating flood damage is starting to make its mark in history.

7. Agriculture: Global warming can affect agriculture. Although the results are not visible yet, but it may show its effects in years to come. As the global temperature will increase, plants will find it harder to survive and will die. Plants are the major source of food for human beings and as a result food shortage may occur. The shortage of the food may lead to war and conflicts in some countries.

8. Heat Waves: Because of greenhouse gases and other causes, unexpected streaks of severe weather are just the tips of the iceberg in global warming. Heat waves cause dangerously hot weather and in recent years, more deaths have occurred due to heat waves than in the last sixty years.

9. Frequent Wildfires: While wildfires are a natural occurrence, with the added carbon dioxide in the air, and hotter summers, the evidence speaks for itself. More frequent wildfires continue to surface in vast amounts each year. The rate at which they burn is longer than the last, and with the release of carbon dioxide into the air, not only are people's lives in danger, but wildlife severely suffers. Each time a wildfire burns, the less oxygen there is to combat the dangerous amounts of carbon dioxide being released into the atmosphere.

10. Severe Precipitation: Not only the insurmountable scientific evidence that global warming is increasing, certain types of events, including extreme precipitation is on the rise. Global warming also creates conditions that can lead to more powerful hurricanes and summer storms. Cities and towns on the coast, where sea levels are already rising, face even more challenges as precipitation poses severe flooding.

11. Longer/Shorter Seasons: Whatever weather and climate you enjoy, it could be happening sooner and shorter, or later and longer. Global warming effects show spring is occurring 10 days sooner than it has in the past. While it may be nice to go from snow pants to shorts sooner, this could cause flooding from reservoirs filling too soon, and droughts were there's not enough precipitation to provide adequate nourishment for crops.

12. Crops: If seasons are changing, weather patterns are going berserk, and flooding is occurring due to rising sea levels, our crops are barely getting a fighting chance. Once the food processing industry goes haywire, the economy will really start getting interesting. The price of staple crops could sky rocket causing major inflation and more economic woes.

13. Oceans: It's reported that coral reefs are continuing to see diminished presence in the ocean due to global warming. Temperature changes affect more than what's happening on our lands. Once **coral reefs** are affected, entire ecosystems that thrive become obsolete.

14. Food Chain: Change in the time and seasons and birds are flying south for winter sooner, hibernation takes longer, and a whole series of events is set in motion for complete collapse of animal life. The entire food chain could be disrupted and enormous consequences could follow.

15. Health Risks: As more carbon dioxide is trapped in the atmosphere, breathable air becomes harder to come by. If global warming continues, the U.S. is looking at 60 billion dollars to combat respiratory diseases and symptoms.

16. Animal Extinction: Nature's best is beautifully displayed in every nook of planet earth- the majestic lion, to the humble deer. Imagine whole populations where animals can no longer thrive. With such a vast eruption in the animal kingdom, our own world becomes in danger.

17. Quality of Life: If doing simple things like taking a walk outside or working in your garden, become unenjoyable due to severe heat waves, think of the quality of life on a much larger scale. With rising global temperature, even the smallest things we took for granite will be sorely missed.

18. Economic Collapse: Who knows how badly the economy could get with decreased vitality of crops, productions, and manufacturing items. Without having nature on our side, the food industry will fall apart. Without the resources to feed the world, manufacturing will collapse. Hunger will be our biggest battle.

19. Air Quality: As more chain of events are set in motion, **air quality** will continue to get worse. As bad as it is now in some areas in the world, multiply that by a million.

20. Decreased Population: If global warming goes unchecked, it's estimated the **world's human population** would decrease by 75 percent. With the increasing severity of storms, floods, earthquakes, and wildfires, **natural disasters** would diminish half of the earth's population. Another 25 percent would succumb to air related illnesses, starvation, and poverty.

21. Fresh Water: Our fresh water supply will great diminish with global warming. With the demise of coral reefs and the ecosystems therein, less fresh water will flow into lakes and tributaries.

22. Disappearing Countries: Countries like Greenland are deteriorating at a highly elevated rate. Beautiful cities, even continents could one day be part of a vast sea.

Global warming control measures:

1. Replace Regular Incandescent Light bulb: Replace regular incandescent light bulb with compact fluorescent light (CFL) bulbs. They consume 70% less energy than ordinary bulbs and have longer lifetime.

2. Drive Less or Carpool: By driving less you are not only saving fuel but also helping in reducing global warming. Also, look out for other possibilities, for e.g.: carpooling. If we have colleagues who live in the same area then we can combine trips. If we need to go to a local market then either walk or go by cycle. Both of them are great form of exercise. The biggest pollution emitting fumes are caused by oil and gasoline. Cutting down consumption, is a huge step to reduce energy wastes.

3. Reduce, Reuse, and Recycle: Reduce your need to buy new products or use less, resulting in a smaller amount of waste. Even if we need to buy, consider **buying eco-friendly**

products. It is most effective of the three R's. It simply says cut back from where are you now.Reuse bottles, plastic containers, and other items bought at the grocery store. Reusing water bottles, yogurt cups, bread ties, and other items is being conscious about what is already out there. It will lessen having to purchase other items that would fulfill the same function. Try to use the disposable products into some other form. Just don't throw them away.Recycling unwanted paper, bottles, etc. is a great earth saving tip. If possible, upcycle tables, furniture, and other outdated items to keep landfills clean. We can recycle almost anything for e.g.: paper, aluminum foils, cans, newspapers. By recycling we can help in reducing landfills.

4. Go Solar: Many people have caught the energy efficient band wagon of solar energy. Having solar panels installed is something readily possible and available. Incentives and discounts given by government agencies and energy companies make **solar energy** something to look into.

5. Buy Energy-Efficient Appliances: Always buy products that are **energy efficient** as they can help you save good amount of money on your energy bill. Energy-efficient products can help us to save energy, save money and reduce our carbon footprint.

6. Reduce Waste: Landfills are the major contributor of methane and other greenhouse gases. When the waste is burnt, it releases toxic gases in the atmosphere which result in global warming. Reusing and recycling old items can significantly reduce our carbon footprint as it takes far less energy to recycle old items than to produce items from scratch.

7. Use less Hot Water: Buy energy saving geysers and dishwasher for our home. Avoid washing clothes in hot water. Just wash them in cold or warm water. Avoid taking frequent showers and use less hot water. It will **help in saving energy** require to produce that energy.

8. Avoid Products with Lot of Packaging: Just don't buy products with lot of packaging. When we buy such products we will end up in throwing the waste material in the garbage, which then will help in filling **landfill sites** and **pollute the environment**. Also, discourage others from buying such products.

9. Turn off the Lights: If we're not using a room, there's no need for the light to be on.

10. Turn off Electronic Devices: Turn off electronic devices when we are moving out for a couple of days or more. Unnecessary usage of electronic appliances will not only save fuel i.e. coal by which we get **electricity** but also increase the lifetime ofour gadgets.

11. Plant a Tree: Planting trees can help much in reducing global warming than any other method. They not only give oxygen but also take in carbon dioxide, during the process of photosynthesis, which is the main source of **global warming.**

12. Use Clean Fuel: Electric, smart cars, cars run on vegetable oil, etc. are great examples for using renewable energy. Supporting companies that provide these products will help the rest of the mainstream manufacturing companies convert over.

13. Look for Renewable Fuel Options: If we can't afford an **electric car,** buy the cleanest gasoline as possible. When car shopping, look at the benefits of options that provide renewable fuel.

14. Save Energy: When we consume less, the less carbon dioxide is released into the atmosphere.

15. Replace Filters on Air Conditioner and Furnace: If we haven't, not only we are wasting energy, but breathing in dirty air. Cleaning a dirty air filter can save several pounds of carbon dioxide a year.

16. Go Green: Using energy star appliances will not only save money, but also the amount of energy wasted in our home.

17. Tune Your Car Regularly: Regular maintenance will help your car function properly and emit less carbon dioxide.

18. Conserve Water: This is a tired tip, but ever so important. If we added up the water wasted by the millions of Americans brushing their teeth, we could provide water to more than 23 nations with unclean, drinking water. Remember, it takes energy to draw and filter water from underground.Taking a quick 5 minute shower will greatly conserve energy. The type of shower head used, will also aid in combating global warming. Take showers instead of baths. Showers use less water than baths by 25%. Over the course of a year that's hundreds of gallons saved.

19. Check Your Tyres: When you drive make sure our tyres are inflated properly. If not, then our vehicle might consume more fuel which in turn releases more CO2 in the atmosphere. Keep our engine properly tuned and drive less aggressively. Aggressive driving and frequent applying of brakes hampers the engine and can even lower the mileage of our car.

20. Spread the Awareness: Always try our best to educate people about global warming and its causes and after affects. Tell them how they can contribute their part by saving energy that will be good for the **environment.** Gather opportunities and establish programs that will help us to share information with friends, relatives and neighbours.

MODULE-II

Earthquake

Earthquake, any sudden shaking of the ground caused by the passage of seismic wavesthrough Earth's rocks. Seismic waves are produced when some form of energy stored in Earth's crust is suddenly released, usually when masses of rock straining against one another suddenly fracture and "slip." Earthquakes occur most often along geologic faults, narrow zones where rock masses move in relation to one another. The major fault lines of the world are located at the fringes of the huge tectonic plates that make up Earth's crust.

Little was understood about earthquakes until the emergence of seismology at the beginning of the 20th century. Seismology, which involves the scientific study of all aspects of earthquakes, has yielded answers to such long-standing questions as why and how earthquakes occur.

About 50,000 earthquakes large enough to be noticed without the aid of instruments occur annually over the entire Earth. Of these, approximately 100 are of sufficient size to produce substantial damage if their centres are near areas of habitation. Very great earthquakes occur on average about once per year. Over the centuries they have been responsible for millions of deaths and an incalculable amount of damage to property.

Causes of earthquakes

Earth's major earthquakes occur mainly in belts coinciding with the margins of tectonic plates. This has long been apparent from early catalogs of felt earthquakes and is even more readily discernible in modern seismicity maps, which show instrumentally determined epicentres. The most important earthquake belt is the Circum-Pacific Belt, which affects many populated coastal regions around the Pacific Ocean—for example, those of New Zealand, New Guinea, Japan, the Aleutian Islands, Alaska, and the western coasts of North and South America. It is estimated that 80 percent of the energy presently released in earthquakes comes from those whose epicentres are in this belt. The seismic activity is by no means uniform throughout the belt, and there are a number of branches at various points. Because at many places the Circum-Pacific Belt is associated with volcanic activity, it has been popularly dubbed the "Pacific Ring of Fire."
A second belt, known as the Alpide Belt, passes through the Mediterranean regioneastward through Asia and joins the Circum-Pacific Belt in the East Indies. The energy released in earthquakes from this belt is about 15 percent of the world total. There also are striking connected belts of seismic activity, mainly along oceanic ridges—including those in the Arctic Ocean, the Atlantic Ocean, and the western Indian Ocean—and along the rift valleys of East Africa. This global seismicity distribution is best understood in terms of its plate tectonic setting.

Natural forces

Earthquakes are caused by the sudden release of energy within some limited region of the rocks of the Earth. The energy can be released by elastic strain, gravity, chemical reactions, or even the motion of massive bodies. Of all these the release of elastic strain is the most important cause, because this form of energy is the only kind that can be stored in sufficient quantity in the Earth to produce major disturbances. Earthquakes associated with this type of energy release are called tectonic earthquakes.

Tectonics

Tectonic earthquakes are explained by the so-called elastic rebound theory, formulated by the American geologist Harry Fielding Reid after the San Andreas Fault ruptured in 1906, generating the great San Francisco earthquake. According to the theory, a tectonic earthquake occurs when strains in rock masses have accumulated to a point where the resulting stresses exceed the strength of the rocks, and sudden fracturing results. The fractures propagate rapidly through the rock, usually tending in the same direction and sometimes extending many kilometres along a local zone of weakness. In 1906, for instance, the San Andreas Fault slipped along a plane 430 km (270 miles) long. Along this line the ground was displaced horizontally as much as 6 metres (20 feet).

As a fault rupture progresses along or up the fault, rock masses are flung in opposite directions and thus spring back to a position where there is less strain. At any one point this movement may take place not at once but rather in irregular steps; these sudden slowings and restartings give rise to the vibrations that propagate as seismic waves. Such irregular properties of fault rupture are now included in the modeling of earthquake sources, both physically and mathematically. Roughnesses along the fault are referred to as asperities, and places where the rupture slows or stops are said to be fault barriers. Fault rupture starts at the earthquake focus, a spot that in many cases is close to 5–15 km under the surface. The rupture propagates in one or both directions over the fault plane until stopped or slowed at a barrier. Sometimes, instead of being stopped at the barrier, the fault rupture recommences on the far side; at other times the stresses in the rocks break the barrier, and the rupture continues.

Earthquakes have different properties depending on the type of fault slip that causes them (as shown in the figure). The usual fault model has a “strike” (that is, the direction from north taken by a horizontal line in the fault plane) and a “dip” (the angle from the horizontal shown by the steepest slope in the fault). The lower wall of an inclined fault is called the footwall. Lying over the footwall is the hanging wall. When rock masses slip past each other parallel to the strike, the movement is known as strike-slip faulting. Movement parallel to the dip is called dip-slip faulting. Strike-slip faults are right lateral or left lateral, depending on whether the block on the opposite side of the fault from an observer has moved to the right or left. In dip-slip faults, if the hanging-wall block moves downward relative to the footwall block, it is called “normal” faulting; the opposite motion, with the hanging wall moving upward relative to the footwall, produces reverse or thrust faulting.

All known faults are assumed to have been the seat of one or more earthquakes in the past, though tectonic movements along faults are often slow, and most geologically ancient faults are now aseismic (that is, they no longer cause earthquakes). The actual faulting associated with an earthquake may be complex, and it is often not clear whether in a particular earthquake the total energy issues from a single fault plane.

Observed geologic faults sometimes show relative displacements on the order of hundreds of kilometres over geologic time, whereas the sudden slip offsets that produce seismic waves may range from only several centimetres to tens of metres. In the 1976 Tangshan earthquake, for example, a surface strike-slip of about one metre was observed along the causative fault east of Beijing, and in the 1999 Taiwan earthquake the Chelung-pu fault slipped up to eight metres vertically.

Volcanism

A separate type of earthquake is associated with volcanic activity and is called a volcanic earthquake. Yet it is likely that even in such cases the disturbance is the result of a sudden slip of rock masses adjacent to the volcano and the consequent release of elastic strain energy. The stored energy, however, may in part be of hydrodynamic origin due to heat

provided by magma moving in reservoirs beneath the volcano or to the release of gas under pressure.
There is a clear correspondence between the geographic distribution of volcanoes and major earthquakes, particularly in the Circum-Pacific Belt and along oceanic ridges. Volcanic vents, however, are generally several hundred kilometres from the epicentres of most major shallow earthquakes, and many earthquake sources occur nowhere near active volcanoes. Even in cases where an earthquake's focus occurs directly below structures marked by volcanic vents, there is probably no immediate causal connection between the two activities; most likely both are the result of the same tectonic processes.

Artificial induction

Earthquakes are sometimes caused by human activities, including the injection of fluids into deep wells, the detonation of large underground nuclear explosions, the excavation of mines, and the filling of large reservoirs. In the case of deep mining, the removal of rock produces changes in the strain around the tunnels. Slip on adjacent, preexisting faults or outward shattering of rock into the new cavities may occur. In fluid injection, the slip is thought to be induced by premature release of elastic strain, as in the case of tectonic earthquakes, after fault surfaces are lubricated by the liquid. Large underground nuclear explosions have been known to produce slip on already strained faults in the vicinity of the test devices.

Reservoir induction

Of the various earthquake-causing activities cited above, the filling of large reservoirs is among the most important. More than 20 significant cases have been documented in which local seismicity has increased following the impounding of water behind high dams. Often, causality cannot be substantiated, because no data exists to allow comparison of earthquake occurrence before and after the reservoir was filled. Reservoir-induction effects are most marked for reservoirs exceeding 100 metres (330 feet) in depth and 1 cubic km (0.24 cubic mile) in volume. Three sites where such connections have very probably occurred are the Hoover Dam in the United States, the Aswan High Dam in Egypt, and the Kariba Dam on the border between Zimbabwe and Zambia. The most generally accepted explanation for earthquake occurrence in such cases assumes that rocks near the reservoir are already strained from regional tectonic forces to a point where nearby faults are almost ready to slip. Water in the reservoir adds a pressure perturbation that triggers the fault rupture. The pressure effect is perhaps enhanced by the fact that the rocks along the fault have lower strength because of increased water-pore pressure. These factors notwithstanding, the filling of most large reservoirs has not produced earthquakes large enough to be a hazard.
The specific seismic source mechanisms associated with reservoir induction have been established in a few cases. For the main shock at the Koyna Dam and Reservoir in India(1967), the evidence favours strike-slip faulting motion. At both the Kremasta Dam in Greece (1965) and the Kariba Dam in Zimbabwe-Zambia (1961), the generating mechanism was dip-slip on normal faults. By contrast, thrust mechanisms have been determined for sources of earthquakes at the lake behind Nurek Dam in Tajikistan. More than 1,800 earthquakes occurred during the first nine years after water was impounded in this 317-metre-deep reservoir in 1972, a rate amounting to four times the average number of shocks in the region prior to filling.

Seismology and nuclear explosions

In 1958 representatives from several countries, including the United States and the Soviet Union, met to discuss the technical basis for a nuclear test-ban treaty. Among the matters considered was the feasibility of developing effective means with which to detect underground nuclear explosions and to distinguish them seismically from earthquakes. After that conference, much special research was directed to seismology, leading to major advances in seismic signal detection and analysis.

Recent seismological work on treaty verification has involved using high-resolution seismographs in a worldwide network, estimating the yield of explosions, studying wave attenuation in the Earth, determining wave amplitude and frequency spectra discriminants, and applying seismic arrays. The findings of such research have shown that underground nuclear explosions, compared with natural earthquakes, usually generate seismic waves through the body of the Earth that are of much larger amplitude than the surface waves. This telltale difference along with other types of seismic evidence suggest that an international monitoring network of 270 seismographic stations could detect and locate all seismic events over the globe of magnitude 4 and above (corresponding to an explosive yield of about 100 tons of TNT).

Effects of earthquakes

Earthquakes have varied effects, including changes in geologic features, damage to man-made structures, and impact on human and animal life. Most of these effects occur on solid ground, but, since most earthquake foci are actually located under the oceanbottom, severe effects are often observed along the margins of oceans.

Surface phenomena

Earthquakes often cause dramatic geomorphological changes, including ground movements—either vertical or horizontal—along geologic fault traces; rising, dropping, and tilting of the ground surface; changes in the flow of groundwater; liquefaction of sandy ground; landslides; and mudflows. The investigation of topographic changes is aided by geodetic measurements, which are made systematically in a number of countries seriously affected by earthquakes.

Earthquakes can do significant damage to buildings, bridges, pipelines, railways, embankments, and other structures. The type and extent of damage inflicted are related to the strength of the ground motions and to the behaviour of the foundation soils. In the most intensely damaged region, called the meizoseismal area, the effects of a severe earthquake are usually complicated and depend on the topography and the nature of the surface materials. They are often more severe on soft alluvium and unconsolidated sediments than on hard rock. At distances of more than 100 km (60 miles) from the source, the main damage is caused by seismic waves traveling along the surface. In minesthere is frequently little damage below depths of a few hundred metres even though the ground surface immediately above is considerably affected.

Earthquakes are frequently associated with reports of distinctive sounds and lights. The sounds are generally low-pitched and have been likened to the noise of an underground train passing through a station. The occurrence of such sounds is consistent with the passage of high-frequency seismic waves through the ground. Occasionally, luminous flashes, streamers, and bright balls have been reported in the night sky during earthquakes. These lights have been attributed to electric induction in the air along the earthquake source.

Tsunamis

Following certain earthquakes, very long-wavelength water waves in oceans or seas sweep inshore. More properly called seismic sea waves or tsunamis (tsunami is a Japanese word for "harbour wave"), they are commonly referred to as tidal waves, although the attractions of the Moon and Sun play no role in their formation. They sometimes come ashore to great heights—tens of metres above mean tide level—and may be extremely destructive.

The usual immediate cause of a tsunami is sudden displacement in a seabed sufficient to cause the sudden raising or lowering of a large body of water. This deformation may be the fault source of an earthquake, or it may be a submarine landslide arising from an earthquake. Large volcanic eruptions along shorelines, such as those of Thera (c. 1580 BCE) and Krakatoa (1883 CE), have also produced notable tsunamis. The most destructive tsunami ever recorded occurred on December 26, 2004, after an earthquake displaced the seabed off the coast of Sumatra, Indonesia. More than 200,000 people were killed by a series of waves that flooded coasts from Indonesia to Sri Lanka and even washed ashore on the Horn of Africa.

Following the initial disturbance to the sea surface, water waves spread in all directions. Their speed of travel in deep water is given by the formula (Square root of $\sqrt{gh}$), where h is the sea depth and g is the acceleration of gravity. This speed may be considerable—100 metres per second (225 miles per hour) when h is 1,000 metres (3,300 feet). However, the amplitude(that is, the height of disturbance) at the water surface does not exceed a few metres in deep water, and the principal wavelength may be on the order of hundreds of kilometres; correspondingly, the principal wave period—that is, the time interval between arrival of successive crests—may be on the order of tens of minutes. Because of these features, tsunami waves are not noticed by ships far out at sea.

When tsunamis approach shallow water, however, the wave amplitude increases. The waves may occasionally reach a height of 20 to 30 metres above mean sea level in U- and V-shaped harbours and inlets. They characteristically do a great deal of damage in low-lying ground around such inlets. Frequently, the wave front in the inlet is nearly vertical, as in a tidal bore, and the speed of onrush may be on the order of 10 metres per second. In some cases there are several great waves separated by intervals of several minutes or more. The first of these waves is often preceded by an extraordinary recession of water from the shore, which may commence several minutes or even half an hour beforehand.

Organizations, notably in Japan, Siberia, Alaska, and Hawaii, have been set up to provide tsunami warnings. A key development is the Seismic Sea Wave Warning System, an internationally supported system designed to reduce loss of life in the Pacific Ocean. Centred in Honolulu, it issues alerts based on reports of earthquakes from circum-Pacific seismographic stations.

Seiches

Seiches are rhythmic motions of water in nearly landlocked bays or lakes that are sometimes induced by earthquakes and tsunamis. Oscillations of this sort may last for hours or even for a day or two.

The great Lisbon earthquake of 1755 caused the waters of canals and lakes in regions as far away as Scotland and Sweden to go into observable oscillations. Seiche surges in lakes in Texas, in the southwestern United States, commenced between 30 and 40 minutes after the 1964 Alaska earthquake, produced by seismic surface waves passing through the area.

A related effect is the result of seismic waves from an earthquake passing through the seawater following their refraction through the seafloor. The speed of these waves is about 1.5 km (0.9 mile) per second, the speed of sound in water. If such waves meet a ship with sufficient intensity, they give the impression that the ship has struck a submerged object. This phenomenon is called a seaquake.

Intensity and magnitude of earthquakes

Intensity scales

The violence of seismic shaking varies considerably over a single affected area. Because the entire range of observed effects is not capable of simple quantitative definition, the strength of the shaking is commonly estimated by reference to intensity scales that describe the effects in qualitative terms. Intensity scales date from the late 19th and early 20th centuries, before seismographs capable of accurate measurement of ground motion were developed. Since that time, the divisions in these scales have been associated with measurable accelerations of the local ground shaking. Intensity depends, however, in a complicated way not only on ground accelerations but also on the periods and other features of seismic waves, the distance of the measuring point from the source, and the local geologic structure. Furthermore, earthquake intensity, or strength, is distinct from earthquake magnitude, which is a measure of the amplitude, or size, of seismic waves as specified by a seismograph reading. See below Earthquake magnitude.
A number of different intensity scales have been set up during the past century and applied to both current and ancient destructive earthquakes. For many years the most widely used was a 10-point scale devised in 1878 by Michele Stefano de Rossi and François-Alphonse Forel. The scale now generally employed in North America is the Mercalli scale, as modified by Harry O. Wood and Frank Neumann in 1931, in which intensity is considered to be more suitably graded. A 12-point abridged form of the modified Mercalli scale is provided below. Modified Mercalli intensity VIII is roughly correlated with peak accelerations of about one-quarter that of gravity (g = 9.8 metres, or 32.2 feet, per second squared) and ground velocities of 20 cm (8 inches) per second. Alternative scales have been developed in both Japan and Europe for local conditions. The European (MSK) scale of 12 grades is similar to the abridged version of the Mercalli.

Modified Mercalli scale of earthquake intensity

- I. Not felt. Marginal and long-period effects of large earthquakes.
- II. Felt by persons at rest, on upper floors, or otherwise favourably placed to sense tremors.
- III. Felt indoors. Hanging objects swing. Vibrations are similar to those caused by the passing of light trucks. Duration can be estimated.
- IV. Vibrations are similar to those caused by the passing of heavy trucks (or a jolt similar to that caused by a heavy ball striking the walls). Standing automobiles rock. Windows, dishes, doors rattle. Glasses clink, crockery clashes. In the upper range of grade IV, wooden walls and frames creak.

- V. Felt outdoors; direction may be estimated. Sleepers awaken. Liquids are disturbed, some spilled. Small objects are displaced or upset. Doors swing, open, close. Pendulum clocks stop, start, change rate.
- VI. Felt by all; many are frightened and run outdoors. Persons walk unsteadily. Pictures fall off walls. Furniture moves or overturns. Weak plaster and masonry cracks. Small bells ring (church, school). Trees, bushes shake.
- VII. Difficult to stand. Noticed by drivers of automobiles. Hanging objects quivering. Furniture broken. Damage to weak masonry. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices. Waves on ponds; water turbid with mud. Small slides and caving along sand or gravel banks. Large bells ringing. Concrete irrigation ditches damaged.
- VIII. Steering of automobiles affected. Damage to masonry; partial collapse. Some damage to reinforced masonry; none to reinforced masonry designed to resist lateral forces. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed pilings broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
- IX. General panic. Weak masonry destroyed; ordinary masonry heavily damaged, sometimes with complete collapse; reinforced masonry seriously damaged. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas, sand and mud ejected; earthquake fountains, sand craters.
- X. Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, and so on. Sand and mud shifted horizontally on beaches and flat land. Railway rails bent slightly.
- XI. Rails bent greatly. Underground pipelines completely out of service.
- XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into air.

With the use of an intensity scale, it is possible to summarize such data for an earthquake by constructing isoseismal curves, which are lines that connect points of equal intensity. If there were complete symmetry about the vertical through the earthquake's focus, isoseismals would be circles with the epicentre (the point at the surface of the Earthimmediately above where the earthquake originated) as the centre. However, because of the many unsymmetrical geologic factors influencing intensity, the curves are often far from circular. The most probable position of the epicentre is often assumed to be at a point inside the area of highest intensity. In some cases, instrumental data verify this calculation, but not infrequently the true epicentre lies outside the area of greatest intensity.

Earthquake magnitude

Earthquake magnitude is a measure of the "size," or amplitude, of the seismic waves generated by an earthquake source and recorded by seismographs. (The types and nature of these waves are described in the section Seismic waves.) Because the size of earthquakes varies enormously, it is necessary for purposes of comparison to compress the range of wave amplitudes measured on seismograms by means of a mathematical device. In 1935 the

American seismologist Charles F. Richter set up a magnitude scale of earthquakes as the logarithm to base 10 of the maximum seismic wave amplitude (in thousandths of a millimetre) recorded on a standard seismograph (the Wood-Anderson torsion pendulum seismograph) at a distance of 100 km (60 miles) from the earthquake epicentre. Reduction of amplitudes observed at various distances to the amplitudes expected at the standard distance of 100 km is made on the basis of empirical tables. Richter magnitudes M_L are computed on the assumption that the ratio of the maximum wave amplitudes at two given distances is the same for all earthquakes and is independent of azimuth.

Richter first applied his magnitude scale to shallow-focus earthquakes recorded within 600 km of the epicentre in the southern California region. Later, additional empirical tables were set up, whereby observations made at distant stations and on seismographs other than the standard type could be used. Empirical tables were extended to cover earthquakes of all significant focal depths and to enable independent magnitude estimates to be made from body- and surface-wave observations. A current form of the Richter scale is shown in the table.

magnitude level	category	effects	earthquakes per year
less than 1.0 to 2.9	micro	generally not felt by people, though recorded on local instruments	more than 100,000
3.0–3.9	minor	felt by many people; no damage	12,000–100,000
4.0–4.9	light	felt by all; minor breakage of objects	2,000–12,000
5.0–5.9	moderate	some damage to weak structures	200–2,000
6.0–6.9	strong	moderate damage in populated areas	20–200
7.0–7.9	major	serious damage over large areas; loss of life	3–20
8.0 and higher	great	severe destruction and loss of life over large areas	fewer than 3

Richter scale of earthquake magnitude

At the present time a number of different magnitude scales are used by scientists and engineers as a measure of the relative size of an earthquake. The P-wave magnitude (M_b), for one, is defined in terms of the amplitude of the P wave recorded on a standard seismograph. Similarly, the surface-wave magnitude (M_s) is defined in terms of the logarithm of the maximum amplitude of ground motion for surface waves with a wave period of 20 seconds.

As defined, an earthquake magnitude scale has no lower or upper limit. Sensitive seismographs can record earthquakes with magnitudes of negative value and have recorded magnitudes up to about 9.0. (The 1906 San Francisco earthquake, for example, had a Richter magnitude of 8.25.)
A scientific weakness is that there is no direct mechanical basis for magnitude as defined above. Rather, it is an empirical parameter analogous to stellar magnitude assessed by astronomers. In modern practice a more soundly based mechanical measure of earthquake size is used—namely, the seismic moment (M_0). Such a parameter is related to the angular leverage of the forces that produce the slip on the causative fault. It can be calculated both from recorded seismic waves and from field measurements of the size of the fault rupture. Consequently, seismic moment provides a more uniform scale of earthquake size based on classical mechanics. This measure allows a more scientific magnitude to be used called moment magnitude (M_w). It is proportional to the logarithm of the seismic moment; values do not differ greatly from M_s values for moderate earthquakes. Given the above definitions, the great Alaska earthquake of 1964, with a Richter magnitude (M_L) of 8.3, also had the values $M_s = 8.4$, $M_0 = 820 \times 10^{27}$ dyne centimetres, and $M_w = 9.2$.

Earthquake energy

Energy in an earthquake passing a particular surface site can be calculated directly from the recordings of seismic ground motion, given, for example, as ground velocity. Such recordings indicate an energy rate of 10^5 watts per square metre (9,300 watts per square foot) near a moderate-size earthquake source. The total power output of a rupturing fault in a shallow earthquake is on the order of 10^{14} watts, compared with the 10^5 watts generated in rocket motors.
The surface-wave magnitude M_s has also been connected with the surface energy E_s of an earthquake by empirical formulas. These give $E_s = 6.3 \times 10^{11}$ and 1.4×10^{25} ergs for earthquakes of $M_s = 0$ and 8.9, respectively. A unit increase in M_s corresponds to approximately a 32-fold increase in energy. Negative magnitudes M_s correspond to the smallest instrumentally recorded earthquakes, a magnitude of 1.5 to the smallest felt earthquakes, and one of 3.0 to any shock felt at a distance of up to 20 km (12 miles). Earthquakes of magnitude 5.0 cause light damage near the epicentre; those of 6.0 are destructive over a restricted area; and those of 7.5 are at the lower limit of major earthquakes.
The total annual energy released in all earthquakes is about 10^{25} ergs, corresponding to a rate of work between 10 million and 100 million kilowatts. This is approximately one one-thousandth the annual amount of heat escaping from the Earth's interior. Ninety percent of the total seismic energy comes from earthquakes of magnitude 7.0 and higher—that is, those whose energy is on the order of 10^{23} ergs or more.

Frequency

There also are empirical relations for the frequencies of earthquakes of various magnitudes. Suppose N to be the average number of shocks per year for which the magnitude lies in a range about M_s. Then$\log_{10} N = a - bM_s$fits the data well both globally and for particular regions; for example, for shallow earthquakes worldwide, a = 6.7 and b = 0.9 when $M_s > 6.0$. The frequency for larger earthquakes therefore increases by a factor of about 10 when the magnitude is diminished by one unit. The increase in frequency with reduction in M_s falls short, however, of matching the decrease in the energy E. Thus, larger earthquakes are overwhelmingly responsible for most of the total seismic energy release. The number of earthquakes per year with M_b > 4.0 reaches 50,000.

Occurrence of earthquakes

Tectonic associations

Global seismicity patterns had no strong theoretical explanation until the dynamic model called plate tectonics was developed during the late 1960s. This theory holds that the Earth's upper shell, or lithosphere, consists of nearly a dozen large, quasi-stable slabs called plates. The thickness of each of these plates is roughly 80 km (50 miles). The plates move horizontally relative to neighbouring plates at a rate of 1 to 10 cm (0.4 to 4 inches) per year over a shell of lesser strength called the asthenosphere. At the plate edges where there is contact between adjoining plates, boundary tectonic forces operate on the rocks, causing physical and chemical changes in them. New lithosphere is created at oceanic ridges by the upwelling and cooling of magma from the Earth's mantle. The horizontally moving plates are believed to be absorbed at the ocean trenches, where a subductionprocess carries the lithosphere downward into the Earth's interior. The total amount of lithospheric material destroyed at these subduction zones equals that generated at the ridges.
Seismological evidence (such as the location of major earthquake belts) is everywhere in agreement with this tectonic model. Earthquake sources are concentrated along the oceanic ridges, which correspond to divergent plate boundaries. At the subduction zones, which are associated with convergent plate boundaries, intermediate- and deep-focus earthquakes mark the location of the upper part of a dipping lithosphere slab. The focal mechanisms indicate that the stresses are aligned with the dip of the lithosphere underneath the adjacent continent or island arc.
Some earthquakes associated with oceanic ridges are confined to strike-slip faults, called transform faults, that offset the ridge crests. The majority of the earthquakes occurring along such horizontal shear faults are characterized by slip motions. Also in agreement with the plate tectonics theory is the high seismicity encountered along the edges of plates where they slide past each other. Plate boundaries of this kind, sometimes called fracture zones, include the San Andreas Fault in California and the North Anatolian fault system in Turkey. Such plate boundaries are the site of interplate earthquakes of shallow focus.

The low seismicity within plates is consistent with the plate tectonic description. Small to large earthquakes do occur in limited regions well within the boundaries of plates; however, such intraplate seismic events can be explained by tectonic mechanisms other than plate boundary motions and their associated phenomena.

Shallow, intermediate, and deep foci

Most parts of the world experience at least occasional shallow earthquakes—those that originate within 60 km (40 miles) of the Earth's outer surface. In fact, the great majority of earthquake foci are shallow. It should be noted, however, that the geographic distribution of smaller earthquakes is less completely determined than more severe quakes, partly because the availability of relevant data is dependent on the distribution of observatories.

Of the total energy released in earthquakes, 12 percent comes from intermediate earthquakes—that is, quakes with a focal depth ranging from about 60 to 300 km. About 3 percent of total energy comes from deeper earthquakes. The frequency of occurrence falls off rapidly with increasing focal depth in the intermediate range. Below intermediate depth the distribution is fairly uniform until the greatest focal depths, of about 700 km (430 miles), are approached.

The deeper-focus earthquakes commonly occur in patterns called Benioff zones that dip into the Earth, indicating the presence of a subducting slab. Dip angles of these slabs average about 45°, with some shallower and others nearly vertical. Benioff zones coincide with tectonically active island arcs such as Japan, Vanuatu, Tonga, and the Aleutians, and they are normally but not always associated with deep ocean trenches such as those along the South American Andes. Exceptions to this rule include Romania and the Hindu Kush mountain system. In most Benioff zones, intermediate- and deep-earthquake foci lie in a narrow layer, although recent precise hypocentral locations in Japan and elsewhere show two distinct parallel bands of foci 20 km apart.

Aftershocks, foreshocks, and swarms

Usually, a major or even moderate earthquake of shallow focus is followed by many lesser-size earthquakes close to the original source region. This is to be expected if the faultrupture producing a major earthquake does not relieve all the accumulated strain energy at once. In fact, this dislocation is liable to cause an increase in the stress and strain at a number of places in the vicinity of the focal region, bringing crustal rocks at certain points close to the stress at which fracture occurs. In some cases an earthquake may be followed by 1,000 or more aftershocks a day.

Sometimes a large earthquake is followed by a similar one along the same fault source within an hour or perhaps a day. An extreme case of this is multiple earthquakes. In most instances, however, the first principal earthquake of a series is much more severe than the aftershocks. In general, the number of aftershocks per day decreases with time. The aftershock frequency is roughly inversely proportional to the time since the occurrence of the largest earthquake of the series.

Most major earthquakes occur without detectable warning, but some principal earthquakes are preceded by foreshocks. In another common pattern, large numbers of small earthquakes may occur in a region for months without a major earthquake. In the Matsushiro region of Japan, for instance, there occurred between August 1965 and August 1967 a series of hundreds of thousands of earthquakes, some sufficiently strong (up to Richter magnitude 5) to cause property damage but no casualties. The maximum frequency was 6,780 small earthquakes on April 17, 1966. Such series of earthquakes are called earthquake swarms. Earthquakes associated with volcanic activity often occur in swarms, though swarms also have been observed in many nonvolcanic regions.

The Study Of Earthquakes

Seismic waves

Principal types of seismic waves

Seismic waves generated by an earthquake source are commonly classified into three main types. The first two, the P (or primary) and S (or secondary) waves, propagate within the body of the Earth, while the third, consisting of Love and Rayleigh waves, propagatesalong its surface. The existence of these types of seismic waves was mathematically predicted during the 19th century, and modern comparisons show that there is a close correspondence between such theoretical calculations and actual measurements of the seismic waves.

The P seismic waves travel as elastic motions at the highest speeds. They are longitudinal waves that can be transmitted by both solid and liquid materials in the Earth's interior. With P waves, the particles of the medium vibrate in a manner similar to sound waves—the transmitting media is alternately compressed and expanded. The slower type of body wave, the S wave, travels only through solid material. With S waves, the particle motion is transverse to the direction of travel and involves a shearing of the transmitting rock.

Because of their greater speed, P waves are the first to reach any point on the Earth's surface. The first P-wave onset starts from the spot where an earthquake originates. This point, usually at some depth within the Earth, is called the focus, or hypocentre. The point at the surface immediately above the focus is known as the epicentre.

Love and Rayleigh waves are guided by the free surface of the Earth. They follow along after the P and S waves have passed through the body of the planet. Both Love and Rayleigh waves involve horizontal particle motion, but only the latter type has vertical ground displacements. As Love and Rayleigh waves travel, they disperse into long wave trains, and, at substantial distances from the source in alluvial basins, they cause much of the shaking felt during earthquakes.

Properties of seismic waves

At all distances from the focus, mechanical properties of the rocks, such as incompressibility, rigidity, and density, play a role in the speed with which the waves travel and the shape and duration of the wave trains. The layering of the rocks and the physical properties of surface soil also affect wave characteristics. In most cases, elastic behaviour occurs in earthquakes, but strong shaking of surface soils from the incident seismic waves sometimes results in nonelastic behaviour, including slumping (that is, the downward and outward movement of unconsolidated material) and the liquefaction of sandy soil.

When a seismic wave encounters a boundary that separates rocks of different elastic properties, it undergoes reflection and refraction. There is a special complication because conversion between the wave types usually also occurs at such a boundary: an incident Por S wave can yield reflected P and S waves and refracted P and S waves. Boundaries between structural layers also give rise to diffracted and scattered waves. These additional waves are in part responsible for the complications observed in ground motion during earthquakes. Modern research is concerned with computing synthetic records of ground motion that are realistic in comparison with observed ground shaking, using the theory of waves in complex structures.

The frequency range of seismic waves is large, from as high as the audible range (greater than 20 hertz) to as low as the frequencies of the free oscillations of the whole Earth, with the gravest period being 54 minutes (see below Long-period oscillations of the globe). Attenuation of the waves in rock imposes high-frequency limits, and in small to moderate earthquakes the dominant frequencies extend in surface waves from about 1 to 0.1 hertz.

The amplitude range of seismic waves is also great in most earthquakes. Displacement of the ground ranges from 10^{-10} to 10^{-1} metre (4^{-12} to 4 inches). In the greatest earthquakes the ground amplitude of the predominant P waves may be several centimetres at periods of two to five seconds. Very close to the seismic sources of great earthquakes, investigators have measured large wave amplitudes with accelerations of the ground exceeding that of gravity (9.8 metres, or 32.2 feet, per second squared) at high frequencies and ground displacements of 1 metre at low frequencies.

Measurement of seismic waves

Seismographs and accelerometers

Seismographs are used to measure ground motion in both earthquakes and microseisms (small oscillations described below). Most of these instruments are of the pendulum type. Early mechanical seismographs had a pendulum of large mass (up to several tons) and produced seismograms by scratching a line on smoked paper on a rotating drum. In later instruments, seismograms were recorded by means of a ray of light from the mirror of a galvanometer through which passed an electric current generated by electromagnetic induction when the pendulum of the seismograph moved. Technological developments in electronics have given rise to higher-precision pendulum seismometers and sensors of ground motion. In these instruments the electric voltages produced by motions of the pendulum or the equivalent are passed through electronic circuitry to amplify and digitize the ground motion for more exact readings.

Generally speaking, seismographs are divided into three types: short-period, long- (or intermediate-) period, and ultralong-period, or broadband, instruments. Short-period instruments are used to record P and S body waves with high magnification of the ground motion. For this purpose, the seismograph response is shaped to peak at a period of about one second or less. The intermediate-period instruments of the type used by the World-Wide Standardized Seismographic Network (described in the section Earthquake observatories) had a response maximum at about 20 seconds. Recently, in order to provide as much flexibility as possible for research work, the trend has been toward the operation of very broadband seismographs with digital representation of the signals. This is usually accomplished with very long-period pendulums and electronic amplifiers that pass signals in the band between 0.005 and 50 hertz.

When seismic waves close to their source are to be recorded, special design criteria are needed. Instrument sensitivity must ensure that the largest ground movements can be recorded without exceeding the upper scale limit of the device. For most seismological and engineering purposes the wave frequencies that must be recorded are higher than 1 hertz, and so the pendulum or its equivalent can be small. For this reason accelerometers that measure the rate at which the ground velocity is changing have an advantage for strong-motion recording. Integration is then performed to estimate ground velocity and displacement. The ground accelerations to be registered range up to two times that of gravity. Recording such accelerations can be accomplished mechanically with short torsion suspensions or force-balance mass-spring systems.

Because many strong-motion instruments need to be placed at unattended sites in ordinary buildings for periods of months or years before a strong earthquake occurs, they usually record only when a trigger mechanism is actuated with the onset of ground motion. Solid-state memories are now used, particularly with digital recordinginstruments, making it possible to preserve the first few seconds before the trigger starts the permanent recording and to store digitized signals on magnetic cassette tape or on a memory chip. In past design absolute timing was not provided on strong-motion records but only accurate relative time marks; the present trend, however, is to provide Universal Time (the local mean time of the prime meridian) by means of special radio receivers, small crystal clocks, or GPS (global positioning system) receivers from satellite clocks.

The prediction of strong ground motion and response of engineered structures in earthquakes depends critically on measurements of the spatial variability of earthquake intensities near the seismic wave source. In an effort to secure such measurements, special arrays of strong-motion seismographs have been installed in areas of high seismicity around the world. Large-aperture seismic arrays (linear dimensions on the order of 1 to 10 km, or 0.6 to 6 miles) of strong-motion accelerometers can now be used to improve estimations of speed, direction of propagation, and types of seismic wavecomponents. Particularly important for full understanding of seismic wave patterns at the ground surface is measurement of the variation of wave motion with depth. To aid in this effort, special digitally recording seismometers have been installed in deep boreholes.

Ocean-bottom measurements

Because 70 percent of the Earth's surface is covered by water, there is a need for ocean-bottom seismometers to augment the global land-based system of recording stations. Field tests have established the feasibility of extensive long-term recording by instruments on the seafloor. Japan already has a semipermanent seismograph system of this type that was placed on the seafloor off the Pacific coast of central Honshu in 1978 by means of a cable.

Because of the mechanical difficulties of maintaining permanent ocean-bottom instrumentation, different systems have been considered. They all involve placement of instruments on the bottom of the ocean, though they employ various mechanisms for data transmission. Signals may be transmitted to the ocean surface for retransmission by auxiliary apparatus or transmitted via cable to a shore-based station. Another system is designed to release its recording device automatically, allowing it to float to the surface for later recovery.

The use of ocean-bottom seismographs should yield much-improved global coverage of seismic waves and provide new information on the seismicity of oceanic regions. Ocean-bottom seismographs will enable investigators to determine the details of the crustal structure of the seafloor and, because of the relative thinness of the oceanic crust, should make it possible to collect clear seismic information about the upper mantle. Such systems are also expected to provide new data on plate boundaries, on the origin and propagation of microseisms, and on the nature of ocean-continent margins.

Measuring microseisms

Small ground motions known as microseisms are commonly recorded by seismographs. These weak wave motions are not generated by earthquakes, and they complicate accurate recording of the latter. However, they are of scientific interest because their form is related to the Earth's surface structure.

Some microseisms have local causes—for example, those due to traffic or machinery or due to local wind effects, storms, and the action of rough surf against an extended steep coast. Another class of microseisms exhibits features that are very similar on records traced at earthquake observatories that are widely separated, including approximately simultaneous occurrence of maximum amplitudes and similar wave frequencies. These microseisms may persist for many hours and have more or less regular periods of about five to eight seconds. The largest amplitudes of such microseisms are on the order of 10^{-3}cm (0.0004 inch) and occur in coastal regions. The amplitudes also depend to some extent on local geologic structure. Some microseisms are produced when large standing water waves are formed far out at sea. The period of this type of microseism is half that of the standing wave.

Observation of earthquakes

Earthquake observatories

Worldwide during the late 1950s, there were only about 700 seismographic stations, which were equipped with seismographs of various types and frequency responses. Few instruments were calibrated; actual ground motions could not be measured, and timing errors of several seconds were common. The World-Wide Standardized Seismographic Network (WWSSN), the first modern worldwide standardized system, was established to help remedy this situation. Each station of the WWSSN had six seismographs—three short-period and three long-period seismographs. Timing and accuracy were maintained by crystal clocks, and a calibration pulse was placed daily on each record. By 1967 the WWSSN consisted of about 120 stations distributed over 60 countries. The resulting data provided the basis for significant advances in research on earthquake mechanisms, global tectonics, and the structure of the Earth's interior.

By the 1980s a further upgrading of permanent seismographic stations began with the installation of digital equipment by a number of organizations. Among the global networks of digital seismographic stations now in operation are the Seismic Research Observatories in boreholes 100 metres (330 feet) deep and modified high-gain, long-period surface observatories. The Global Digital Seismographic Network in particular has remarkable capability, recording all motions from Earth tides to microscopic ground motions at the level of local ground noise. At present there are about 128 sites. With this system the long-term seismological goal will have been accomplished to equip global observatories with seismographs that can record every small earthquake anywhere over a broad band of frequencies.

Locating earthquake epicentres

Many observatories make provisional estimates of the epicentres of important earthquakes. These estimates provide preliminary information locally about particular earthquakes and serve as first approximations for the calculations subsequently made by large coordinating centres.

If an earthquake's epicentre is less than 105° away from an observatory, the epicentre's position can often be estimated from the readings of three seismograms recording perpendicular components of the ground motion. For a shallow earthquake the epicentral distance is indicated by the interval between the arrival times of P and S waves; the azimuth and angle of wave emergence at the surface are indicated by a comparison of the sizes and directions of the first movements shown in the seismograms and by the relative sizes of later waves, particularly surface waves. It should be noted, however, that in certain regions the first wave movement at a station arrives from a direction differing from the azimuth toward the epicentre. This anomaly is usually explained by strong variations in geologic structures.

When data from more than one observatory are available, an earthquake's epicentre may be estimated from the times of travel of the P and S waves from source to recorder. In many seismically active regions, networks of seismographs with telemetry transmission and centralized timing and recording are common. Whether analog or digital recording is used, such integrated systems greatly simplify observatory work: multichannel signal displays make identification and timing of phase onsets easier and more reliable. Moreover, online microprocessors can be programmed to pick automatically, with some degree of confidence, the onset of a significant common phase, such as P, by correlation of waveforms from parallel network channels. With the aid of specially designed computer programs, seismologists can then locate distant earthquakes to within about 10 km (6 miles) and the epicentre of a local earthquake to within a few kilometres.

Catalogs of earthquakes felt by humans and of earthquake observations have appeared intermittently for many centuries. The earliest known list of instrumentally recorded earthquakes with computed times of origin and epicentres is for the period 1899–1903. In subsequent years, cataloging of earthquakes has become more uniform and complete. Especially valuable is the service provided by the International Seismological Centre (ISC) at Newbury, Eng. Each month it receives more than 1,000,000 readings from more than 2,000 stations worldwide and preliminary estimates of the locations of approximately 1,600 earthquakes from national and regional agencies and observatories. The ISC publishes a monthly bulletin—with about a two-year delay—that provides all available information on each of more than 5,000 earthquakes.

Various national and regional centres control networks of stations and act as intermediaries between individual stations and the international organizations. Examples of long-standing national centres include the Japan Meteorological Agency and United States National Earthquake Information Center in Colorado (a subdivision of the United States Geological Survey). These centres normally make estimates of the magnitudes, epicentres, origin times, and focal depths of local earthquakes. On the Internet, data on global seismicity is continually accessible through the Web site of the Incorporated Research Institutions for Seismology (IRIS).

An important research technique is to infer the character of faulting in an earthquake from the recorded seismograms. For example, observed distributions of the directions of the first onsets in waves arriving at the Earth’s surface have been effectively used. Onsets are called “compressional” or “dilatational” according to whether the direction is away from or toward the focus, respectively. A polarity pattern becomes recognizable when the directions of the P-wave onsets are plotted on a map—there are broad areas in which the first onsets are predominantly compressions, separated from predominantly dilatational areas by nodal curves near which the P-wave amplitudes are abnormally small.

In 1926 the American geophysicist Perry E. Byerly used patterns of P onsets over the entire globe to infer the orientation of the fault plane in a large earthquake. The polarity method yields two P-nodal curves at the Earth’s surface; one curve is in the plane containing the assumed fault, and the other is in the plane (called the auxiliary plane) that passes through the focus and is perpendicular to the forces of the plane. The recent availability of worldwide broad-based digital recording has enabled computer programs to be written that estimate the fault mechanism and seismic moment from the complete pattern of seismic wave arrivals. Given a well-determined pattern at a number of earthquake observatories, it is possible to locate two planes, one of which is the plane containing the fault.

Earthquake prediction

Observation and interpretation of precursory phenomena

The search for periodic cycles in earthquake occurrence is an old one. Generally, periodicities in time and space for major earthquakes have not been widely detected or accepted. One problem is that long-term earthquake catalogs are not homogeneous in their selection and reporting. The most extensive catalog of this kind comes from Chinaand begins about 700 BCE. The catalog contains some information on about 1,000 destructive earthquakes. The sizes of these earthquakes have been assessed from the reports of damage, intensity, and shaking.

Another approach to the statistical occurrence of earthquakes involves the postulation of trigger forces that initiate the rupture. Such forces have been attributed to severe weatherconditions, volcanic activity, and tidal forces, for example. Usually correlations are made between the physical phenomena assumed to provide the trigger and the repetition of earthquakes. Inquiry must always be made to discover whether a causative link is actually present, but in no cases to the present has a trigger mechanism, at least for moderate to large earthquakes, been unequivocally found that satisfies the various necessary criteria.

Statistical methods also have been tried with populations of regional earthquakes. It has been suggested, but never established generally, that the slope b of the regression line between the logarithm of the number of earthquakes and the magnitude for a regionmay change characteristically with time. Specifically, the claim is that the b value for the population of foreshocks of a major earthquake may be significantly smaller than the mean b value for the region averaged over a long interval of time.

The elastic rebound theory of earthquake sources allows rough prediction of the occurrence of large shallow earthquakes. Harry F. Reid gave, for example, a crude forecast of the next great earthquake near San Francisco. (The theory also predicted, of course, that the place would be along the San Andreas or an associated fault.) The geodetic data indicated that during an interval of 50 years relative displacements of 3.2 metres (10.5 feet) had occurred at distant points across the fault. The maximum elastic-rebound offset along the fault in the 1906 earthquake was 6.5 metres. Therefore, $(6.5 \div 3.2) \times 50$, or about 100, years would again elapse before sufficient strain accumulated for the occurrence of an earthquake comparable to that of 1906. The premises are that the regional strain will grow uniformly and that various constraints have not been altered by the great 1906 rupture itself (such as by the onset of slow fault slip). Such strain rates are now being more adequately measured along a number of active faults such as the San Andreas, using networks of GPS sensors.

For many years prediction research has been influenced by the basic argument that strain accumulates in the rock masses in the vicinity of a fault and results in crustal deformation. Deformations have been measured in the horizontal direction along active faults (by trilateration and triangulation) and in the vertical direction by precise leveling and tiltmeters. Some investigators believe that changes in groundwater level occur prior to earthquakes; variations of this sort have been reported mainly from China. Because water levels in wells respond to a complex array of factors such as rainfall, such factors will have to be removed if changes in water level are to be studied in relation to earthquakes.

The theory of dilatancy (that is, an increase in volume) of rock prior to rupture once occupied a central position in discussions of premonitory phenomena of earthquakes, but it now receives less support. It is based on the observation that many solids exhibit dilatancy during deformation. For earthquake prediction the significance of dilatancy, if real, is in its effects on various measurable quantities of the Earth's crust, such as seismic velocities, electric resistivity, and ground and water levels. The consequences of dilatancy for earthquake prediction are summarized in the table. The best-studied consequence is the effect on seismic velocities. The influence of internal cracks and pores on the elastic properties of rocks can be clearly demonstrated in laboratory measurements of those properties as a function of hydrostatic pressure. In the case of saturated rocks, experiments predict—for shallow earthquakes—that dilatancy occurs as a portion of the crust is stressed to failure, causing a decrease in the velocities of seismic waves. Recovery of velocity is brought about by subsequent rise of the pore pressure of water, which also has the effect of weakening the rock and enhancing fault slip.

Strain buildup in the focal region may have measurable effects on other observable properties, including electrical conductivity and gas concentration. Because the electrical conductivity of rocks depends largely on interconnected water channels within the rocks, resistivity may increase before the cracks become saturated. As pore fluid is expelled from the closing cracks, the local water table would rise and concentrations of gases such as radioactive radon would increase. No unequivocal confirming measurements have yet been published.

Geologic methods of extending the seismicity record back from the present also are being explored. Field studies indicate that the sequence of surface ruptures along major active faults associated with large earthquakes can sometimes be constructed. An example is the series of large earthquakes in Turkey in the 20th century, which were caused mainly by successive westward ruptures of the North Anatolian Fault. Liquefaction effects preserved in beds of sand and peat have provided evidence—when radiometric dating methods are used—for large paleoearthquakes extending back for more than 1,000 years in many seismically active zones, including the Pacific Northwest coast of the United States.

Less well-grounded precursory phenomena, particularly earthquake lights and animal behaviour, sometimes draw more public attention than the precursors discussed above. Many reports of unusual lights in the sky and abnormal animal behaviour preceding earthquakes are known to seismologists, mostly in anecdotal form. Both these phenomena are usually explained in terms of a release of gases prior to earthquakes and electric and acoustic stimuli of various types. At present there is no definitive experimental evidence to support claims that animals sometimes sense the coming of an earthquake.

Methods of reducing earthquake hazards

Considerable work has been done in seismology to explain the characteristics of the recorded ground motions in earthquakes. Such knowledge is needed to predict ground motions in future earthquakes so that earthquake-resistant structures can be designed. Although earthquakes cause death and destruction through such secondary effects as landslides, tsunamis, fires, and fault rupture, the greatest losses—both of lives and of property—result from the collapse of man-made structures during the violent shaking of the ground. Accordingly, the most effective way to mitigate the damage of earthquakes from an engineering standpoint is to design and construct structures capable of withstanding strong ground motions.

Interpreting recorded ground motions

Most elastic waves recorded close to an extended fault source are complicated and difficult to interpret uniquely. Understanding such near-source motion can be viewed as a three-part problem. The first part stems from the generation of elastic waves by the slipping fault as the moving rupture sweeps out an area of slip along the fault plane within a given time. The pattern of waves produced is dependent on several parameters, such as fault dimension and rupture velocity. Elastic waves of various types radiate from the vicinity of the moving rupture in all directions. The geometry and frictional properties of the fault critically affect the pattern of radiation from it.

The second part of the problem concerns the passage of the waves through the intervening rocks to the site and the effect of geologic conditions. The third part involves the conditions at the recording site itself, such as topography and highly attenuating soils. All these questions must be considered when estimating likely earthquake effects at a site of any proposed structure.

Experience has shown that the ground strong-motion recordings have a variable pattern in detail but predictable regular shapes in general (except in the case of strong multiple earthquakes). An example of actual shaking of the ground (acceleration, velocity, and displacement) recorded during an earthquake is given in the . In a strong horizontal shaking of the ground near the fault source, there is an initial segment of motion made up mainly of P waves, which frequently manifest themselves strongly in the vertical motion. This is followed by the onset of S waves, often associated with a longer-period pulse of ground velocity and displacement related to the near-site fault slip or fling. This pulse is often enhanced in the direction of the fault rupture and normal to it. After the Sonset there is shaking that consists of a mixture of S and P waves, but the S motions become dominant as the duration increases. Later, in the horizontal component, surface waves dominate, mixed with some S body waves. Depending on the distance of the site from the fault and the structure of the intervening rocks and soils, surface waves are spread out into long trains.

Constructing seismic hazard maps

In many regions, seismic expectancy maps or hazard maps are now available for planning purposes. The anticipated intensity of ground shaking is represented by a number called the peak acceleration or the peak velocity.

To avoid weaknesses found in earlier earthquake hazard maps, the following general principles are usually adopted today:

1. The map should take into account not only the size but also the frequency of earthquakes.
2. The broad regionalization pattern should use historical seismicity as a database, including the following factors: major tectonic trends, acceleration attenuation curves, and intensity reports.
3. Regionalization should be defined by means of contour lines with design parameters referred to ordered numbers on neighbouring contour lines (this procedure minimizes sensitivity concerning the exact location of boundary lines between separate zones).
4. The map should be simple and not attempt to microzone the region.
5. The mapped contoured surface should not contain discontinuities, so that the level of hazard progresses gradually and in order across any profile drawn on the map.

Developing resistant structures

Developing engineered structural designs that are able to resist the forces generated by seismic waves can be achieved either by following building codes based on hazard maps or by appropriate methods of analysis. Many countries reserve theoretical structural analyses for the larger, more costly, or critical buildings to be constructed in the most seismically active regions, while simply requiring that ordinary structures conform to local building codes. Economic realities usually determine the goal, not of preventing all damage in all earthquakes but of minimizing damage in moderate, more common earthquakes and ensuring no major collapse at the strongest intensities. An essential part of what goes into engineering decisions on design and into the development and revision of earthquake-resistant design codes is therefore seismological, involving measurement of strong seismic waves, field studies of intensity and damage, and the probability of earthquake occurrence.

Earthquake risk can also be reduced by rapid post-earthquake response. Strong-motion accelerographs have been connected in some urban areas, such as Los Angeles, Tokyo, and Mexico City, to interactive computers. The recorded waves are correlated with seismic intensity scales and rapidly displayed graphically on regional maps via the World Wide Web.

Exploration of the Earth's interior with seismic waves

Seismological tomography

Seismological data on the Earth's deep structure come from several sources. These include P and S waves in earthquakes and nuclear explosions, the dispersion of surface waves from distant earthquakes, and vibrations of the whole Earth from large earthquakes.

One of the major aims of seismology is to infer the minimum set of properties of the Earth's interior that will explain recorded seismic wave trains in detail. Notwithstanding the tremendous progress made in the exploration of the Earth's deep structure during the first half of the 20th century, realization of this goal was severely limited until the 1960s because of the laborious effort required to evaluate theoretical models and to process the large amounts of earthquake data recorded. The application of high-speed computers with their enormous storage and rapid retrieval capabilities opened the way for major advances in both theoretical work and data handling.

Since the mid-1970s, researchers have studied realistic models of the Earth's structure that include continental and oceanic boundaries, mountains, and river valleys rather than simple structures such as those involving variation only with depth. In addition, various technical developments have benefited observational seismology. For example, the implications of seismic exploratory techniques developed by the petroleum industry (such as seismic reflection) have been recognized and the procedures adopted. Equally significant has been the application of three-dimensional imaging methods to the exploration of the Earth's deep structure. This has been made possible by the development of very fast microprocessors and computers with peripheral display equipment.

The major method for determining the structure of the Earth's deep interior is the detailed analysis of seismograms of seismic waves. (Such earthquake readings also provide estimates of wave velocities, density, and elastic and inelastic parameters in the Earth.) The primary procedure is to measure the travel times of various wave types, such as P and S, from their

source to the recording seismograph. First, however, identification of each wave type with its ray path through the Earth must be made.
Seismic rays for many paths of P and S waves leaving the earthquake focus F are shown in the figure. Rays corresponding to waves that have been reflected at the Earth's outer surface (or possibly at one of the interior discontinuity surfaces) are denoted as PP, PS, SP, PSS, and so on. For example, PS corresponds to a wave that is of P type before surface reflection and of S type afterward. In addition, there are rays such as pPP, sPP, and sPS, the symbols p and s corresponding to an initial ascent to the outer surface as P or S waves, respectively, from a deep focus.

An especially important class of rays is associated with a discontinuity surface separating the central core of the Earth from the mantle at a depth of about 2,900 km (1,800 miles) below the outer surface. The symbol c is used to indicate an upward reflection at this discontinuity. Thus, if a P wave travels down from a focus to the discontinuity surface in question, the upward reflection into an S wave is recorded at an observing station as the ray PcS and similarly with PcP, ScS, and ScP. The symbol K is used to denote the part (of Ptype) of the path of a wave that passes through the liquid central core. Thus, the ray SKScorresponds to a wave that starts as an S wave, is refracted into the central core as a Pwave, and is refracted back into the mantle, wherein it finally emerges as an S wave. Such rays as SKKS correspond to waves that have suffered an internal reflection at the boundary of the central core.
The discovery of the existence of an inner core in 1936 by the Danish seismologist Inge Lehmann made it necessary to introduce additional basic symbols. For paths of waves inside the central core, the symbols i and I are used analogously to c and K for the whole Earth; therefore, i indicates reflection upward at the boundary between the outer and inner portions of the central core, and I corresponds to the part (of P type) of the path of a wave that lies inside the inner portion. Thus, for instance, discrimination needs to be made between the rays PKP, PKiKP, and PKIKP. The first of these corresponds to a wave that has entered the outer part of the central core but has not reached the inner core, the second to one that has been reflected upward at the inner core boundary, and the third to one that has penetrated into the inner portion.
By combining the symbols p, s, P, S, c, K, i, and I in various ways, notation is developed for all the main rays associated with body earthquake waves. The symbol J has been introduced to correspond to S waves in the inner core, should evidence ever be found for such waves.
Finally, the use of times of travel along rays to infer hidden structure is analogous to the use of X-rays in medical tomography. The method involves reconstructing an image of internal anomalies from measurements made at the outer surface. Nowadays, hundreds of thousands of travel times of P and S waves are available in earthquake catalogs for the tomographic imaging of the Earth's interior and the mapping of internal structure.

Structure of the Earth's interior

Studies with earthquake recordings have given a picture inside the Earth of a solid but layered and flow-patterned mantle about 2,900 km (1,800 miles) thick, which in places lies within 10 km (6 miles) of the surface under the oceans.
The thin surface rock layer surrounding the mantle is the crust, whose lower boundary is called the Mohorovičić discontinuity. In normal continental regions the crust is about 30 to 40 km thick; there is usually a superficial low-velocity sedimentary layer underlain by a zone in which seismic velocity increases with depth. Beneath this zone there is a layer in which P-

wave velocities in some places fall from 6 to 5.6 km per second. The middle part of the crust is characterized by a heterogeneous zone with P velocities of nearly 6 to 6.3 km per second. The lowest layer of the crust (about 10 km thick) has significantly higher Pvelocities, ranging up to nearly 7 km per second.

In the deep ocean there is a sedimentary layer that is about 1 km thick. Underneath is the lower layer of the oceanic crust, which is about 4 km thick. This layer is inferred to consist of basalt that formed where extrusions of basaltic magma at oceanic ridges have been added to the upper part of lithospheric plates as they spread away from the ridge crests. This crustal layer cools as it moves away from the ridge crest, and its seismic velocities increase correspondingly.

Below the mantle lies a shell that is 2,255 km thick, which seismic waves show to have the properties of a liquid. At the very centre of the planet is a separate solid core with a radius of 1,216 km. Recent work with observed seismic waves has revealed three-dimensional structural details inside the Earth, especially in the crust and lithosphere, under the subduction zones, at the base of the mantle, and in the inner core. These regional variations are important in explaining the dynamic history of the planet.

Long-period oscillations of the globe

Sometimes earthquakes are large enough to cause the whole Earth to ring like a bell. The deepest tone of vibration of the planet is one with a period (the length of time between the arrival of successive crests in a wave train) of 54 minutes. Knowledge of these vibrations has come from a remarkable extension in the range of periods of ground movements that can be recorded by modern digital long-period seismographs that span the entire allowable spectrum of earthquake wave periods: from ordinary P waves with periods of tenths of seconds to vibrations with periods on the order of 12 and 24 hours such as those that occur in Earth tidal movements.

The measurements of vibrations of the whole Earth provide important information on the properties of the interior of the planet. It should be emphasized that these free vibrationsare set up by the energy release of the earthquake source but continue for many hours and sometimes even days. For an elastic sphere such as the Earth, two types of vibrations are known to be possible. In one type, called S modes, or spheroidal vibrations, the motions of the elements of the sphere have components along the radius as well as along the tangent. In the second type, which are designated as T modes, or torsional vibrations, there is shear but no radial displacements. The nomenclature is nSl and nTl, where the letters n and l are related to the surfaces in the vibration at which there is zero motion. Four examples are illustrated in the figure. The subscript n gives a count of the number of internal zero-motion (nodal) surfaces, and l indicates the number of surface nodal lines

Several hundred types of S and T vibrations have been identified and the associated periods measured. The amplitudes of the ground motion in the vibrations have been determined for particular earthquakes, and, more important, the attenuation of each component vibration has been measured. The dimensionless measure of this decay constant is called the quality factor Q. The greater the value of Q, the less the wave or vibration damping. Typically, for ${}_oS_{10}$ and ${}_oT_{10}$, the Q values are about 250.

The rate of decay of the vibrations of the whole Earth with the passage of time can be seen in the figure, where they appear superimposed for 20 hours of the 12-hour tidal deformations of the Earth. At the bottom of the figure these vibrations have been split up into a series of peaks, each with a definite frequency, similar to that of the spectrum of light. Such a

spectrum indicates the relative amplitude of each harmonic present in the free oscillations. If the physical properties of the Earth's interior were known, all these individual peaks could be calculated directly. Instead, the internal structure must be estimated from the observed peaks.
Recent research has shown that observations of long-period oscillations of the Earth discriminate fairly finely between different Earth models. In applying the observations to improve the resolution and precision of such representations of the planet's internal structure, a considerable number of Earth models are set up, and all the periods of their free oscillations are computed and checked against the observations. Models can then be successively eliminated until only a small range remains. In practice, the work starts with existing models; efforts are made to amend them by sequential steps until full compatibility with the observations is achieved, within the uncertainties of the observations. Even so, the resulting computed Earth structure is not a unique solution to the problem.

Extraterrestrial seismic phenomena

Space vehicles have carried equipment to the surface of the Moon and Mars with which to record seismic waves, and seismologists on Earth have received telemetered signals from seismic events in both cases.
By 1969, seismographs had been placed at six sites on the Moon during the U.S. Apollo missions. Recording of seismic data ceased in September 1977. The instruments detected between 600 and 3,000 moonquakes during each year of their operation, though most of these seismic events were very small. The ground noise on the lunar surface is low compared with that of the Earth, so that the seismographs could be operated at very high magnifications. Because there was more than one station on the Moon, it was possible to use the arrival times of P and S waves at the lunar stations from the moonquakes to determine foci in the same way as is done on the Earth.
Moonquakes are of three types. First, there are the events caused by the impact of lunar modules, booster rockets, and meteorites. The lunar seismograph stations were able to detect meteorites hitting the Moon's surface more than 1,000 km (600 miles) away. The two other types of moonquakes had natural sources in the Moon's interior: they presumably resulted from rock fracturing, as on Earth. The most common type of natural moonquake had deep foci, at depths of 600 to 1,000 km; the less common variety had shallow focal depths.
Seismological research on Mars has been less successful. Only one of the seismometers carried to the Martian surface by the U.S. Viking landers during the mid-1970s remained operational, and only one potential marsquake was detected in 546 Martian days.

Major Historical Earthquakes

Major historical earthquakes are listed chronologically in the table.

year	**affected area**	**magnitude***	**intensity***	**approximate number of deaths**	**comments**

year	affected area	magnitude*	intensity*	approximate number of deaths	comments

*Measures may differ from other sources.

Data sources: National Oceanic and Atmospheric Administration, National Geophysical Data Center, Significant Earthquake Database, a searchable online database using the Catalog of Significant Earthquakes 2150 B.C.–1991 A.D., with addenda; and U.S. Geological Survey Earthquake Hazards Program.

c. 1500 BCE	Knossos, Crete, Greece	…	X	…	One of several events that leveled the capital of Minoan civilization, this quake accompanied the explosion of the nearby volcanic island of Thera.
27 BCE	Thebes, Egypt	…	…	…	This quake cracked one of the statues known as the Colossi of Memnon, and for almost two centuries the "singing Memnon" emitted musical tones on certain mornings as it was warmed by the Sun's rays.
62 CE	Pompeii and Herculaneum, Italy	…	X	…	These two prosperous Roman cities had not yet recovered from the quake of 62 when they were buried by the eruption of Mount Vesuvius in 79.

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
115	Antioch(Antakya, Turkey)	…	XI	…	A centre of Hellenistic and early Christian culture, Antioch suffered many devastating quakes; this one almost killed the visiting Roman emperor Trajan.
1556	Shaanxiprovince, China	…	IX	830,000	This may have been the deadliest earthquake ever recorded.
1650	Cuzco, Peru	8.1	VIII	…	Many of Cuzco's Baroque monuments date to the rebuilding of the city after this quake.
1692	Port Royal, Jamaica	…	…	2,000	Much of this British West Indies port, a notorious haven for buccaneers and slave traders, sank beneath the sea following the quake.
1693	southeastern Sicily, Italy	…	XI	93,000	Syracuse, Catania, and Ragusawere almost completely destroyed before being rebuilt with a Baroque splendour that still attracts tourists.
1755	Lisbon, Portugal	…	XI	62,000	The Lisbon earthquake

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
					of 1755was felt as far away as Algiers and caused a tsunami that reached the Caribbean.
1780	Tabrīz, Iran	7.7	…	200,000	This ancient highland city was destroyed and rebuilt, as it had been in 791, 858, 1041, and 1721 and would be again in 1927.
1811–12	New Madrid, Missouri, U.S.	7.5 to 7.7	XII	…	A series of quakes at the New Madrid Fault caused few deaths, but the New Madrid earthquake of 1811–12 rerouted portions of the Mississippi River and was felt from Canada to the Gulf of Mexico.
1812	Caracas, Venezuela	9.6	X	26,000	A provincial town in 1812, Caracas recovered and eventually became Venezuela's capital.
1835	Concepción, Chile	8.5	…	35	British naturalist Charles Darwin, witnessing this quake, marveled at the power of the Earth to destroy cities and alter landscapes.

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
1886	Charleston, South Carolina, U.S.	…	IX	60	This was one of the largest quakes ever to hit the eastern United States.
1895	Ljubljana, Slovenia	6.1	VIII	…	Modern Ljubljana is said to have been born in the rebuilding after this quake.
1906	San Francisco, California, U.S.	7.9	XI	700	San Francisco still dates its modern development from the San Francisco earthquake of 1906 and the resulting fires.
1908	Messina and Reggio di Calabria, Italy	7.5	XII	110,000	These two cities on the Strait of Messina were almost completely destroyed in what is said to be Europe's worst earthquake ever.
1920	Gansuprovince, China	8.5	…	200,000	Many of the deaths in this quake-prone province were caused by huge landslides.
1923	Tokyo-Yokohama, Japan	7.9	…	142,800	Japan's capital and its principal port, located on soft alluvial ground, suffered severely from the Tokyo-Yokohama earthquake of 1923.

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
1931	Hawke Bay, New Zealand	7.9	…	256	The bayside towns of Napierand Hastings were rebuilt in an Art Deco style that is now a great tourist attraction.
1935	Quetta, Pakistan	7.5	X	20,000	The capital of Balochistan province was severely damaged in the most destructive quake to hit South Asia in the 20th century.
1948	Ashgabat, Turkmenistan	7.3	X	176,000	Every year, Turkmenistan commemorates the utter destruction of its capital in this quake.
1950	Assam, India	8.7	X	574	The largest quake ever recorded in South Asia killed relatively few people in a lightly populated region along the Indo-Chinese border.
1960	Valdivia and Puerto Montt, Chile	9.5	XI	1,655	The Chile earthquake of 1960, the largest quake ever recorded in the world, produced a tsunami that crossed the Pacific Ocean to Japan, where it killed more than 100 people.

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
1963	Skopje, Macedonia	6.9	X	1,070	The capital of Macedonia had to be rebuilt almost completely following this quake.
1964	Prince William Sound, Alaska, U.S.	9.2	…	131	Anchorage, Seward, and Valdezwere damaged, but most deaths in the Alaska earthquake of 1964 were caused by tsunamis in Alaska and as far away as California.
1970	Chimbote, Peru	7.9	…	70,000	Most of the damage and loss of life resulting from the Ancash earthquake of 1970 was caused by landslides and the collapse of poorly constructed buildings.
1972	Managua, Nicaragua	6.2	…	10,000	The centre of the capital of Nicaragua was almost completely destroyed; the business section was later rebuilt some 6 miles (10 km) away.
1976	Guatemala City, Guatemala	7.5	IX	23,000	Rebuilt following a series of devastating quakes in 1917–18, the capital of Guatemala

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
					again suffered great destruction.
1976	Tangshan, China	7.5	X	242,000	In the Tangshan earthquake of 1976, this industrial city was almost completely destroyed in the worst earthquake disaster in modern history.
1979	Tumaco, Colombia	7.7	IX	600	The earthquake struck near the border between Colombia and Ecuador on the Pacific coast, producing 10-foot (3-metre) tsunami waves.
1985	Michoacán state and Mexico City, Mexico	8.1	IX	10,000	The centre of Mexico City, built largely on the soft subsoil of an ancient lake, suffered great damage in the Mexico City earthquake of 1985.
1988	Spitak and Gyumri, Armenia	6.8	X	25,000	This quake destroyed nearly one-third of Armenia's industrial capacity.
1989	Loma Prieta, California, U.S.	7.1	IX	62	The San Francisco–Oakland earthquake of 1989, the first sizable movement of the San

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
					Andreas Fault since 1906, collapsed a section of the San Francisco–Oakland Bay Bridge.
1994	Northridge, California, U.S.	6.8	IX	60	Centred in the urbanized San Fernando Valley, the Northridge earthquake of 1994 collapsed freeways and some buildings, but damage was limited by earthquake-resistant construction.
1995	Kōbe, Japan	6.9	XI	5,502	The Great Hanshin Earthquakedestroyed or damaged 200,000 buildings and left 300,000 people homeless.
1999	İzmit, Turkey	7.4	X	17,000	The İzmit earthquake of 1999heavily damaged the industrial city of İzmit and the naval base at Gölcük.
1999	Nan-t'oucounty, Taiwan	7.7	X	2,400	The Taiwan earthquake of 1999, the worst to hit Taiwan since 1935, provided a wealth of digitized data for seismic and

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
					engineering studies.
2001	Bhuj, Gujaratstate, India	8.0	X	20,000	The Bhuj earthquake of 2001, possibly the deadliest ever to hit India, was felt across India and Pakistan.
2003	Bam, Iran	6.6	IX	26,000	This ancient Silk Road fortress city, built mostly of mud brick, was almost completely destroyed.
2004	Acehprovince, Sumatra, Indonesia	9.1	…	200,000	The deaths resulting from this offshore quake actually were caused by a tsunami originating in the Indian Oceanthat, in addition to killing more than 150,000 in Indonesia, killed people as far away as Sri Lanka and Somalia.
2005	Azad Kashmir(Pakistani-administered Kashmir)	7.6	VIII	80,000	The Kashmir earthquake of 2005, perhaps the deadliest shock ever to strike South Asia, left hundreds of thousands of people exposed to the coming winter weather.

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
2006	Yogyakarta, Indonesia	6.3	IX	5,700	The Yogyakarta earthquake injured nearly 40,000 people and destroyed or damaged nearly 600,000 homes in the Bantul-Yogyakarta area.
2008	Sichuanprovince, China	7.9	IX	69,000	The Sichuan earthquake of 2008 left over five million people homeless across the region, and over half of Beichuan city was destroyed by the initial seismic event and the release of water from a lake formed by nearby landslides.
2009	L'Aquila, Italy	6.3	VIII	300	The L'Aquila earthquake of 2009left more than 60,000 people homeless and damaged many of the city's medieval buildings.
2010	Port-au-Prince, Haiti	7.0	IX	316,000	The Haiti earthquake of 2010devastated the metropolitan area of Port-au-Prince and left an estimated 1.5 million survivors homeless.

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
2010	Maule, Chile	8.8	VIII	521	The Chile earthquake of 2010produced widespread damage in Chile's central region and triggered tsunami warnings throughout the Pacific basin.
2010–11	Christchurch, New Zealand	7.0	VIII	180	Most of the devastation associated with the Christchurch earthquakes of 2010–11 resulted from a magnitude-6.3 aftershock that struck on February 22, 2011.
2011	Honshu, Japan	9.0	VIII	20,000	The powerful Japan earthquake and tsunami of 2011, which sent tsunami waves across the Pacific basin, caused widespread damage throughout eastern Honshu.
2011	Erciş and Van, Turkey	7.2	IX	600	The Erciş-Van earthquake of 2011 destroyed several apartment complexes and shattered mud-brick homes throughout the region.
2015	Kathmandu, Nepal	7.8	IX	9,000	The Nepal earthquake of 2015was accompanied by two

year	affected area	magnitude*	intensity*	approximate number of deaths	comments
					aftershocks of magnitude 6.6 and 6.7 within the first hour after the quake. A magnitude-7.3 aftershock struck the region on May 12, killing more than 100 people.
2016	Muisne, Ecuador	7.8	VIII	500	The Ecuador earthquake injured more than 4,600 people and flattened thousands of structures in towns and villages along the Pacific coast and inland.
Notable earthquakes in history					

Landslide

A landslide, sometimes known as landslip, slope failure or slump, is an uncontrollable downhill flow of rock, earth, debris or the combination of the three. Landslides stem from the failure of materials making up the hill slopes and are beefed up by the force of gravity. When the ground becomes saturated, it can become unstable, losing its equilibrium in the long run. That’s when a landslide breaks loose. When people are living down these hills or mountains, it’s usually just a matter of time before disaster happens.

Causes of Landslides

While landslides are considered naturally occurring disasters, human-induced changes in the environment have recently caused their upsurge. Although the causes of landslides are wide ranging, they have 2 aspects in common; they are driven by forces of gravity and result from failure of soil and rock materials that constitute the hill slope:

Natural Causes of Landslides

1. Climate

Long-term climatic changes can significantly impact soil stability. A general reduction in precipitation leads to lowering of water table and reduction in overall weight of soil mass, reduced solution of materials and less powerful freeze-thaw activity. A significant upsurge in precipitation or ground saturation would dramatically increase the level of ground water. When sloped areas are completely saturated with water, landslides can occur. If there is absence of mechanical root support, the soils start to run off.

2. Earthquakes

Seismic activities have, for a long time, contributed to landslides across the globe. Any moment tectonic plates move, the soil covering them also moves along. When earthquakes strike areas with steep slopes, on numerous occasion, the soil slips leading to landslides. In addition, ashen debris flows instigated by earthquakes could also cause mass soil movement.

3. Weathering

Weathering is the natural procedure of rock deterioration that leads to weak, landslide-susceptive materials. Weathering is brought about by the chemical action of water, air, plants and bacteria. When the rocks are weak enough, they slip away causing landslides.

4. Erosion

Erosion caused by sporadic running water such as streams, rivers, wind, currents, ice and waves wipes out latent and lateral slope support enabling landslides to occur easily.

5. Volcanoes

Volcanic eruptions can trigger landslides. If an eruption occurs in a wet condition, the soil will start to move downhill instigating a landslide. Stratovolcano is a typical example of volcano responsible for most landslides across the globe.

6. Forest fires

Forest fires instigate soil erosion and bring about floods, which might lead to landslides

7. Gravity

Steeper slopes coupled with gravitational force can trigger a massive landslide.

Human causes of landslides

1. Mining

Mining activities that utilize blasting techniques contribute mightily to landslides. Vibrations emanating from the blasts can weaken soils in other areas susceptible to landslides. The weakening of soil means a landslide can occur anytime.

2. Clear cutting

Clear cutting is a technique of timber harvesting that eliminates all old trees from the area. This technique is dangerous since it decimates the existing mechanical root structure of the area.

Effects of Landslides

1. Lead to economic decline

Landslides have been verified to result in destruction of property. If the landslide is significant, it could drain the economy of the region or country. After a landslide, the area affected normally undergoes rehabilitation. This rehabilitation involves massive capital outlay. For example, the 1983 landslide at Utah in the United States resulted in rehabilitation cost of about $500 million. The annual loss as a result of landslides in U.S. stands at an estimated $1.5 billion.

2. Decimation of infrastructure

The force flow of mud, debris, and rocks as a result of a landslide can cause serious damage to property. Infrastructure such as roads, railways, leisure destinations, buildings and communication systems can be decimated by a single landslide.

3. Loss of life

Communities living at the foot of hills and mountains are at a greater risk of death by landslides. A substantial landslide carries along huge rocks, heavy debris and heavy soil with it. This kind of landslide has the capacity to kills lots of people on impact. For instance, Landslides in the UK that happened a few years ago caused rotation of debris that destroyed a school and killed over 144 people including 116 school children aged between 7 and 10 years. In a separate event, NBC News reported a death toll of 21 people in the March 22, 2014, landslide in Oso, Washington.

4. Affects beauty of landscapes

The erosion left behind by landslides leaves behind rugged landscapes that are unsightly. The pile of soil, rock and debris downhill can cover land utilized by the community for agricultural or social purposes.

5. Impacts river ecosystems

The soil, debris, and rock sliding downhill can find way into rivers and block their natural flow. Many river habitats like fish can die due to interference of natural flow of water. Communities depending on the river water for household activities and irrigation will suffer if flow of water is blocked.

Types of Landslides

- Falls

Falls are sudden movements of loads of soil, debris, and rock that break away from slopes and cliffs. Falls landslides occur as a result of mechanical weathering, earthquakes, and force of gravity.

- Slides

This is a kind of mass movement whereby the sliding material breakaways from underlying stable material. The kinds of slides experienced during this type of landslide include rotational and transitional. Rotational slides are sometimes known as slumps since they move with rotation.

Transitional slides consist of a planer or 2 dimensional surface of rupture. They involve landslide mass movement following a roughly planar surface with reduced rotation or backward slanting. Slides occur when the toe of the slope is undercut. They move moderately, and the consistency of material is maintained.

- Topples

Topple landslides occur when the topple fails. Topple failure encompasses the forward spinning and movement of huge masses of rock, debris, and earth from a slope. This type of slope failure takes place around an axis near or at the bottom of the block of rock. A topple landslide mostly lead to formation of a debris cone below the slope. This pile of debris is known as a Talus cone.

- Spreads

They are commonly known as lateral spreads and takes place on gentle terrains via lateral extension followed by tensile fractures.

- Flows

This type of landslide is categorized into five; earth flows, debris avalanche, debris flow, mudflows, and creep, which include seasonal, continuous and progressive.

Flows are further subcategorized depending upon the geological material, for example, earth, debris, and bedrock.

The most prevalent occurring landslides are rock falls and debris flow.

Landslide Prevention Methods

A landslide can occur when earth, soil or rock can no longer hold itself up and gives way to gravity due to earthquakes, volcano or rainfall. Landslides can move slowly or quickly with disastrous effects. To prevent landslides on your property, there are a few things you can do both temporarily and permanently. Keep in mind that if a landslide threatens your home, you should evacuate immediately.

Slope Vegetation

One of the quickest and easiest ways to prevent a landslide on a slope is to vegetate it. This landslide prevention method works best on slopes that are not too steep or if the movement hasn't already begun. You can do this method yourself by planting a groundcover or hire a landscaper to vegetate the slope.

Retaining Walls

A solid, well-designed retaining should be made of sturdy materials such as masonry, brick, stone or steel. Drainage materials behind the wall help increase the stability of the wall.

Diverting Debri Pathways

Building pathways to divert debris is another option to prevent landslides on your property. You can create these pathways with the help of retaining walls. However, if you build walls to divert debris flow and then that flow lands on a neighbor's property, you can be liable for damage.

Temporary Prevention

For temporary landslide prevention, sandbags can be used to divert water from uncontrolled spilling just as retaining walls or diverted pathways do. Another method is to protect unstable areas with plastic sheeting, tarps or even burlap, especially in areas without vegetation because of recent fires.

Measures against landslides

Stabilisation of landslide Bannholz after storm in 2005.

Personal measures

- Reinforcement of floor slabs and external walls in existing buildings.
- Installation of drainage pipes for rainwater, slope drainage.
- Planting of slopes that are vulnerable to landslides with deep-rooted trees and shrubs.

Technical/biological measures

- Drainage and/or grading of slope profiles increase the shear resistance
- Supporting structures such as anchors and piles (pinning of the slip plane) can restrain landslides
- Removal of material in the 'driving' section, or material deposition in the 'braking' section, can prevent further descent of the sliding body
- Protective forest

Planning measures and local protection

- The use of slopes prone to landslides must be avoided, or uses suitably modified
- Hydraulic and electrical connections must be flexible.

Organisational measures

- The relatively long advance warning period permits timely evacuation.

MODULE-III

FLOODS

Floods are natural occurrences where an area or land that is normally dry abruptly becomes submerged in water. In simple terms, flood can be defined as an overflow of large quantities of water onto a normally dry land. Flooding happens in many ways due to overflow of streams, rivers, lakes or oceans or as a result of excessive rain.

Whenever flooding takes place, there is the possibility of loss of life, hardship to people, and extensive damage to property. This is because flooding can carry bridges, cars, houses, and even people. Flooding also destroys crops and can wipe away trees and other important structures on land. Some floods occur abruptly and recede quickly whereas others take several days or even months to form and to recede because of variation in size, duration, and the area affected.

According to Wikipedia, "A flood is an overflow of water that submerges land which is usually dry. The European Union (EU) Floods Directive defines a flood as a covering by water of land not normally covered by water. In the sense of "flowing water", the word may also be applied to the inflow of the tide."

Causes of Flooding

Many conditions result in flooding. Hurricanes, clogged drainages, and rainfall are some of the conditions that have led to flooding in various regions across the globe. Here are the leading causes of flooding.

1. **Rain**

Rain is the leading contributor to most of the flooding cases witnessed across the world. Too much rain causes water to flow overland contributing to flooding. In particular, it is due to high rainfall intensity over a prolonged period.

Depending on the rainfall distribution, the amount of rain, and soil moisture content, short rainfall period can also result in flooding. Light rains for longer periods – several days or weeks, can also result in floods. The rain water erosive force can weaken the foundations of buildings, causing tumbles and cracks.

2. **River Overflows**

Rivers or streams can overflow their banks. This happens when the river or stream holds more water upstream than usual, and it flows downstream to the neighboring low-lying areas, typically referred to as the floodplains. As a consequence, this creates a sudden discharge of water into the adjacent lands leading to flooding.

Dams in rivers may also at times overwhelm rivers when the carriage capacity is exceeded, causing the water to burst and get into the floodplains. Flood caused by river overflow has the potential of sweeping everything in its path downstream.

3. **Lakes and Coastal Flooding**

Lake and Coastal flooding occurs when large storms or tsunamis causes the water body to surge inland. These overflows have destructive power since they can destroy ill-equipped structures to withstand water's strength such as bridges, houses, and cars.

In the coastal areas, strong and massive winds and hurricanes drive water onto the dry coastal lands and give rise to flooding. The situation is even worsened when the winds blowing from the ocean carry rains in them. Sea waters from the tsunami or hurricane can cause widespread damage.

4. **Dam Breakage**

Dams are man-made structures used to hold water from flowing down from a raised ground. The potential energy stored in the dam water is used to generate electricity. At times, the walls can become weak and break because of overwhelming carriage capacity. Due to this reason, breakage of the dam can cause extensive flooding in the adjacent areas.

Flooding occurs when the embankments built along the sides of the river to stop high water from flowing onto the land breaks. Sometimes, the excess water from the dam is deliberately released from the dam to prevent it from breaking thereby causing floods.

5. **Melting of the Glaciers and Mountain Tops**

In the cold regions, ice and snows build up during the winters. When the temperature rises in summer, the accumulated snows and ice are subjected to melting resulting in vast movements of water into lands that are normally dry. Regions with mountains that have ice on top of them also experience the same outcome when the atmospheric temperature rises. This type of flooding is usually termed as snowmelt flood.

6. **Clogged Drainages**

Flooding also takes place when snowmelt or rainfall runoff cannot be channeled appropriately into the drainage systems forcing the water to flow overland. Clogged or lack of proper drainage system is usually the cause of this type of flooding.

Types of Flooding

This section describes some common types of flooding:

- Coastal flooding
- River flooding
- Flash flooding
- Groundwater flooding
- Sewer flooding

If you are worried about the types of floods that may occur in your area and need advice on how to prepare for them, contact the Environment Agency (EA) or the Scottish Environment Protection Agency (SEPA) on their shared Floodline - 0845 988 1188. Both the EA website and the SEPA website allow you to assess flood risk by postcode and contain wide-ranging advice. The EA website includes sections for families, older people and businesses. Please note that in many cases the advice has legal implications (see the section on your rights and duties).

Coastal flooding

Heavy storms or other extreme weather conditions combined with high tides can cause sea levels to rise above normal, force sea water to the land and cause coastal flooding. Proper flood defences need to be in place to safeguard life and property. The Environment Agency and SEPA constantly monitor sea levels and release flood warnings when required.

River flooding

This type of flooding, where a river bursts or overtops its banks and floods the areas around it, is more common than coastal flooding in the UK. River flooding is generally caused by prolonged, extensive rain. Flooding can be worsened by melting snow. Flooding can also occur if the free flow of a river gets blocked by fallen trees, natural overgrowth or rubbish.

People who own land around rivers (riparian owners) in England have a legal duty to prevent flooding by making sure that they avoid blocking the free flow of the river.

Flash flooding

A flash flood is a fast-moving and unexpected flood. Flash flooding is usually due to heavy rain. While natural events may be responsible for most flash flooding, it may also arise if flood defences fail or drainage systems are insufficient. It is expected that flash flooding may become more frequent due to climate change and over-development in flood plains.

Groundwater flooding

Groundwater flooding can occur when water levels underneath the ground rise above normal levels approaching the surface. It is usually caused by prolonged periods of rainfall. Groundwater flooding can last for weeks and months. The UK Groundwater Forum estimates that groundwater flooding affects several hundred thousand properties in the UK. It differs from surface water flooding which is caused when heavy rain directly hits the ground surface.

Sewer flooding

Sewer flooding may result from a failure of the sewerage system. It may also happen when the sewer system does not have enough capacity to take water entering the system from heavy rainfall or river or highway flooding.

Sewage water flowing into a building is classified as internal flooding. When it floods a garden or other open space such as roads or public grounds it is considered as external flooding.

If sewage flooding on your property is caused by a fault in your private drainage, you are responsible for sorting out the problem. In England, sewerage undertakers now have responsibility for some private sewers (as opposed to private drains – the distinction being that sewers drain more than one property). If the flooding is due to a fault in the public sewerage system, your local sewerage provider is responsible for fixing it.

In England, your local council will normally be responsible for drains and sewers around council homes while the EA would sort out any problem arising from river and coastal floods. Unitary authorities and county councils are responsible for highway drainage.

In Scotland, Scottish Water manages the public water and sewerage network, which includes assessing the risk of surface and sewer flooding.

The Highways Agency is responsible for maintaining the main road networks in England. Transport Scotland is responsible for motorways and trunk roads in Scotland. The Welsh Government manages motorways and trunk roads in Wales.

If it is not clear who is responsible, contact your local office of the Consumer Council for Water (CCW) for independent advice. Find your local CCW in England and Wales at www.ccwater.org.uk. (For more details, including Scotland and Northern Ireland contacts, see Further Resources.)

Inland flooding occurs when moderate precipitation accumulates over several days, intense precipitation falls over a short period, or a river overflows because of an ice or debris jam or dam or levee failure. Hurricane Floyd (1999), aided by Tropical Storm Dennis (1999), caused widespread severe flooding that caused the majority of the $3 to 6 billion in damage reported after those storms.

Storm surge is an abnormal rise in water level in coastal areas, over and above the regular astronomical tide, caused by forces generated from a severe storm's wind, waves, and low atmospheric pressure. Storm surge is extremely dangerous, because it is capable of flooding large coastal areas. Extreme flooding can occur in coastal areas particularly when storm surge coincides with normal high tide, resulting in storm tides reaching up to 20 feet or more in some cases. Along the coast, storm surge is often the greatest threat to life and property from a hurricane. In the past, large death tolls have resulted from the rise of the ocean associated with many of the major hurricanes that have made landfall. Hurricane Katrina (2005) is a prime example of the damage and devastation that can be caused by surge. At least 1500 persons lost their lives during Katrina and many of those deaths occurred directly, or indirectly, as a result of storm surge.

Effects of Floods

Flooding of areas used for socio-economic activities produces a variety of negative impacts. The magnitude of adverse impacts depends on the vulnerability of the activities and population and the frequency, intensity and extent of flooding. Some of these factors are shown below;

Loss of lives and property: Immediate impacts of flooding include loss of human life, damage to property, destruction of crops, loss of livestock, non-functioning of infrastructure facilities and deterioration of health condition owing to waterborne diseases. Flash floods, with little or no warning time, cause more deaths than slow-rising riverine floods.

Loss of livelihoods: As communication links and infrastructure such as power plants, roads and bridges are damaged and disrupted, economic activities come to a standstill, resulting in dislocation and the dysfunction of normal life for a period much beyond the duration of the flooding. Similarly, the direct effect on production assets, be it in agriculture or industry, can inhibit regularly activity and lead to loss of livelihoods. The spill over effects of the loss of livelihoods can be felt in business and commercial activities even in adjacent non-flooded areas.

Decreased purchasing and production power: Damage to infrastructure also causes long-term impacts, such as disruptions to clean water and electricity, transport, communication, education and health care. Loss of livelihoods, reduction in purchasing power and loss of land value in the flood plains lead to increased vulnerabilities of communities living in the area. The additional cost of rehabilitation, relocation of people and removal of property from flood-affected areas can divert the capital required for maintaining production.

Mass migration: Frequent flooding, resulting in loss of livelihoods, production and other prolonged economic impacts and types of suffering can trigger mass migration or population displacement. Migration to developed urban areas contributes to the overcrowding in the cities. These migrants swell the ranks of the urban poor and end up living in marginal lands in cities that are prone to floods or other risks. Selective out-migration of the workforce sometimes creates complex social problems.

Psychosocial effects: The huge psycho-social effects on flood victims and their families can traumatize them for long periods of time. The loss of loved ones can generate deep impacts, especially on children. Displacement from one’s home, loss of property and livelihoods and disruption to business and social affairs can cause continuing stress. The stress of overcoming these losses can be overwhelming and produce lasting psychological impacts.

Hindering economic growth and development: The high cost of relief and recovery may adversely impact investment in infrastructure and other development activities in the area and in certain cases may cripple the frail economy of the region. Recurrent flooding in a region may discourage long-term investments by the government and private sector alike. Lack of livelihoods, combined with migration of skilled labour and inflation may have a negative impact on a region's economic growth. Loss of resources can lead to high costs of goods and services, delaying its development programmes.

Political implications: Ineffective response to relief operations during major flood events may lead to public discontent or loss of trust in the authorities or the state and national governments. Lack of development in flood-prone areas may cause social inequity and even social unrest posing threat to peace and stability in the region.

Positive Effects of Floods

People have come to regard floods as disasters in terms of lives lost and property damaged. Humans have altered the flow of natural waterways to meet their needs but with sometimes disastrous consequences. Though floods can be devastating to population centers, they have always been an integral part of nature's renewal process, providing many long-term positive effects.

Renewal of Wetlands

Floods contribute to the health of ecologically important wetland areas. Healthy wetlands promote healthy water supplies and even affect air quality. Floods inundate wetlands with fresh waste. They also carry and deposit nutrient-rich sediments that support both plant and animal life in wetlands. In addition, flooding adds nutrients to lakes and streams that help support healthy fisheries.

Returning Nutrients to Soil

Floods distribute and deposit river sediments over large areas of land. These river sediments replenish nutrients in topsoil and make agricultural lands more fertile. The populations of many ancient civilizations concentrated along the floodplains of rivers such as the Nile, the Tigris and the Yellow because periodic flooding resulted in fertile, productive farmland. The construction of the Aswan High Dam in Egypt prevented the Nile from flooding major population centers downriver, but it also depleted once fertile agricultural lands along the banks of the river.

Preventing Erosion and Maintaining Land Mass Elevation

Soil deposited by flood waters prevents erosion and helps maintain the elevation of land masses above sea level. The rapidly receding land of the Mississippi River Delta is a direct result of man-made flood controls and levees that prevent topsoil-replenishing sediments from being deposited in the delta.

Recharge and Replenish Ground Water

Many population centers depend upon ground water and underground aquifers for fresh water. Flood waters absorb into the ground and percolate down through the rock to recharge these underground aquifers, which supply natural springs, wells, rivers and lakes with fresh water.

10 measures that must be taken to prevent more flooding in the future

1. Introduce better flood warning systems

The UK must "improve our flood warning systems", giving people more time to take action during flooding, potentially saving lives, the deputy chief executive of the Environment Agency, David Rooke, said. Advance warning and pre-planning can significantly reduce the impact from flooding.

2. Modify homes and businesses to help them withstand floods

The focus should be on “flood resilience” rather than defence schemes, according to Laurence Waterhouse, director of civil engineering flood consultancy Pell Frischmann. He advised concreting floors and replacing materials such as MDF and plasterboard with more robust alternatives. “We are going to have to live with flooding. It's here to stay,” Mr Waterhouse said. “We need to be prepared." His recommendations were echoed by Mr Rooke, who suggested waterproofing homes and businesses and moving electric sockets higher up the walls to increase resilience.

3. Construct buildings above flood levels

Britain should construct all new buildings one metre from the ground to prevent flood damage, the former president of the Institution of Civil Engineers has suggested. Professor David Balmforth, who specialises in flood risk management, said conventional defences had to be supplemented with more innovative methods to lower the risk of future disasters.

4. Tackle climate change

Climate change has contributed to a rise in extreme weather events, scientists believe. Earlier this month the leader of the Green Party, Natalie Bennett, welcomed the landmark Paris Agreement, whereby governments from 195 countries pledged to “pursue efforts” to limit the increase in global average temperatures to 1.5°C above pre-industrial levels. “It is now crucial that world leaders deliver on the promise of Paris,” Ms Bennett said. “The pressure is now on the British government to reverse its disastrous environmental policy-making.”

5. Increase spending on flood defences

Figures produced by the House of Commons library suggest that real terms spending on flood defences has fallen by 20 per cent since David Cameron came to power. Yesterday [MON] the Prime Minister rejected this allegation, insisting the amount being spent had risen. Mr Cameron promised to review spending on flood defences after chairing a conference call of the government's emergency Cobra committee at the weekend.

6. Protect wetlands and introduce plant trees strategically

The creation of more wetlands – which can act as sponges, soaking up moisture – and wooded areas can slow down waters when rivers overflow. These areas are often destroyed to make room for agriculture and development, the WWF said. Halting deforestation and wetland drainage, reforesting upstream areas and restoring damaged wetlands could significantly reduce the impact of climate change on flooding, according to the conservation charity.

7. Restore rivers to their natural courses

Many river channels have been historically straightened to improve navigability. Remeandering straightened rivers by introducing their bends once more increases their length and can delay the flood flow and reduce the impact of the flooding downstream.

8. Introduce water storage areas

Following the severe flooding of 2009 a £5.6 million flood alleviation scheme was established in Thacka Beck, on the outskirts of Penrith, Cumbria. More than 675 metres of culverts underneath the streets of Penrith were replaced and a 76,000m^3 flood storage reservoir – the equivalent of 30 Olympic sized swimming pools – was constructed upstream to hold back flood water. The risk of flooding from the beck was reduced from a 20 per cent chance in any given year to a one per cent chance, according to Cumbria Wildlife Trust.

9. Improve soil conditions

Inappropriate soil management, machinery and animal hooves can cause soil to become compacted so that instead of absorbing moisture, holding it and slowly letting it go, water runs off it immediately. Well drained soil can absorb huge quantities of rainwater, preventing it from running into rivers.

10. Put up more flood barriers

The Environment Agency uses a range of temporary or "demountable" defences in at-risk areas. These can be removed completely when waters recede. Temporary barriers can also be added to permanent flood defences, such as raised embankments, increasing the level of protection. "As the threat and frequency of flood risk increases, the use of passive flood defence has to be the only realistic long term solution," Frank Kelly, CEO of UK Flood Barriers claimed earlier this month in Infrastructure Intelligence, a magazine for the infrastructure sector. Mr Kelly's company was responsible for designing a self-activating flood barrier he said had proved to be “invaluable” in protecting properties close to the River Cocker.

Management and Mitigation of Floods:

Floods cause tremendous destruction of life and property. But there are ways of protection against floods:

i. If an area is prone to floods, houses in the region should be constructed on raised platforms. River banks should also be raised.

ii. Administrative authorities should properly map areas that are prone to floods.

iii. Rivers should be mapped and the surrounding areas appropriately prepared for floods.

iv. Houses should be insured to protect against economic losses.

v. Placing sandbags around houses can save property.

vi. Dams can be constructed to prevent against losses from floods. They control the water flow.

vii. Afforestation programs should be supported because depletion of forests is causing a rise in the number of floods witnessed almost every year across the globe.

viii. Rivers should be cleared of harmful garbage like plastics.

ix. Floods should be well forecasted and warnings systems should be in place.

Cyclones

Location, location, location! This is especially important when we're talking about ocean storms because the location of the storm determines what we call it. For example, if the storm occurs in the Atlantic Ocean and Northeast Pacific, it's called a hurricane. If the exact same type of storm occurs in the Northwest Pacific, this is a typhoon. And if we find those same storms in the South Pacific and Indian Ocean, these are called tropical cyclones.

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, which is well known for being eerily calm compared with the areas under the spinning 'arms' of the storm. You could say that the eye is watching what's going on down below, so it needs a clear path, but the arms are where all the action happens because this is where the storm is throwing out all of its rain and wind.

Types of Cyclones

The term 'cyclone' actually refers to several different types of storms. They occur in different places, and some occur over land while others occur over water. What they all have in common is that they are spinning storms rotating around that low-pressure center.

Tropical cyclones are what most people are familiar with because these are cyclones that occur over tropical ocean regions. Hurricanes and typhoons are actually types of tropical cyclones, but they have different names so that it's clear where that storm is occurring. Hurricanes are found in the Atlantic and Northeast Pacific, typhoons are found in the Northwest Pacific. If you hear 'tropical cyclone,' you should assume that it's occurring in the South Pacific or Indian Ocean, but for this lesson, we'll use it refer to all types of tropical ocean cyclones.

We can also further describe tropical cyclones based on their wind speeds. They are called category 1, 2, 3, 4 or 5, increasing with intensity and wind speed as the number increases. A category 1 cyclone is the weakest, with wind speeds of 74-95 mph. A category 5 cyclone, on the other hand, is extremely dangerous and has the potential for major damage. Category 5 cyclones have wind speeds of 155 mph and above!

Polar cyclones are cyclones that occur in polar regions like Greenland, Siberia and Antarctica. Unlike tropical cyclones, polar cyclones are usually stronger in winter months. As you can see, these storms really do prefer the colder weather! They also occur in areas that aren't very populated, so any damage they do is usually pretty minimal.

A **mesocyclone** is when part of a thunderstorm cloud starts to spin, which may eventually lead to a tornado. 'Meso' means 'middle', so you can think of this as the mid-point between one type of storm and the other. Tornadoes all come from thunderstorm clouds, but not all thunderstorm clouds make tornadoes. In order for a tornado to occur, part of that cloud has to spin, and though you can't really see this happening, this is the intermediate, or 'meso' step from regular cloud to dangerous spinning cloud running along the ground.

Cyclones, Hurricanes, Typhoons are the same. In the Indian seas it is called cyclones, in the Atlantic and eastern pacific ocean it is called Hurricanes, and in the western pacific it is called Typhoons.

In the Indian seas the various stages of development of a cyclonic storm are:-

- Low pressure
- Well marked low pressure
- Depression (winds at 36-54 km/hr)
- Deep Depression (winds at 54-66 km/hr)
- Cyclonic storm (winds at 66-94 km/hr)
- Sever cyclonic storm (winds at 94-126 km/hr)
- Very sever cyclonic storm (winds at 126-240 km/hr)
- Super Cyclonic Storm (winds at 240 km/hr and above)

Formation

Cyclones are formed from simple thunderstorms. However, these thunderstorms can grow to cyclone strength only with warm ocean waters and moist atmospheric conditions. First of all, the ocean waters have to be warmer than 26 degrees Celsius . The heat and the moisture from warm waters is the source of energy for cyclones. Cyclones will weaken rapidly as they travel over land or colder ocean waters where there is less of warmth and moisture. Not only, to having warm ocean water, high humidity levels in the lower and middle troposphere are also required for cyclone development.

The vertical wind shear in a tropical cyclone's environment is also important. Wind shear is defined as the amount of change in the wind's direction or speed with increasing altitude.

A weak wind shear means that the cyclone grows vertically, and the latent heat from condensation is released into the air directly above the storm, aiding in its development. A stronger wind shear means that the cyclones become more slanted and the latent heat release is dispersed over a much larger area.

Stages of Development

Stages of Development from tropical depression to cyclone

A tropical disturbance in time can grow to a more intense stage by attaining a specified sustained wind speed.

Cyclones can last for more than a week, depending upon their sea travel duration. They usually give rise to a cluster of clouds bringing thunderstorms over the tropical ocean waters. Once a disturbance has graduated to a tropical depression status, the amount of time that its takes go to the next stage i.e. a tropical storm, usually half a day up to a couple of days. Also it may not happen at all. The amount of moisture and warmth of the ocean waters play a major role in determining these events.

Movement of Cyclones

Movement of Cyclones is steered by the zonal winds

The location of a cyclone in these wind belt decides its path. a cyclone originating in the easterly zonal wind area is driven westward by easterly winds in the tropics.

Most storms in the tropics move northwestward initially. They re-curve and travel northeastward on entering the region of strong westerlies.

The energy of the cyclone depends upon warm surface water of the tropics which is why cyclones dissipate rapidly over cold water. Also, the tropical storms do not develop in the proximity of equator.

Categories of Cyclones

Cyclones are categorized according to wind speeds and the damage they cause.

Category 1 Cyclones: Wind speeds between 90 and 125 kilometers per hour, some noticeable damage to houses and trees.

Category 2: Wind speeds between 125 and 164 kilometers per hour, damage to houses and significant damage to crops and trees.

Category 3: Wind speeds between 165-224 kilometers per hour, structural damage to houses, extensive damage to crops and uprooted trees, upturned vehicles and destruction of buildings.

Category 4: Wind speeds between 225 and 279 kilometers per hour, power failure and much damage to cities and villages.

Category 5: Wind speeds over 280 kilometers per hour, widespread damage.

Causes of a cyclone

A cyclone is formed when a warm temperature of the sea reaches a threshold level and the wind structure is rising. In other words, TC's derive their energy from the warm tropical oceans and do not form unless the sea-surface temperature is above 26.5°C. However, once formed they can persist at lower temperatures and dissipate over land or colder oceans (BOM, 1994). GA (2008) describes it this way,

1. "The development of a tropical cyclone also relies on favorable broad-scale wind regimes and can persist for several days with many following quite erratic paths. They lose their source of energy when they move over land or colder oceans causing them to dissipate. Weakening may occur also if the cyclone moves into an unfavorable wind regime which disrupts the structure of the system. Sometimes a decaying tropical cyclone may interact with a weather system in higher latitudes to cause impacts far from the tropics" (Ibid, 2008).
To understand further, there are four stages that form a cyclone which include:

1. Formative Stage
2. Immature Cyclone
3. Mature Cyclone
4. Decay stage
The precautionary warning of cyclones is usually made during the formative stages. Then, if necessary, an evacuation will take place during the immature stages. The most dangerous stage is the mature progress, where the cyclone reaches the peak limit of its strength causes the most damage. Finally, the cyclone will ease into the decay stage and dissipate.

Effects of Cyclones and Hurricanes:

i. Tropical cyclones cause heavy rainfall and landslides.

ii. They cause a lot of harm to towns and villages, causing severe damage to kuccha houses. Coastal businesses like shipyards and oil wells are destroyed.

iii. They harm the ecosystem of the surrounding region.

iv. Civic facilities are disturbed.

v. Agricultural land is severely affected, especially in terms of water supply and soil erosion.

vi. It causes harm to human, plant and animal life.

vii. Communication systems are badly affected due to cyclones.

The Effects of Cyclones on the Environment

A cyclone is a spinning storm caused by a low-pressure area in the atmosphere. The air in a cyclone turns counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. Tropical cyclones develop over tropical or subtropical waters. These large weather systems have different names in different parts of the world, but are most commonly known as typhoons or hurricanes. Cyclones are classified according to their wind speed, ranging from 74 to more than 156 miles per hour. Tropical cyclones often cause environmental changes far beyond the area where they make landfall.

Winds

The winds from a Category 1 cyclone cause minimal damage to shrubbery and trees. Category 5 storms are the most forceful, bringing winds of more than 156 miles per hour. Winds this fast can rip trees from the ground and flatten buildings. Cyclones that fall in between cause varying degrees of destruction, including tearing branches from trees and destroying vegetation. This often results in loss of animal habitats, interrupting and changing ecosystems. Flying debris from any of these windstorms can kill people or animals. Cyclonic winds also can damage infrastructure, such as power lines, communication towers, bridges and roads.

Flooding

Cyclones can produce flooding in two ways. First, tropical cyclones frequently cause a surge in ocean waters causing sea levels to rise above normal. These surges, sometimes called tidal waves, can drown people and animals, and are often the greatest killers in a cyclone. Cyclones also can bring torrential rains that lead to flooding.

Whatever the cause, overflowing waters can damage buildings and infrastructure in coastal areas. In addition, they can destroy vegetation and flow into estuaries, damaging the plant and animal communities that live there.

Erosion

A cyclone’s high winds can erode the soil, thereby damaging existing vegetation and ecosystems. This erosion leaves the area exposed and prone to even more wind erosion. Soil and sand that is blown into other areas can damage the vegetation there.

Erosion also can be caused by storm surges from tropical cyclones. Waves that reach far onto a beach drag the sand back into the ocean, leaving the affected area highly eroded. This can damage beach and dune ecosystems as well as structures. The sea will eventually bring the sand back to the beach, but this can take years.

Storm Churn

Storm churn happens when a cyclone's winds churn up cold water as it moves across the ocean. This churning lowers the water temperatures after the storm has passed, squelching the formation of new storms.

Storm churn also invigorates the ocean current that moves warm water from tropical oceans to the poles and cold water from the poles to the tropics. Michael Huber of Purdue University believes that storm churn will continue cooling the ocean's surface temperatures for several hundred years, countering fears that global warming will lead to an increase in the strength, quantity and length of future tropical cyclones.

Effective Safety Measures:

(1) Safety services towards cyclone and other disaster by Government and other agencies:

- Cyclone forecast and warning services: With the advances in technology, cyclone can be forecast in about 24 to 48 hours in advance. This becomes possible because of satellites and computers. When a cyclone is nearer to the coastline, the cyclone warning is forecasted almost at every half an hour.
- Rapid communication to the Government and concerned people: Communication about the cyclone is given quickly to the Government and the people so that proper safety measures and rescue operations can be carried out.
- Construction of cyclone shelters in the cyclone prone area.
- Shifting the people quickly to a safer place.

(2) Action on the part of people:

- Pay attention towards warning broadcasts from time to time.
- In case of a cyclone warning, stock necessary food items and medicines.
- If possible, move to a safer place.
- Fishermen should not venture into the sea during a cyclone warning.
- Cooperate with others in the community.
- Help the rescue team.

Management and Mitigation of Cyclones and Hurricanes:

i. Coastal areas should be well prepared to meet eventualities that arise from cyclones.

ii. Houses should be constructed such that they can withstand the heavy rainfall and forceful winds.

iii. Shelter beds should be created to check soil erosion and speed of winds.

iv. Remote sensing techniques should be used to forecast cyclones appropriately.

v. When a cyclone does occur, rescue and relief operations should be in place.

Tsunami

The word "tsunami" comprises the Japanese words"tsu" (meaning harbour) and "nami" (meaning wave). A tsunami is a series of enormous waves created by an underwater disturbance usually associated with earthquakes occurring below or near the ocean.

Volcanic eruptions, submarine landslides, and coastal rock falls can also generate a tsunami, as can a large asteroid impacting the ocean. They originate from a vertical movement of the sea floor with the consequent displacement of water mass.

Tsunami waves often look like walls of water and can attack the shoreline and be dangerous for hours, with waves coming every 5 to 60 minutes.

The first wave may not be the largest, and often it is the 2nd, 3rd, 4th or even later waves that are the biggest. After one wave inundates, or floods inland, it recedes seaward often as far as a person can see so the seafloor is exposed. The next wave then rushes ashore within minutes and carries with it many floating debris that were destroyed by previous waves. When waves enter harbors, very strong and dangerous water currents are generated that can easily break ship moorings, and bores that travel far inland can be formed when tsunamis entire rivers or other waterway channels.

Tsunami is a Japanese word with the English translation, "harbor wave." Represented by two characters, the top character, "tsu," means harbor, while the bottom character, "nami," means "wave."
In the past, tsunamis were sometimes referred to as "tidal waves" by the general public, and as "seismic sea waves" by the scientific community. The term "tidal wave" is a misnomer; although a tsunami's impact upon a coastline is dependent upon the tidal level at the time a tsunami strikes, tsunamis are unrelated to the tides. Tides result from the imbalanced, extraterrestrial, gravitational influences of the moon, sun, and planets.
The term "seismic sea wave" is also misleading. "Seismic" implies an earthquake-related generation mechanism, but a tsunami can also be caused by a non-seismic event, such as a landslide or meteorite impact.

Causes of tsunamis

Earthquakes

It can be generated by movements along fault zones associated with plate boundaries. The region where two plates come in contact is a plate boundary, and the way in which one plate moves relative to another determines the type of boundary:

- spreading, where two plates move away from each other;
- subduction, where two plates move towards each other and one slides beneath the other;

- transform where two plates slide horizontally past each other.

Most strong earthquakes occur in subduction zones where an ocean plate slides under a continental plate or another younger ocean plate.

All earthquakes do not cause tsunamis. There are four conditions necessary for an earthquake to cause a tsunami:

1. The earthquake must occur beneath the ocean or cause material to slide into the ocean.
2. The earthquake must be strong, at least magnitude6.5 on the Richter Scale
3. The earthquake must rupture the Earth's surface and it must occur at shallow depth – less than 70km below the surface of the Earth.
4. The earthquake must cause vertical movement of the sea floor (up to several metres).

Landslides

A landslide which occurs along the coast can force large amounts of water into the sea, disturbing the water and generate a tsunami. Underwater landslides can also result in tsunamis when the material loosened by the landslide moves violently, pushing the water in front of it.

Volcanic Eruption

Although relatively infrequent, violent volcanic eruptions represent also impulsive disturbances, which can displace a great volume of water and generate extremely destructive tsunami waves in the immediate source area. According to this mechanism, waves may be generated by the sudden displacement of water caused by a volcanic explosion, by a volcanos slope failure, or more likely by a phreatomagmatic explosion and collapse/engulfment of the volcanic magmatic chambers.

One of the largest and most destructive tsunamis ever recorded was generated in August 26, 1883 after the explosion and collapse of the volcano of Krakatoa (Krakatau), in Indonesia. This explosion generated waves that reached 135 feet, destroyed coastal towns and villages along the Sunda Strait in both the islands of Java and Sumatra, killing 36, 417 people.

Extraterrestrial Collision

Tsunamis caused by extraterrestrial collision (i.e. asteroids, meteors) are an extremely rare occurrence. Although no meteor/asteroid induced tsunami have been recorded in recent history, scientists realize that if these celestial bodies should strike the ocean, a large volume of water would undoubtedly be displaced to cause a tsunami. Scientists have calculated that if a moderately large asteroid, 5-6 km in diameter, should strike the middle of the large ocean basin such as the Atlantic Ocean, it would produce a tsunami that would travel all the way to the Appalachian Mountains in the upper two-thirds of the United States. On both sides of the Atlantic, coastal cities would be washed out by such a tsunami. An asteroid 5-6 kilometers in diameter impacting between the Hawaiian Islands and the West Coast of North America, would produce a tsunami which would wash out the coastal cities on the West coasts of Canada, U.S. and Mexico and would cover most of the inhabited coastal areas of the Hawaiian islands.

Types of tsunamis

Dependent on the distance of the tsunami from its source, it may be classified as a:

- **Local tsunami:**

A local tsunami is one that originates from within about 100 km or less than 1 hour tsunami travel time from the impacted coastline. Local tsunamis can result in a significant number of casualties since authorities have little time to warn/evacuate the population.

- **Regional tsunami:**

A regional tsunami is one that is capable of destruction in a particular geographical region, generally within 1,000 km from its source. Regional tsunamis can arrive to affected coastlines within 1-3 hours of being generated, however, as with local tsunamis, due to the limited warning time they can still prove very destructive and deadly.

- **Tele-tsunami/Ocean-wide tsunami/Distant tsunami:**

A tsunami originating from a source, generally more than 1,000 km or more than 3 hours tsunami travel time from the impacted coastline is called an ocean-wide or distant or tele-tsunami. These tsunamis are less frequent, but more hazardous than regional tsunamis, as they usually start as a local tsunami that causes extensive destruction to a shoreline near the source, and the waves continue to travel across an entire ocean basin with sufficient energy to cause additional casualties and destruction on shores more than a 1,000 km from the source. These tsunamis have the ability to cause widespread destruction, not only in the immediate region but across an entire ocean. All ocean-wide tsunamis have been generated by major earthquakes.

Effects of Tsunamis

Tsunamis are massive waves generated by a displacement of water and can have disastrous effects on people. Earthquakes or underwater explosions can trigger these waves, such as those caused by volcanic activity or underwater testing of nuclear devices. Tsunamis can travel at over 500 mph in deep water and can reach 1,700 feet in height at their most extreme.

TL;DR (Too Long; Didn't Read)

Tsunamis can have a devastating effect on human lives. They can destroy homes, change landscapes, hurt economies, spread disease and kill people.

Devastation of Homes

Tsunamis can destroy entire buildings and can cause serious property damage. Many individuals who live in an area hit by a tsunami lose everything they own, which leaves them homeless and without resources in the initial aftermath. Some of the tsunami effects include leveling homes down to their foundations and exposing bedrock. The rebuilding process is expensive, time-consuming and psychologically tumultuous for people.

Loss of Life

Tsunami dangers are difficult to detect far out at sea, since waves do not begin to gain size until they reach shallower waters. As a result, they strike with very little warning, often resulting in a huge loss of human life. The tsunami that struck northern Japan after an offshore earthquake on March 11, 2011, killed at least 14,340 people, which crushed buildings and left thousands trapped under debris or pulled out to sea.

Damage to the Economy

Daily life for individuals in a nation affected by a tsunami changes because of the damage the disaster causes to the economy. Locations that were previously popular destinations for visitors suffer depression as a result of lost tourism, with people staying away out of fear and during reconstruction. Rebuilding after a tsunami puts a significant financial strain on governments as well, resulting in an economic downturn that can affect entire regions of the world.

Disease and Contamination

After a tsunami, contaminated water and food supplies pose a risk to people's health. Flood waters can carry many sources of contamination such as dirt or oil. In addition, infectious diseases increase after a tsunami. Malaria and cholera may become more common. People may have to stay in shelters or other close quarters that make spreading diseases easier.

Other Health Effects

Tsunamis can lead to other devastating health consequences. People may have traumatic injuries from the destruction of property and landscapes. Many people may suffer from broken bones or brain injuries. The loss of normal shelters can also leave them exposed to wind and hot or cold temperatures. They may also suffer mental health issues such as post-traumatic stress disorder or anxiety.

Serious Environmental Changes

After a tsunami strikes, landscapes that previously constituted picturesque beaches or seaside towns become a wasteland. In addition to the destruction of human construction, tsunamis destroy vegetation such as trees, resulting in landslides and coastlines that slip into the sea as deep root systems that previously held land in place get ripped out. These changes force human inhabitants to rebuild in an entirely different way, redesigning their lifestyles and livelihoods around an altered environment.

Prevention:

It is not possible to prevent tsunami, but we can mitigate losses from it by

1. Making sea wall
2. Making flood gates and channels to redirect the water from incoming tsunami
3. Plantation of mangroves and coastal forests along the coastal line
4. Making tsunami resistant buildings
5. Development of tsunami detection, forecasting and warning centres

IF you are on the coast and feel a large earthquake, it is possible a tidal wave will strike in the following few minutes.
The seismological center offers the following advice to avert injury or death:
1. Cover yourself and stay protected during the earthquake.
2. If authorities warn or you have reason to believe a tsunami is imminent,climb to higher ground or higher floors, at least 30 meters above sea level. If there is no higher ground available, a forest could offer protection.
3. If you see the sea recede, put as much distance and height between yourself and the waterline as possible.
4. Tsunamis can penetrate inland along rivers up to several kilometers, so stay away from rivers when trying to escape a tsunami.
5. Don’t return to the potentially threatened areas until authorities indicate the danger has passed.

MODULE IV

Types of Anthropogenic Disasters-I

Soil degradation

Many people do conceive the idea of soil degradation but a good number lacks the knowledge of its precise definition. To fill this knowledge gap, soil degradation simply means the decline in soil quality which comes about due to aspects such as improper land use, agriculture, and pasture, urban or industrial purposes. It involves the decline of the soil’s physical, biological and chemical state.

Soil degradation examples include decline in soil fertility, adverse changes in alkalinity, acidity or salinity, extreme flooding, use of toxic soil pollutants, erosion, and deterioration of the soil’s structural condition. These elements contribute to a significant amount of soil quality depreciation annually. Excessive soil degradation thus gives rise to immediate and long-term impacts which translate into serious global environmental headaches.

While soil degradation may occur naturally, it has been highly exuberated by anthropogenic activities. Besides, climate change combined with human activities continues to worsen soil degradation. With the objective of understanding the distinct nature of soil quality decline, here are the causes, effects, and solutions of soil degradation.

Causes of Soil Degradation

1. Physical Factors

There are several physical factors contributing to soil degradation distinguished by the manners in which they change the natural composition and structure of the soil. Rainfall, surface runoff, floods, wind erosion, tillage, and mass movements result in the loss of fertile top spoil thereby declining soil quality.

All these physical factors produces different types of soil erosion (mainly water and wind erosion) and soil detachment actions, and their resultant physical forces eventually changes the composition and structure of the soil by wearing away the soil's top layer as well as organic matter. In the long-term, the physical forces and weathering processes lead to the decline in soil fertility and adverse changes in the soil's composition/structure.

2. Biological Factors

Biological factors refer to the human and plant activities that tend to reduce the quality of soil. Some bacteria and fungi overgrowth in an area can highly impact the microbial activity of the soil through bio-chemical reactions, which reduces crop yield and the suitability of soil productivity capacity. Human activities such as poor farming practices may also deplete soil nutrients thus diminishing soil fertility. The biological factors affect mainly lessens the microbial activity of the soil.

3. Chemical Factors

The reduction of soil nutrients because of alkalinity or acidity or water logging are all categorized under the chemical components of soil degradation. In the broadest sense, it comprises alterations in the soil's chemical property that determine nutrient availability. It is mainly caused by salt buildup and leaching of nutrients which corrupt the quality of soil by creating undesirable changes in the essential soil chemical ingredients. These chemical factors normally bring forth irreversible loss of soil nutrients and productivity capacity such as the hardening of iron and aluminum rich clay soils into hardpans.

4. Deforestation

Deforestation causes soil degradation on the account of exposing soil minerals by removing trees and crop cover, which support the availability of humus and litter layers on the surface of the soil. Vegetation cover primarily promotes thee binding of the soil together and soil formation, hence when it is removed it considerably affects the capabilities of the soil such as aeration, water holding capacity, and biological activity.

When trees are removed by logging, infiltration rates become elevated and the soil remains bare and exposed to erosion and the buildup of toxicities. Some of the contributing activities include logging and slash and burn techniques used by individuals who invade forest areas for farming, rendering the soils unproductive and less fertile in the end.

5. Misuse or excess use of fertilizers

The excessive use and the misuse of pesticides and chemical fertilizers kill organisms that assist in binding the soil together. Most agricultural practices involving the use of fertilizers and pesticides often entail misuse or excessive application, thereby contributing to the killing of soil's beneficial bacteria and other micro-organisms that help in soil formation.

The complex forms of the fertilizer's chemicals are also responsible for denaturing essential soil minerals, giving rise to nutrient losses from the soil. Therefore, the misuse or excessive use of fertilizers increases the rate of soil degradation by destroying the soil's biological activity and builds up of toxicities through incorrect fertilizer use.

6. Industrial and Mining activities

Soil is chiefly polluted by industrial and mining activities. As an example, mining destroys crop cover and releases a myriad of toxic chemicals such as mercury into the soil thereby poisoning it and rendering it unproductive for any other purpose. Industrial activities, on the other hand, release toxic effluents and material wastes into the atmosphere, land, rivers, and ground water that eventually pollute the soil and as such, it impacts on soil quality. Altogether, industrial and mining activities degrade the soil's physical, chemical and biological properties.

7. Improper cultivation practices

There are certain agricultural practices that are environmentally unsustainable and at the same time, they are the single biggest contributor to the worldwide increase in soil quality decline. The tillage on agricultural lands is one of the main factors since it breaks up soil into finer particles, which increase erosion rates. The soil quality decline is exuberated more and more as a result of the mechanization of agriculture that gives room for deep plowing, reduction of plant cover, and the formation of the hardpan. Other improper cultivation activities such as farming on steep slope and mono-cropping, row-cropping and surface irrigation wear away the natural composition of the soil and its fertility, and prevent soil from regenerating.

8. Urbanization

Urbanization has major implications on the soil degradation process. Foremost of all, it denudates the soil's vegetation cover, compacts soil during construction, and alters the drainage pattern. Secondly, it covers the soil in an impermeable layer of concrete that amplifies the amount of surface runoff which results in more erosion of the top soil. Again, most of the runoff and sediments from urban areas are extremely polluted with oil, fuel, and other chemicals. Increased runoff from urban areas also causes a huge disturbance to adjacent water sheds by changing the rate and volume of water that flows through them, and impoverishing them with chemically polluted sediment deposits.

9. Overgrazing

The rates of soil erosion and the loss of soil nutrients as well as the top soil are highly contributed by overgrazing. Overgrazing destroys surface crop cover and breaks down soil particles, increasing the rates of soil erosion. As a result, soil quality and agricultural productivity is greatly affected.

Effects of Soil Degradation

1. Land degradation

Soil quality decline is one of the main causes of land degradation and is considered to be responsible for 84% of the ever diminishing acreage. Year after year, huge acres of land lost due to soil erosion, contamination and pollution. About 40% of the world's agricultural land is severely diminished in quality because of erosion and the use of chemical fertilizers, which prevent land from regenerating. The decline in soil quality as a result of agricultural chemical fertilizers also further leads to water and land pollutionthereby lowering the land's worth on earth.

2. Drought and aridity

Drought and aridity are problems highly influenced and amplified by soil degradation. As much as it's a concern associated with natural environments in arid and semi-arid areas, the UN recognizes the fact that drought and aridity are anthropogenic induced factors especially as an outcome of soil degradation. Hence, the contributing factors to soil quality decline such as overgrazing, poor tillage methods, and deforestation are also the leading causes of desertification characterized by droughts and arid conditions. On the same context, soil degradation may also bring about loss of biodiversity.

3. Loss of arable land

Because soil degradation contributes to land degradation, it also means that it creates a significant loss of arable land. As stated earlier, about 40% of the world's agricultural land is lost on the account of soil quality depreciation caused by agro-chemicals and soil erosion. Most of the crop production practices result in the topsoil loss and the damage of soil's natural composition that make agriculture possible.

4. Increased flooding

Land is commonly altered from its natural landscape when it rids its physical composition from soil degradation. For this reason, the transformed land is unable to soak up water, making flooding more frequent. In other words, soil degradation takes away the soil's natural capability of holding water thus contributing to more and more cases of flooding.

5. Pollution and clogging of waterways

Most of the soil eroded from the land together with the chemical fertilizers and pesticides utilized in agricultural fields are discharged into waterways and streams. With time, the sedimentation process can clog waterways, resulting in water scarcity. The agricultural fertilizers and pesticides also damage marine and freshwater ecosystemsand the limits the domestic uses of the water for the populations that depend on them for survival.

Solutions of Soil Degradation

1. Reducing deforestation

Avoiding deforestation completely is an uphill task. However, deforestation can be cut down and this can create an impressive way of reshaping and restoring forests and vegetation cover. As populations grow, individuals can be sensitized and educated regarding sustainable forest management and reforestation efforts. Also, preserving the integrity of guarded areas can significantly reduce demonstration.

Hence, there is a necessity for individuals all over the world to respect forest cover and reduce some of the human-driven actions that encourage logging. With the reduction of deforestation, soil's ability to naturally regenerate can be restored. Governments, international organizations, and other environmental stakeholders need to ensure there are appropriate measures for making zero net deforestation a reality so as to inhibit soil degradation.

2. Land reclamation

The outcomes of soil erosion and quality decline are widely irreversible. Still, soil organic matter and plant nutrients can be replenished. To restore the lost soil mineral matter and organic content, it would require what is known as land reclamation. Land reclamation encompasses activities centered towards restoring the previous organic matter and soil's vital minerals. This may include activities such as the addition of plant residues to degraded soils and improving range management.

Salinized soils can be restored by salt level correction reclamation projects and salinity control. One of the simplest but most forgotten methods of land reclamation is planting of vegetation such as trees, crops, and flowers over the affected soils. Plants act as protective covers as they are helpful at making the soil stronger by stabilizing the land surface.

3. Preventing salinization

Just like the old adage states that "prevention is better than cure," so does the same concept apply in solving the worldwide problem of soil degradation through salinization. The costs of preventing salinization are incredibly cheaper than the reclamation projects in salinized areas. Consequently, actions such as reducing irrigation, planting salt tolerant crops, and improving irrigation efficiency will have high pay offs because the inputs and the labor-demanding aspects associated with reclamation projects are zero. Preventing salanization in the first place is thus an environmentally friendly means of offering solution to soil degradation.

4. Conservation tillage

Proper tillage mechanisms hold as one of the most sustainable ways of avoiding soil quality decline. This is otherwise known as conservation tillage, which means tillage mechanisms targeted at making very minimal changes to the soil's natural condition and at the same time improving the soil's productivity. Examples include leaving the previous year's crop residue on the surface to shield the soil from erosion and avoiding poor tillage methods such as deep plowing.

Desertification

Desertification is defined as a process of land degradation in arid, semi-arid and sub-humid areas due to various factors including climatic variations and human activities. Or, to put it in another way, desertification results in persistent degradation of dryland and fragile ecosystems due to man-made activities and variations in climate. Desertification, in short, is when land that was originally of another type of biome turns into a desert biome because of changes of all sorts. A huge issue that many countries have is the fact that there are large pockets of land that are going through a process that is known as desertification.

Overgrazing is the major cause of desertification worldwide. Other factors that cause desertification include urbanization, climate change, overdrafting of groundwater, deforestation, natural disasters and tillage practices in agriculture that place soils more vulnerable to wind. Desertification affects topsoil, groundwater reserves, surface runoff, human, animal and plant populations. Water scarcity in drylands limits the production of wood, crops, forage and other services that ecosystems provide to our community.

According to UNESCO, one third of world's land surface is threatened by desertification and across the world it affects livelihood of millions of people who depend on the benefits of ecosystems that drylands provides. Desertification is another major environmental concern and a major barrier to meeting human basic needs in drylands and are being constantly threatened by increases in human pressures and climatic variability. In this article, we're going to give you an idea as to what are the causes of desertification, the effects that desertification has, and what we can do in order to deal with the problem at hand. Let's take a closer look at all of these topics.

"Desertification is a type of land degradation in which a relatively dry land region becomes increasingly arid, typically losing its bodies of water as well as vegetation and wildlife. It is caused by a variety of factors, such as climate change and human activities. Desertification is a significant global ecological and environmental problem."

Causes of Desertification

- **Overgrazing:** Animal grazing is a huge problem for many areas that are starting to become desert biomes. If there are too many animals that are overgrazing in certain spots, it makes it difficult for the plants to grow back, which hurts the biome and makes it lose its former green glory.

- **Deforestation:** When people are looking to move into an area, or they need trees in order to make houses and do other tasks, then they are contributing to the problems related to desertification. Without the plants (especially the trees) around, the rest of the biome cannot thrive.

- **Farming Practices:** Some farmers do not know how to use the land effectively. They may essentially strip the land of everything that it has before moving on to another plot of land. By stripping the soil of its nutrients, desertification becomes more and more of a reality for the area that is being used for farming.

- **Urbanization and other types of land development.** As mentioned above, development can cause people to go through and kill the plant life. It can also cause issues with the soil due to chemicals and other things that may harm the ground. As areas become more urbanized, there are less places for plants to grow, thus causing desertification.

- **Climate Change:** Climate change plays a huge role in desertification. As the days get warmer and periods of drought become more frequent, desertification becomes more and more eminent. Unless climate change is slowed down, huge areas of land will become desert; some of those areas may even become uninhabitable as time goes on.

- **Stripping the land of resources.** If an area of land has natural resources like natural gas, oil, or minerals, people will come in and mine it or take it out. This usually strips the soil of nutrients, which in turn kills the plant life, which in turn starts the process toward becoming a desert biome as time goes on.

- **Natural Disasters:** There are some cases where the land gets damaged because of natural disasters, including drought. In those cases, there isn’t a lot that people can do except work to try and help rehabilitate the land after it has already been damaged by nature.

Effects of Desertification

- **Farming becomes next to impossible.** If an area becomes a desert, then it’s almost impossible to grow substantial crops there without special technologies. This can cost a lot of money to try and do, so many farmers will have to sell their land and leave the desert areas.

- **Hunger:** Without farms in these areas, the food that those farms produce will become much scarcer, and the people who live in those local areas will be a lot more likely to try and deal with hunger problems. Animals will also go hungry, which will cause even more of a food shortage.

- **Flooding:** Without the plant life in an area, flooding is a lot more eminent. Not all deserts are dry; those that are wet could experience a lot of flooding because there is nothing to stop the water from gathering and going all over the place. Flooding can also negatively affect the water supply, which we will discuss next.

- **Poor Water Quality:** If an area becomes a desert, the water quality is going to become a lot worse than it would have been otherwise. This is because the plant life plays a significant role in keeping the water clean and clear; without its presence, it becomes a lot more difficult for you to be able to do that.

- **Overpopulation:** When areas start to become desert, animals and people will go to other areas where they can actually thrive. This causes crowding and overpopulation, which will, in the long run, end up continuing the cycle of desertification that started this whole thing anyway.

- **Poverty:** All of the issues that we've talked about above (related to the problem of desertification) can lead to poverty if it is not kept in check. Without food and water, it becomes harder for people to thrive, and they take a lot of time to try and get the things that they need.

Solutions for Desertification

- **Policy Changes Related to How People can Farm.** In countries where policy change will actually be enforced on those in the country, policy change related to how often people can farm and how much they can farm on certain areas could be put into place to help reduce the problems that are often associated with farming and desertification.

- **Policy Changes to Other Types of Land Use.** If people are using land to get natural resources or they are developing it for people to live on, then the policies that govern them should be ones that will help the land to thrive instead of allowing them to harm the land further. The policy changes could be sweeping or they could be depending on the type of land use at hand.

- **Education:** In developing countries, education is an incredibly important tool that needs to be utilized in order to help people to understand the best way to use the land that they are farming on. By educating them on sustainable practices, more land will be saved from becoming desert.

- **Technology Advances.** In some cases, it's difficult to try and prevent desertification from happening. In those cases, there needs to be research and advancements in technology that push the limits of what we currently know. Advancements could help us find more ways to prevent the issue from becoming epidemic.

- **Putting Together Rehabilitation Efforts.** There are some ways that we can go back and rehabilitate the land that we've already pushed into desertification; it just takes some investment of time and money. By putting these together, we can prevent the issue from becoming even more widespread in the areas that have already been affected.

- **Sustainable practices to prevent desertification from happening.** There are plenty of sustainable practices that can be applied to those acts that may be causing desertification. By adding these to what we should be doing with land, we can ensure that we don't turn the entire world into a desert.

MODULE-V

Types of Anthropogenic Disasters-II

AIR POLLUTION

Pollution is now a common place term that our ears are attuned to. We hear about the various forms of **pollution** and read about it through the mass media. Air pollution is one such form that refers to the contamination of the air, irrespective of indoors or outside. A physical, biological or chemical alteration to the air in the atmosphere can be termed as pollution. It occurs when any harmful gases, dust, smoke enters into the atmosphere and makes it difficult for plants, animals and humans to survive as the air becomes dirty.

Air pollution is a change in the physical, chemical and biological characteristic of air that causes adverse effects on humans and other organisms. The ultimate result is a change in the natural environment and/or ecosystem.The substances that are responsible for causing air pollution are called air pollutants. These air pollutants can be either natural (e.g. wildfires) or anthropogenic (man-made); they may be in the form of gas, liquid or solid.

Another way of looking at Air pollution could be any substance that holds the potential to hinder the atmosphere or the well-being of the living beings surviving in it. The sustainment of all things living is due to a combination of gases that collectively form the atmosphere; the imbalance caused by the increase or decrease of the percentage of these gases can be harmful for survival. The Ozone layer considered crucial for the existence of the ecosystems on the planet is depleting due to increased pollution. Global warming, a direct result of the increased imbalance of gases in the atmosphere has come to be known as the biggest threat and challenge that the contemporary world has to overcome in a bid for survival.

Air pollution is the **world's deadliest environmental problem**. It kills 7 million people each year, or one in eight deaths globally. 4.3 million of these deaths are due to 2.8 billion people in the developing world who cook and keep warm inside their homes, by burning dung, firewood and coal – filling their living spaces with smoke and pollutants. **Indoor air pollution from cooking and heating with open fires is equivalent to smoking two packets of cigarettes a day**.**Providing 50% of these 2.8 billion people with improved cooking stoves** – which dispels smoke outside through chimneys and vents, is one effective solution. The stoves are cheap and provide numerous benefits in terms of time, fuel and importantly health. It will **save almost half a million lives each year**, and avoid 2.5 billion disease days.

However, giving people improved cook stoves is **not a panacea** for air pollution, even if everyone has one. Because improved cook-stoves, still pollute inside (but less) and at the same time **worsen the situation outside** by blowing smoke into the community.Instead, we should aim to eventually have everyone use smoke free sources **such as LPG stoves or electricity**. The benefits from using LPG stoves are greater, but the costs much greater.For **outdoor air pollution**, the problem is even more difficult. Globally, reaching the WHO's targets for air pollution, through low-sulphur diesel and car filters is **too expensive relative to the benefit**.

Causes of air pollution:

1. Burning of Fossil Fuels: Sulphur dioxide emitted from the combustion of **fossil fuels** like coal, petroleum and other factory combustibles is one the major cause of air pollution. Pollution emitting from vehicles including trucks, jeeps, cars, trains, airplanes cause immense amount of pollution. We rely on them to fulfill our daily basic needs of transportation. But, there overuse is killing our environment as dangerous gases are polluting the environment. Carbon Monoxide caused by improper or incomplete combustion and generally emitted from vehicles is another major pollutant along with Nitrogen Oxides that is produced from both natural and man-made processes.

2. Agricultural activities: Ammonia is a very common by product from agriculture related activities and is one of the most hazardous gases in the atmosphere. Use of insecticides, pesticides and fertilizers in agricultural activities has grown quite a lot. They emit harmful chemicals into the air and can also cause **water pollution.**

3. Exhaust from factories and industries: Manufacturing industries release large amount of carbon monoxide, hydrocarbons, organic compounds, and chemicals into the air thereby depleting the quality of air. Manufacturing industries can be found at every corner of the earth and there is no area that has not been affected by it. Petroleum refineries also release hydrocarbons and various other chemicals that pollute the air and also cause **land pollution.**

4. Mining operations: Mining is a process wherein minerals below the earth are extracted using number of large equipments. During the process dust and chemicals are released in the air causing massive air pollution. This is one of the reasons which are responsible for the deteriorating health conditions of workers and nearby residents.

5. Indoor air pollution: Household cleaning products, painting supplies emit toxic chemicals in the air and cause air pollution. Have you ever noticed that once you paint walls of your house, it creates some sort of smell which makes it literally impossible for you to breathe?Suspended particulate matter popular by its acronym SPM, is another cause of pollution. Referring to the particles afloat in the air, SPM is usually caused by dust, combustion etc.

Types of air pollutants:

An air pollutant is known as a substance in the air that can cause harm to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made. Pollutants can be classified as either primary or secondary. Usually, **primary pollutants** are substances directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulphur dioxide released from factories etc.

Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is ground level ozone — one of the many secondary pollutants that make up photochemical smog. Other examples are Peroxy Acetyl Nitrate (PAN), formal dehyde etc.

Major primary pollutants produced by human activity include:

i. Sulphur oxides (SO_x):SO_2 is produced by volcanoes and in various industrial processes. Since coal and petroleum often contain sulphur compounds, their combustion generates sulphur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain. This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.

ii. Nitrogen oxides (NO_x): Especially nitrogen dioxides are emitted from high temperature combustion. Nitrogen dioxide is the chemical compound with the formula $N0_2$. It is responsible for photochemical smog, acid rain etc.

iii. Carbon monoxide: It is a colourless, odourless, non-irritating but very poisonous gas. It is a product by incomplete combustion of fuel such as natural gas, coal or wood. Vehicular exhaust is a major source of carbon monoxide.

iv. Carbon dioxide (CO_2):A greenhouse gas emitted from combustion but is also a gas vital to living organisms. It is a natural gas in the atmosphere.

v. Volatile organic compounds (VOCs):VOCs are an important outdoor air pollutant. In this field they are often divided into the separate categories of methane (CH_4) and non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to global warming.Other hydrocarbon VOCs are also significant greenhouse gases via their role in creating ozone and in prolonging the life of methane in the atmosphere, although the effect varies depending on local air quality. Within the NMVOCs, the aromatic compounds benzene, toluene and xylene are suspected carcinogens and may lead to leukaemia through prolonged exposure. 1, 3-butadiene is another dangerous compound which is often associated with industrial uses.

vi. Particulate matter: Particulates alternatively referred to as particulate matter (PM) or fine particles, are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to particles and the gas together. Sources of particulate matter can be manmade or natural.Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols.

Averaged over the globe, anthropogenic aerosols—those made by human activities—currently account for about 10 per cent of the total amount of aerosols in our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer.

vii. Persistent free radicals: connected to airborne fine particles could cause cardiopulmonary disease.
viii. Toxic metals: such as lead, cadmium and copper.
ix. Chlorofluorocarbons (CFCs): harmful to the ozone layer emitted from products currently banned from use.
x. Ammonia (NH_3): emitted from agricultural processes. Ammonia is a compound with the formula NH_3. It is normally encountered as a gas with a characteristic pungent odor. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous.
xi. Odours: such as from garbage, sewage, and industrial processes
xii. Radioactive pollutants: produced by nuclear explosions, war explosives, and natural processes such as the radioactive decay of radon.

Secondary pollutants include:
i. Particulate matter: formed from gaseous primary pollutants and compounds in photochemical smog. Smog is a kind of air pollution; the word "smog" is a portmanteau of smoke and fog. Classic smog results from large amounts of coal burning in an area caused by a mixture of smoke and sulphur dioxide. Modern smog does not usually come from coal but from vehicular and industrial emissions that are acted on in the atmosphere by sunlight to form secondary pollutants that also combine with the primary emissions to form photochemical smog.

ii. Ground level ozone (O_3): formed from NO_x and VOCs. Ozone (O_3) is a key constituent of the troposphere (it is also an important constituent of certain regions of the stratosphere commonly known as the Ozone layer). Photochemical and chemical reactions involving it drive many of the chemical processes that occur in the atmosphere by day and by night. At abnormally high concentrations brought about by human activities (largely the combustion of fossil fuel), it is a pollutant, and a constituent of smog.
iii. Peroxyacetyl nitrate (PAN) – similarly formed from NO_x and VOCs.

Sources of air pollution:

Sources of air pollution refer to the various locations, activities or factors which are responsible for the releasing of pollutants in the atmosphere. These sources can be classified into two major categories which are:**Anthropogenic and Natural sources.**

Anthropogenic sources (human activity) mostly related to burning different kinds of fuel:

i. "Stationary Sources" include smoke stacks of power plants, manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices.

ii. "Mobile Sources" include motor vehicles, marine vessels, aircraft and the effect of sound etc.

iii. Chemicals, dust and controlled burn practices in agriculture and forestry management. Controlled or prescribed burning is a technique sometimes used in forest management, farming, prairie restoration or greenhouse gas abatement. Fire is a natural part of both forest and grassland ecology and controlled fire can be a tool for foresters. Controlled burning stimulates the germination of some desirable forest trees, thus renewing the forest.

iv. Fumes from paint, hair spray, varnish, aerosol sprays and other solvents.

v. Waste deposition in landfills, which generate methane. Methane is not toxic; however, it is highly flammable and may form explosive mixtures with air. Methane is also an asphyxiate and may displace oxygen in an enclosed space. Asphyxia or suffocation may result if the oxygen concentration is reduced to below 19.5% by displacement.

v. Military, such as nuclear weapons, toxic gases, germ warfare and rocketry.

Natural sources:
i. Dust from natural sources, usually large areas of land with little or no vegetation.

ii. Methane, emitted by the digestion of food by animals, for example cattle.

iii. Radon gas from radioactive decay within the Earth's crust. Radon is a colourless, odourless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking.

iv. Smoke and carbon monoxide from wildfires.

v. Volcanic activity, which produce sulphur, chlorine, and ash particulates.

Effects of air pollution:

1. Respiratory and heart problems: The effects of Air pollution are alarming. Eye irritation, nose and throat irritation, increase in mortality rate and morbidity rate, bronchitis etc. may happen. They are known to create several respiratory and heart conditions along with Cancer, among other threats to the body. Several millions are known to have died due to direct or indirect effects of Air pollution. Children in areas exposed to air pollutants are said to commonly suffer from pneumonia and asthma.

2. Global warming: Another direct effect is the immediate alterations that the world is witnessing due to **Global warming.** With increased temperatures worldwide, increase in sea levels and melting of ice from colder regions and icebergs, displacement and loss of habitat have already signaled an impending disaster if actions for preservation and normalization aren't undertaken soon.

3. Acid Rain: Harmful gases like nitrogen oxides and sulfur oxides are released into the atmosphere during the burning of **fossil fuels.** When it rains, the water droplets combines with these air pollutants, becomes acidic and then falls on the ground in the form of acid rain. **Acid rain** can cause great damage to human, animals and crops.

4. Eutrophication: Eutrophication is a condition where high amount of nitrogen present in some pollutants gets developed on sea's surface and turns itself into algae and adversely affects fish, plants and animal species. The green colored algae that is present on lakes and ponds is due to presence of this chemical only.

5. Effects on Plants and animals: Just like humans, animals also face some devastating effects of air pollution. Toxic chemicals present in the air can force wildlife species to move to new place and change their habitat. The toxic pollutants deposit over the surface of the water and can also affect sea animals. Suppressed growth and premature ageing in plants, leaf bleaching, acid deposition can damage aquatic life, respiratory problems in animals etc. may happen.

6. Depletion of Ozone layer: Ozone exists in earth's stratosphere and is responsible for protecting humans from harmful ultraviolet (UV) rays. Earth's ozone layer is depleting due to the presence of chlorofluorocarbons, hydro chlorofluorocarbons in the atmosphere. As ozone layer will go thin, it will emit harmful rays back on earth and can cause skin and eye related problems. UV rays also have the capability to affect crops.

7. Effects on Environment and property: Reduces visibility due to smog formation, acid rain, ozone layer depletion, global warming, acid deposition can corrode metals and eat away stone on statues and monuments, discolour buildings, cloth fabrics etc. may happen.

Effects of air pollutants:

There are Various Harmful Effects of the air Pollutants:

i. Carbon monoxide (source- Automobile exhaust, photochemical reactions in the atmosphere, biological oxidation by marine organisms, etc.)- Affects the respiratory activity as haemoglobin has more affinity towards CO than oxygen. Thus, CO combines with HB and thus reduces the oxygen-carrying capacity of blood. This results in blurred vision, headache, unconsciousness and death due to asphyxiation (lack of oxygen).

ii. Carbon dioxide (source- Carbon burning of fossil fuels, depletion of forests (that remove excess carbon dioxide and help in maintaining the oxygen-carbon dioxide ratio) – causes global warming.

iii. Sulphur dioxide (source- Industries, burning of fossil fuels, forest fires, electric generation plants, smelting plants, industrial boilers, petroleum refineries and volcanic eruptions)- Respiratory problems, severe headache, reduced productivity of plants, yellowing and reduced storage time for paper, yellowing and damage to limestone and marble, damage to leather, increased rate of corrosion of iron, steel, zinc and aluminium.

iv. Hydrocarbons Poly-nuclear Aromatic Compounds(PAC) and Poly-nuclear Aromatic Hydrocarbons(PAH) (source- Automobile exhaust and industries, leaking fuel tanks, leaching from toxic waste dumping sites and coal tar lining of some water supply pipes)- Carcinogenic (may cause leukaemia).

v. Chloro-fluoro carbons (CFCs) (source- Refrigerators, air conditioners, foam shaving cream, spray cans and cleaning solvents)- Destroy ozone layer which then permits harmful

UV rays to enter the atmosphere. The ozone layer protects the earth from the ultraviolet rays sent down by the sun. If the ozone layer is depleted by human action, the effects on the planet could be catastrophic.

vi. Nitrogen Oxides (source- Automobile exhausts, burning of fossil fuels, forest fires, electric generation plants, smelting plants, industrial boilers, petroleum refineries and volcanic eruptions)- Forms photochemical smog, at higher concentrations causes leaf damage or affects the photosynthetic activities of plants and causes respiratory problems in mammals.

vii. Particulate matter Lead halides (lead pollution) (source- Combustion of leaded gasoline products) – Toxic effect in man.

viii. Asbestos particles (source- Mining activities) – Asbestosis – a cancerous disease of the lungs.

ix. Silicon dioxide (source- Stone cutting, pottery, glass manufacturing and cement industries) – Silicosis, a cancerous disease.

x. Mercury (source- combustion of fossil fuel & plants)-brain & kidney damage.

Air pollutants affect plants by entering through stomata (leaf pores through which gases diffuse), destroy chlorophyll and affect photosynthesis. During the day time the stomata are wide open to facilitate photosynthesis. Air pollutants during day time affect plants by entering the leaf through these stomata more than night.

Pollutants also erode waxy coating of the leaves called cuticle. Cuticle prevents excessive water loss and damage from diseases, pests, drought and frost. Damage to leaf structure causes necrosis (dead areas of leaf), chlorosis (loss or reduction of chlorophyll causing yellowing of leaf) or epinasty (downward curling of leaf), and abscission (dropping of leaves).

Particulates deposited on leaves can form encrustations and plug the stomata and also reduce the availability of sunlight. The damage can result in death of the plant.S02 causes bleaching of leaves, chlorosis, injury and necrosis of leaves. N02 results in increased abscission and suppressed growth. O3 causes flecks on leaf surface, premature aging, necrosis and bleaching.

Peroxyacetyl nitrate (PAN) causes silvering of lower surface of leaf, damage to young and more sensitive leaves and suppressed growth. Fluorides cause necrosis of leaf-tip while ethylene results in epinasty, leaf abscission and dropping of flowers.

Air pollution control measures:

1. Use public mode of transportation: Encourage people to use more and more **public modes of transportation** to reduce pollution. Also, try to make use of carpooling. If you and your colleagues come from the same locality and have same timings you can explore this option to save energy and money.

2. Conserve energy: Switch off fans and lights when you are going out. Large amount of fossil fuels are burnt to produce electricity. You can save the environment from degradation by reducing the amount of fossil fuels to be burned. Since electricity production releases a huge number of air pollutants, using as little energy as possible can help minimize the amount produced in any one day. If you spread the message too, you can have a noticeable **impact on electricity** production. Simply changing lightbulbs to **energy efficient alternatives,** turning off appliances when not in use and reducing the amount of time spent in front of the television or on the computer are good starts.

3. Understand the concept of Reduce, Reuse and Recycle: Do not throw away items that are of no use to you. In-fact reuse them for some other purpose. For e.g. you can use old jars to store cereals or pulses. Who wouldn't have heard of 3 words **Reduce, Reuse and Recycle.** Reduce simple means reducing the consumption of goods like plastic bags that can hurt the environment. Reuse means reusing the same thing for some different purpose; like reusing the old jar for storing cereals or pulses. Recycling stands for recycling old items so that they can be made into some useful products again.

4. Emphasis on clean energy resources: Clean energy technologies like **solar, wind** and **geothermal** are on high these days. Governments of various countries have been providing grants to consumers who are interested in installing **solar panels** for their home. This will go a long way to curb air pollution.

5. Use energy efficient devices: CFL lights consume **less electricity** as against their counterparts. They live longer, consume less electricity, lower electricity bills and also help you to reduce pollution by consuming less energy.

1. **Raise awareness.** Whether it is through joining non-profits, activist groups, or even just posting about the matter online, raising people's awareness about air pollution and its causes is an important step in reducing the problem around the world.
2. **Try to minimize travel in cars and airplanes.** While driving is often unavoidable, there are many who could quite easily cut down on their fuel consumption by making use of public transportation or even bikes. Similarly, making use of a more fuel-efficient vehicle is a good way to make the car travel we do undertake much less harmful. Keeping a car serviced and safe will dramatically improve its fuel-efficiency and reduce the volume of emissions it releases. Airplanes are among the **worst contributors to air pollution,** so consider staying in the country when vacationing.
3. **Get your car's engine tune up.** Keeping your car's engine tune up will make sure that it does not consume more fuel and gives you a better mileage.
4. **Keep tires properly inflated.** Cars consume more gasoline when tires are not properly inflated. Keep the air pressure to optimum level will reduce your **impact on the environment.**
5. **Get energy audit done for your home**. Get **energy audit done** and ask the auditor about changes that we can make in order to ensure that **your home is as energy efficient** as possible. They can give us recommendations that will help us out and even save us money in the long run.
6. **Consider going green.** There are **various ways to go green** without even spending a extra penny. For e.g.: use **public mode of transportation** instead of car, opt for eco-friendly hotels when go out on a holiday, buy items with less packaging, buy energy-

efficient appliances, use daylight as much as possible, avoid buying plastic water bottles, and many more.

7. **Plant trees and plants**, as these can help to increase the amount of breathable air available, and reduce levels of certain pollutants that **cause harm to the environment.**

Several attempts are being made worldwide on personal, industrial and governmental levels to curb the intensity at which Air Pollution is rising and regain a balance as far as the proportions of the foundation gases are concerned. This is a direct attempt at slacking Global warming. We are seeing a series of innovations and experiments aimed at alternate and unconventional options to reduce pollutants. Air Pollution is one of the larger mirrors of man's follies, and a challenge we need to overcome to see a tomorrow.

COMMON AIR POLLUTANTS AND THEIR HEALTH EFFECTS

POLLUTANT	**SOURCES**	**EFFECTS**
Benzene	Motor vehicle exhausts and petrol evaporation	Human carcinogen
1-3 Butadiene	Motor vehicle exhausts and chemical industrial processes.	Human carcinogen
Carbon Monoxide	Incomplete combustion of organic materials (Carbon containing). Wood, coal, oil, gas. Outdoors: vehicle exhausts, heating appliances. Indoors: smoking, heaters (unvented).	Reduces the oxygen-carrying capacity of the blood leading to headache, nausea, vomiting, eventually collapse and death.
Lead	Outdoors: motor vehicle exhausts. Indoors: may be present in water pipes and/or old paint.	Cumulative effects on the nervous system that may impair children's intelligence and concentration.
Nitrogen Dioxide	Combustion of fossil fuels, road vehicles' power generation, industrial processes. Indoors: unvented gas cookers and other appliances.	Throat and eye irritation (also involved in photochemical smog formation).
Ozone	Product of chemical reaction between other pollutants (Nitrogen Oxide and hydrocarbons in the presence of sunlight).	Running eyes, throat irritation, breathing difficulties.
PM10 (particles less	Combustion processes and	Small particles can penetrate

than 10 micrometres in diameter)	natural sources such as dust, diesel and smoke.	deep into the lungs and cannot be expelled. They may cause irritation and/or carry with them toxic or carcinogenic substances.
Sulphur Dioxide	Domestic and industrial burning of coal.	Irritation of the nerves in the nose, throat and airways. May also lead to constriction of the airways.
Asbestos	Building material, wall cladding, insulation, brake linings. Exposure usually indoors during building work and car maintenance.	Scarring of the lungs and increased risk of lung, chest and abdominal cancer.
Volatile Organic Compounds, e.g. Formaldehyde	Paints, varnishes, glues and preservatives used in wood products. Foam insulation. Exposure indoors during decoration or construction.	Breathing difficulties, eye and skin irritation, nausea and dizziness.
Radon	Rocks which contain naturally occurring radioactive material emit Radon gas.	Increased risk of lung cancer.
Cigarette smoke, Nicotine, tar, formaldehyde, oxides of nitrogen and Carbon Monoxide	Smoking	Eye, throat and lung irritation. Increased liability to respiratory illness. Increased risk of lung cancer. Non-smokers breathing in others' smoke are also at risk.
Micro-organisms and allergens	Biological contaminants, moulds, spores, viruses and bacteria	Pneumonia-like respiratory illnesses, allergic reactions.

WATER POLLUTION

Over two thirds of Earth's surface is covered by **water;** less than one third is taken up by land. As Earth's population continues to grow, people are putting ever-increasing pressure on the planet's water resources. In a sense, our oceans, rivers, and other inland waters are being "squeezed" by human activities—not so they take up less room, but so their quality is reduced. Poorer water quality means **water pollution**.

Water is one of the most precious natural resources. Although more than 70% of earth's surface is covered with water, 97% of it is in Oceans and thus saline. Fresh water constitutes only 3% which is present in rivers, lakes and glaciers. Out of these, only 1% is available for human use. We know that pollution is a human problem because it is a relatively recent development in the planet's history: before the 19th century Industrial Revolution, people lived more in harmony with their immediate environment. As industrialization has spread around the globe, so the problem of pollution has spread with it. When Earth's population was much smaller, no one believed pollution would ever present a serious problem. It was once popularly believed that the oceans were far too big to pollute. Today, with around 7 billion people on the planet, it has become apparent that there are limits. Pollution is one of the signs that humans have exceeded those limits.

According to the environmental campaign organization, **"Pollution from toxic chemicals threatens life on this planet. Every ocean and every continent, from the tropics to the once-pristine polar regions, is contaminated."**

With about 70% of the earth's cover being water, it undeniably becomes one of our greatest resources and water is used in almost every important human chores and processes. It is an important element in both domestic as well as industrial purposes. However closer inspections of our water resources today, give us a rude shock.

Infested with waste ranging from floating plastic bags to chemical waste, our water bodies have turned into a pool of poison. The contamination of water bodies in simplest words means water pollution. Thereby the abuse of lakes, ponds, oceans, rivers, reservoirs etc is water pollution. Pollution of water occurs when substances that will modify the water in negative fashion are discharged in it. This discharge of pollutants can be direct as well as indirect.**Water pollution can be defined as the contamination of water due to alteration of its physical, chemical or biological properties which may render the water harmful to public health or to domestic, commercial, industrial, agricultural or any other uses.**

Water pollution is an appalling problem, powerful enough to lead the world on a path of destruction. Water is an easy solvent, enabling most pollutants to dissolve in it easily and contaminate it. The most basic effect of water pollution is directly suffered by the organisms and vegetation that survive in water, including amphibians. On a human level, several people die each day due to consumption of polluted and infected water.

As per the Economist report (dated 2008) each day over 1000 children die of diarrheal sickness in India and the numbers have only increased alarming in the last five years. Water is polluted by both natural as well as man-made activities. Volcanic eruptions, earthquakes, Tsunamis etc are known to alter water and contaminate it, also affecting ecosystems that survive under water.**Here are some UN statistics on water pollution:**

1. Every day 2 million tons of human wastes are disposed of in water bodies.

2. In developing countries 70% of industrial wastes are dumped untreated into water bodies where they pollute the usable water supply.

3. Projected increases in fertilizers use for food production and in waste water effluents over the next three decades suggest there will be a 10-20 percent global increase in rivernitrogen flows into coastal systems.

4. Half of the world's wetlands, which act as natural filters have been lost since 1900.

Sources of water pollution:

There are various classifications of water pollution. The two chief sources of water pollution can be seen as **Point and Non Point.**

Point source refers to the pollutants that belong to a single source. Point sources discharge relatively large quantities of waste water into bodies of surface water at specific locations. Point sources can be easily identified at a single location. It is easy to identify, monitor and control point sources. Water pollution caused by these sources can be minimized if the effluents from these sources are controlled, treated up to acceptable levels and disposed of. Examples: pipe lines of municipal or industrial waste water.

Non-Point source on the other hand means pollutants emitted from multiple sources. Non-point sources are diffused sources whose source of origin cannot be easily identified. Non-point sources are diffused across a broader area and their locations cannot be easily identified. Here the pollutants scattered on the ground ultimately reach the water sources and cause pollution. It is very difficult to control pollution from diffused sources. Examples: run off from agricultural areas, streets, garages, mining areas etc. Contaminated water after rains that has traveled through several regions may be considered as a Non-point source of pollution.

Causes of water pollution:

1. Industrial waste: Industries produce huge amount of waste which contains toxic chemicals and pollutants which can cause pollution and damage to us and our environment. They contain pollutants such as lead, mercury, sulphur, asbestos, nitrates and many other harmful chemicals. Many industries do not have proper waste management system and drain the waste in the fresh water which goes into rivers, canals and later in to sea. The toxic chemicals have the capability to change the colour of water, increase the amount of minerals, also known as Eutrophication, change the temperature of water and pose serious hazard to water organisms.

2. Sewage and waste water: The sewage and waste water that is produced by each household is chemically treated and released in to sea with fresh water. The sewage water carries harmful bacteria and chemicals that can cause serious health problems. Pathogens are known as a common water pollutant; the sewers of cities house several pathogens and thereby diseases. Microorganisms in water are known to be causes of some very deadly diseases and become the breeding grounds for other creatures that act like carriers. These carriers inflict these diseases via various forms of contact onto an individual. A very common example of this process would be Malaria.

3. Mining activities: Mining is the process of crushing the rock and extracting coal and other minerals from underground. These elements when extracted in the raw form contain harmful chemicals and can increase the amount of toxic elements when mixed up with water which may result in health problems. Mining activities emit several metal waste and sulphides from the rocks and is harmful for the water.

4. Marine dumping: The garbage produced by each household in the form of paper, aluminum, rubber, glass, plastic, food if collected and deposited into the sea in some countries. These items take from 2 weeks to 200 years to decompose. When such items enter the sea, they not only cause water pollution but also harm animals in the sea.

5. Accidental Oil leakage: Oil spill pose a huge concern as large amount of oil enters into the sea and does not dissolve with water; there by opens problem for local marine wildlife such as fish, birds and sea otters. For e.g.: a ship carrying large quantity of oil may spill oil if met with an accident and can cause varying damage to species in the ocean depending on the quantity of oil spill, size of ocean, toxicity of pollutant.

6. Burning of fossil fuels: Fossil fuels like coal and oil when burnt produce substantial amount of ash in the atmosphere. The particles which contain toxic chemicals when mixed with water vapor result in **acid rain.** Also, carbon dioxide is released from **burning of fossil fuels** which result in global warming.

7. Chemical fertilizers and pesticides: Chemical fertilizers and pesticides are used by farmers to protect crops from insects and bacteria. They are useful for the plants growth. However, when these chemicals are mixed up with water produce harmful effects on plants and animals, also, when it rains, the chemicals mixes up with rainwater and flow down into rivers and canals which pose serious damages for aquatic animals.

8. Leakage from sewer lines: A small leakage from the sewer lines can contaminate the underground water and make it unfit for the people to drink. Also, when not repaired on time, the leaking water can come on to the surface and become a breeding ground for insects and mosquitoes.

9. Global warming: An increase in earth’s temperature due to **greenhouse effect** results in **global warming.** It increases the water temperature and result in death of aquatic animals and marine species which later results in water pollution.

10. Radioactive waste: **Nuclear energy** is produced using nuclear fission or fusion. The element that is used in **production of nuclear energy** is Uranium which is highly toxic chemical. The nuclear waste that is produced by radioactive material needs to be disposed of to prevent any nuclear accident. Nuclear waste can have serious environmental hazards if not disposed of properly. Few major accidents have already taken place in Russia and Japan.

11. Urban development: As population has grown, so has the demand for housing, food and cloth. As more cities and towns are developed, they have resulted in increased use of fertilizers to produce more food, soil erosion due to **deforestation,** increase in construction activities, inadequate sewer collection and treatment, landfills as more garbage is produced, increase in chemicals from industries to produce more materials.

12. Leakage from the landfills: Landfills are nothing but huge pile of garbage that produces awful smell and can be seen across the city. When it rains, the landfills may leak and the leaking landfills can pollute the underground water with large variety of contaminants.

13. Animal waste: The waste produced by animals is washed away into the rivers when it rains. It gets mixed up with other harmful chemicals and causes various water borne diseases like cholera, diarrhea, jaundice, dysentery and typhoid.

14. Underground storage leakage: Transportation of coal and other petroleum products through underground pipes is well known. Accidentals leakage may happen anytime and may cause damage to environment and result in **soil erosion.**

Types of water pollution:

1. Surface Water Pollution:Surface water pollution is the most visible form of pollution and we can see it floating on our waters in lakes, streams, and oceans.Trash from human consumption, such as water bottles, plastics and other waste products, is most often evident on water surfaces.This type of pollution also comes from oil spills and gasoline waste, which float on the surface and affect the water and its inhabitants.

2. Groundwater Pollution:This type of pollution is becoming more and more relevant because it affects our drinking water and the aquifers below the soil.Groundwater pollution is usually caused by highly toxic chemicals and pesticides from farming that leak through the ground to contaminate the wells and aquifers below the surface.

3. Microbial Pollution:Microbiological pollution is the natural form of water pollution that is caused by microorganisms in uncured water. Most of these organisms are harmless but some bacteria, viruses, and protozoa can cause serious diseases such as cholera and typhoid.This is a significant problem for people in third world countries who have no clean drinking water and/or facilities to cure the water.

4. Oxygen Depletion Pollution: Microorganisms that thrive in water feed on biodegradable substances.When there is an influx of biodegradable material from such things as waste or erosion from farming, the numbers of these microorganisms increase and utilize the obtainable oxygen.When these oxygen levels are depleted, harmless aerobic microorganisms die and anaerobic microorganisms thrive. Some of these organisms produce damaging toxins like sulfide and ammonia.

5. Nutrient Pollution: Nutrients are usually found in wastewater and fertilizers. These can cause excess vegetation in the water such as algae and weeds, using up the oxygen in the water and hurting the surrounding marine life and other organisms in the water.

6. Suspended Matter Pollution: This type of pollution occurs when pollutants enter the water and do not mix in with the water molecules.These suspended particles form fine silt on the waterbed, harming the marine life by taking away the nutrients and disturbing their habitat.

7. Chemical Pollution: Due to the nature of industry these days and the mass production in industrial plants and farms, we have a lot of chemical run-off that flows into the nearby rivers and water sources.Metals and solvents flow out of factories and into the water, polluting the water and harming the wildlife. Pesticides from farms are like poison to the wildlife in the water and kill and endanger the aquatic life.If birds or humans eat these infected fish, the toxins are transferred to us and we swallow these dangerous pesticides and toxins, affecting our health.Petroleum is a different type of chemical pollutant that dramatically affects the aquatic life. This oil kills the fish and marine life and sticks to the feathers of birds, causing them to lose their ability to fly.

Water pollutants include both organic and inorganic factors: Organic factors include volatile organic compounds, fuels, waste from trees, plants etc. Inorganic factors include ammonia, chemical waste from factories, discarded cosmetics etc. The water that travels via fields is usually contaminated with all forms of waste inclusive of fertilizers that it swept along the way. This infected water makes its way to our water bodies and sometimes to the seas endangering the flora, fauna and humans that use it along its path.

The current scenario has led to a consciousness about water preservation and efforts are being made on several levels to redeem our water resources. Industries and factory set-ups are restricted from contaminating the water bodies and are advised to treat their contaminated waste through filtration methods. People are investing in rain water harvesting projects to collect rainwater and preserve it in wells below ground level.Water Pollution is common, and is an area of high alert. Water needs to be preserved and respected today, for us to live a tomorrow.

Effects of water pollution:

- Groundwater contamination from pesticides causes reproductive damage within wildlife in ecosystems.
- Sewage, fertilizer, and agricultural run-off contain organic materials that when discharged into waters, increase the growth of algae, which causes the depletion of oxygen. The low oxygen levels are not able to support most indigenous organisms in the area and therefore upset the natural ecological balance in rivers and lakes.
- Old Roofs can cause pollution if they are not properly maintained. If water is being held on roofs the water can become polluted and then run down the home and cause more pollution to the water table. Ifwe invest in a green roof we can help to reduce the water pollution from our home.
- Swimming and drinking contaminated water causes skin rashes and health problems like cancer, reproductive problems, typhoid fever and stomach sickness in humans, which is why it’s very important to make sure that our water is clean and safe to drink.
- Industrial chemicals and agricultural pesticides that end up in aquatic environments can accumulate in fish that are later eaten by humans. Fish are easily poisoned with metals that are also later consumed by humans. Mercury is particularly poisonous to small children and

women. Mercury has been found to interfere with the development of the nervous system in fetuses and young children.

- Ecosystems are destroyed by the rising temperature in the water, as coral reefs are affected by the bleaching effect due to warmer temperatures. Additionally, the warm water forces indigenous water species to seek cooler water in other areas, causing an ecological damaging shift of the affected area.
- Human-produced litter of items such as plastic bags and 6-pack rings can get aquatic animals caught and killed from suffocation.
- Water pollution causes flooding due to the accumulation of solid waste and soil erosion in streams and rivers.
- Oil spills in the water causes animal to die when they ingest it or encounter it. Oil does not dissolve in water so it causes suffocation in fish and birds.

Water pollution control measures:

1. Sewage treatments: The household water should be treated properly so that they become environmentally safe. Adequate care should be taken to ensure that effective sewage treatment process is in place and that contaminated water does not get mixed with the environment. In order to prevent **water pollution,** human and animal excreta should be prevented from mixing with its sources. Construction of pit toilet and proper sewage treatments can offer some solution to this problem.

2. Prevent river water to get polluted: The flowing water of the river cannot be cleaned easily by natural process. Since, a large number of external substances are discharged into the water, the river water becomes polluted. This may cause diseases to the people using river water. Thus, every effort should be made to prevent the river water to get contaminated. People should not be allowed to throw wastes into the river water.

3. Treatment of wastes before discharge: Factories are expected to treat its effluent wastes prior to discharge. Toxic material must be treated chemically and converted into harmless materials. If possible, factories should try to recycle the treated water.

4. Strict adherence to water laws: Laws and legislation relating to pollution should be strictly followed by all. People should be made aware that adherence to water laws is in their own interest.

5. Treatment of drainage water: It cities, a huge amount of water is put into drains every day. The water that flows through the city drainage system should be properly treated. Harmful pollutants are removed, before they are introduced into reservoirs. If this water allowed going into water reservoirs without treatment, it will pollute them.

6. Treatment plants: Big cities and towns usually have effluent treatment plants. These plants filter out undissolved materials. Chemical treatment is also given to separate out unwanted dissolved chemicals. The treated water is either allowed to go into the water reservoirs or refused in houses. Occasionally, the treated water is used for farming if the fields to be irrigated lie in the vicinity of the water treatment plants.

7. Keep the pond water clean and safe: Washing, bathing of cattle in the pond that is used by human should not be done. Washing of dirty clothes and bathing of cattle make the pond water dirty and unsuitable for human use. If these ponds are continually misuses, then it may lead of severe consequences.

8. Routine cleaning: Ponds, lakes and wells meant for human use should be routinely cleaned and treated, so that it remains fit for human use. It is an essential step that should not be avoided. A system of regular testing of pond and lake water can be introduced to ensure the safety of the water.

9. Don't pour insecticides in sinks and toilets: Never pour household insecticides, medicines, etc. down the sink, drain or toilet. At homes, people often throw wastes and old medicines into the bathroom toilet. This practice is discouraged for the reason that the chemical compounds of medicines, insecticides, etc., when mixed with other chemicals, may result in formation of harmful substances.

10. Self-hygiene: Self hygiene must be maintained and drinking water must not be polluted. Drinking water should be kept undercover in a clean place. One should not put his hands into the drinking water containers. Also, the practice of cleaning the drinking water reservoirs on a regular basis needs to be strictly followed. The water meant for drinking should be purified prior to use. In the absence of good water purifier, it is recommended to drink boiled water. This is also important to **prevent water borne diseases.**

11. Sanitation: Sanitation system must be improved. The benefits of cleanliness on human health need to be understood. Human contact with hazardous materials should be prevented. After using the toilet, one should always use the flush and wash their hands with soap and water.

12. Public Awareness: Common public should be aware about the effect of water pollution. Voluntary organization should go door-to-door to educate the people about environmental problems. They should perform street plays for creating awareness about the environment. They should run environmental education centers. Students can impart **health education** to enable people to prevent water pollution.

MODULE-VI

Hazard and disaster management plans for floods

Flood

Floods are the most common and widespread of all natural disasters. India is one of the highly flood prone countries in the world. Around 40 million hectares of land in India is prone to floods as per National Flood Commission report. Floods cause damage to houses, industries, public utilities and property resulting in huge economic losses, apart from loss of lives. Though it is not possible to control the flood disaster totally, by adopting suitable structural and non-structural measures the flood damages can be minimised. For planning any flood management measure latest, reliable, accurate and timely information is required. In this context satellite remote sensing plays an important role.

Rescue & Evacuation

Evacuation is a pre-emptive move to protect life and property, where as rescue is a post-disaster phenomenon of helping people to move from areas that have been hit by disaster to a safer place. However, the situation of evacuation and rescue comes along with numerous unanswered queries in mind. Very often, due to lack of information or in haste, living during evacuation and rescue becomes difficult and painful. However, during such the situations, following precautionary norms should be kept in mind.

Preparing for a Flood

Here are some basic steps to take to prepare for the flood:

- Contact the local geologist or town planning department or meteorology department to find out if your home is located in a flash-flood-prone area or landslide-prone area.
- Learn about your community's emergency plans, warning signals, evacuation routes, and locations of emergency shelters.
- Plan and practice a flood evacuation route with your family. Ask an out-of-state relative or friend to be the "family contact" in case your family is separated during a flood. Make sure everyone in your family knows the name, address, and phone number of this contact person.
- Post emergency phone numbers at every phone.
- Inform local authorities about any special needs, i.e., elderly or bedridden people, or anyone with a disability.
- Identify potential home hazards and know how to secure or protect them before the flood strikes. Be prepared to turn off electrical power when there is standing water, fallen power lines etc. Turn off gas and water supplies before you evacuate. Secure structurally unstable building materials.
- Buy a fire extinguisher and make sure your family knows where it is and how to use it.
- Buy and install sump pumps with back-up power.
- Have a licensed electrician to raise electric components (switches, sockets, circuit breakers and wiring) at least 12" above your home's projected flood elevation.
- For drains, toilets, and other sewer connections, install backflow valves or plugs to prevent floodwaters from entering.
- Anchor fuel tanks which can contaminate your basement if torn free. An unanchored tank outside can be swept downstream and damage other houses.

If you are under a flood watch or warning:

- Gather the emergency supplies you previously stocked in your home and stay tuned to local radio or television station for updates.
- Turn off all utilities at the main power switch and close the main gas valve if evacuation appears necessary.
- Have your immunization records handy or be aware of your last tetanus shot, in case you should receive a puncture wound or a wound becomes contaminated during or after the flood.

- Fill bathtubs, sinks and plastic soda bottles with clean water. Sanitize the sinks and tubs first by using bleach. Rinse and fill with clean water.
- Bring outdoor possessions, such as lawn furniture, grills and trash cans inside or tie them down securely.

Emergency Supplies You Will Need

You should stock your home with supplies that may be needed during the emergency period. At a minimum, these supplies should include:

- Several clean containers for water, large enough for a 3-5 day supply of water (about five gallons for each person).
- A 3-5 day supply of non-perishable food and a non-electric can opener.
- A first aid kit and manual and prescription medicines and special medical needs.
- A battery-powered radio, flashlights, and extra batteries.
- Sleeping bags or extra blankets.
- Water-purifying supplies, such as chlorine or iodine tablets or unscented, ordinary household chlorine bleach.
- Baby food and/or prepared formula, diapers, and other baby supplies.
- Disposable cleaning cloths, such as "baby wipes" for the whole family to use in case bathing facilities are not available.
- Personal hygiene supplies, such as soap, toothpaste, sanitary napkins, etc.
- An emergency kit for your car with food, flares, booster cables, maps, tools, a first aid kit, fire extinguisher, sleeping bags, etc.
- Rubber boots, sturdy shoes, and waterproof gloves.
- Insect repellent containing DEET, screens, or long-sleeved and long-legged clothing for protection from mosquitoes which may gather in pooled water remaining after the flood.

Preparing to Evacuate

Expect the need to evacuate and prepare for it. When a flood watch is issued, you should:

- Fill your vehicle's gas tank and make sure the emergency kit for your car is ready.
- If no vehicle is available, make arrangements with friends or family for transportation.
- Fill your clean water containers.
- Review your emergency plans and supplies, checking to see if any items are missing.
- Tune in the radio or television for weather updates.
- Listen for disaster sirens and warning signals.
- Put livestock and family pets in a safe area. Due to food and sanitation requirements, emergency shelters cannot accept animals.
- Adjust the thermostat on refrigerators and freezers to the coolest possible temperature.

If You Are Ordered to Evacuate

You should never ignore an evacuation order. Authorities will direct you to leave if you are in a low-lying area, or within the greatest potential path of the rising waters. If a flood warning is issued for your area or you are directed by authorities to evacuate the area, follow the below mentioned checklists:

- Take only essential items with you.
- If you have time, turn off the gas, electricity, and water.
- Disconnect appliances to prevent electrical shock when power is restored.
- Follow the designated evacuation routes and expect heavy traffic.
- Do not attempt to drive or walk across creeks or flooded roads.

If You Are Ordered NOT to Evacuate

To get through the storm in the safest possible manner:

- Monitor the radio or television for weather updates.
- Prepare to evacuate to a shelter or to a neighbour's home if your home is damaged, or if you are instructed to do so by emergency personnel

Safety and Security

Any natural calamities espouse itself with serious devastation to transportation, communication chaneel, supply of electricity etc. Hence, in the immediate aftermath of any calamity, the surrounding environment becomes dangerous and unsafe due to it's exposure to toxic and harmful objects. This becomes more important for children as they are usually overlooked by the parents during the calamity or in the immediate aftermath of it. The following safety and security guidelines can be kept in mind:

MANAGEMENT TECHNOLOGIES FOR FLOOD AFFECTED FIELD

Management Technology for submerged paddy / flooded paddy at harvest

Unforeseen situation may arise during any stage of paddy cultivation. If late incessant rains are received, standing paddy crop may be submerged even for days together and it may be even at harvest stage. Technologies to manage this situation are:

1. As a first step drainage should be aided and all possible means are to be taken up.
2. Immediately after the standing water column recedes, combine harvesters can be used for rapid harvesting of the crop. Special harvesters are available to work in a mire situation.
3. The grain at this situation may be excessively wet. If drying is difficult for few days, the harvested grain may be mixed with common salt and the produce may be sun dried at the earliest opportunity.

Mitigation of Water logging Stress

1. Providing adequate drainage for draining excessive stagnating water around the root system.
2. Spray of growth retardant of 500 ppm cycocel for arresting apical dominance and thereby promoting growth of laterals
3. Foliar spray of 2% DAP + 1% KCl (MOP)
4. Nipping terminal buds for arresting apical dominance and thus promoting growth sympodial branches (as in cotton) for increasing productivity
5. Spray of 40 ppm NAA for controlling excessive pre-mature fall of flowering/buds/young developing fruits and pods

6. Spray of 0.5 ppm brassinolide for increasing photosynthetic activity
7. Foliar spray of 100 ppm salicylic acid for increasing stem reserve utilization under high moisture stress
8. Foliar spray of 0.3 % Boric acid + 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ + 1.0 % urea during critical stages of the stress.

DRAINAGE

The adverse effects of waterlogging can be reduced to some extent by supplying nitrogenous fertilizers. The best method of avoiding waterlogging is by providing suitable drainage.

AGRICULTURAL DRAINAGE

Agricultural drainage is the provision of a suitable system for the removal of excessive irrigation or rain water from the land surface so as to provide suitable soil conditions for better plant growth.

Advantages of agricultural drainage

1. Provision of drainage facilitates early sowing of the crop.
2. Agricultural land can be used for a long time without any deterioration due to damaged soil structure and salt concentration.
3. Drainage lowers underground water table so as to facilitate increased root zone depth. Drainage improves soil aeration and increases soil temperature

Drainage for agricultural land is provided by surface and subsurface drainage.

SURFACE DRAINAGE

1. Surface drainage is the simplest and the most common method.
2. Drainage is achieved by digging open drains at suitable intervals and depth.
3. Irrigation channels also serve as drainage channels.

Advantages of surface drainage

1. Provision of surface drainage is cheap.
2. The defects in the open drainage can be seen easily and rectified.
3. It requires less available fall or grade to have an adequate outlet.

Disadvantages in surface drainage system

1. Considerable amount of land is wasted for open drains.
2. These drains cause hindrance to field preparation and intercultivation.
3. The drains get silted and periodical desilting is necessary.
4. Weed growth in the drains is heavy and this has to be removed.
5. Open drains are damaged by rodents and farm animals.

Different methods of surface drainage

Random Field Ditch Method

Standing water may be present in the field at several places distributed randomly. These depressions or micro ponds are connected by mean of shallow channels or ditches and these are led into an outlet.

Land Smoothing

The elevated area is cut off and excess soil is spread over low areas so that the surface is even with uniform slope. Excess surface run off is collected and conveyed into the field ditches provided at the lower end of the field.

Bedding

Small furrows are formed at known intervals parallel to the slope for draining out water. These furrows are known as dead furrows and land between these furrows is known as beds. Small ridges or bunds are made at the centre of the bed with gradual slope to drain water into the dead furrows.

Parallel Field Ditch system

It is almost similar to bedding system except for deep drains and uneven interval between drains.

Broad Bed and Furrow Method

The field is laid out with beds and wide furrows across the slope. About 0.5 per cent slope is provided for the furrows for free drainage. Crops are sown on the beds and furrows help in drainage of water when there is excess rain.

Hazard and disaster management plans for tidal waves or tsunami

Recover and build

- You should continue using a Weather Radio or staying tuned to a Coast Guard emergency frequency station or a local radio or television station for updated emergency information.
- Check yourself for injuries and get first aid if necessary before helping injured or trapped persons.
- If someone needs to be rescued, call professionals with the right equipment to help Many people have been killed or injured trying to rescue others in flooded areas.
- Help people who require special assistance—Infants, elderly people, those without transportation, large families who may need additional help in an emergency situation, people with disabilities, and the people who care for them.
- Avoid disaster areas. Your presence might hamper rescue and other emergency operations and put you at further risk from the residual effects of floods, such as contaminated water, crumbled roads, landslides, mudflows, and other hazards.
- Use the telephone only for emergency calls.Telephone lines are frequently overwhelmed in disaster situations. They need to be clear for emergency calls to get through.
- Stay out of a building if water remains around it. Tsunami water, like floodwater, can undermine foundations, causing buildings to sink, floors to crack, or walls to collapse.

- When re-entering buildings or homes, use extreme caution. Tsunami-driven floodwater may have damaged buildings where you least expect it. Carefully watch every step you take.
- Wear long pants, a long-sleeved shirt, and sturdy shoes. The most common injury following a disaster is cut feet.
- Use battery-powered lanterns or flashlights when examining buildings. Battery-powered lighting is the safest and easiest to use, and it does not present a fire hazard for the user, occupants, or building. DO NOT USE CANDLES.
- Examine walls, floors, doors, staircases, and windows to make sure that the building is not in danger of collapsing.
- Inspect foundations for cracks or other damage. Cracks and damage to a foundation can render a building uninhabitable.
- Look for fire hazards. Under the earthquake action there may be broken or leaking gas lines, and under the tsunami flooded electrical circuits, or submerged furnaces or electrical appliances. Flammable or explosive materials may have come from upstream. Fire is the most frequent hazard following floods.
- Check for gas leaks. If you smell gas or hear a blowing or hissing noise, open a window and get everyone outside quickly. Turn off the gas using the outside main valve if you can, and call the gas company from a neighbour's home. If you turn off the gas for any reason, it must be turned back on by a professional.
- Look for electrical system damage. If you see sparks or broken or frayed wires, or if you smell burning insulation, turn off the electricity at the main fuse box or circuit breaker. If you have to step in water to get to the fuse box or circuit breaker, call an electrician first for advice. Electrical equipment should be checked and dried before being returned to service
- Check for damage to sewage and water lines.If you suspect sewage lines are damaged under the quake, avoid using the toilets and call a plumber. If water pipes are damaged, contact the water company and avoid using water from the tap. You can obtain safe water from undamaged water heaters or by melting ice cubes that were made before the tsunami hit. Turn off the main water valve before draining water from these sources. Use tap water only if local health officials advise it is safe.
- Watch out for wild animals, especially poisonous snakes that may have come into buildings with the water. Use a stick to poke through debris. Tsunami floodwater flushes snakes and animals out of their homes.
- Watch for loose plaster, drywall, and ceilings that could fall.
- Take pictures of the damage, both of the building and its contents, for insurance claims. Open the windows and doors to help dry the building.
- Shovel mud before it solidifies.
- Check food supplies.Any food that has come in contact with floodwater may be contaminated and should be thrown out.
- Expect aftershocks. If the earthquake is of large magnitude (magnitude 8 to 9+ on the Richter scale) and located nearby, some aftershocks could be as large as magnitude 7+ and capable of generating another tsunami. The number of aftershocks will decrease over the course of several days, weeks, or months depending on how large the main shock was.
- Watch your animals closely.
- Keep all your animals under your direct control.

Emergency Kit

- Battery operated torch

- Extra batteries
- Battery operated radio
- First aid kit and manual
- Emergency food (dry items) and water (packed and sealed)
- Candles and matches in a waterproof container
- Knife
- Chlorine tablets or powdered water purifiers
- Can opener.
- Essential medicines
- Cash, Aadhar Card and Ration Card
- Thick ropes and cords
- Sturdy shoes

Do's and Dont's

- You should find out if your home, school, workplace, or other frequently visited locations are in tsunami hazard areas along sea-shore.
- Know the height of your street above sea level and the distance of your street from the coast or other high-risk waters. (Local administration may put sign boards).
- Plan evacuation routes from your home, school, workplace, or any other place you could be where tsunamis present a risk.
- If your children's school is in an identified inundation zone, find out what the school evacuation plan is.
- Practice your evacuation routes.
- Use a Weather Radio or stay tuned to a local radio or television station to keep informed of local watches and warnings.
- Talk to your insurance agent. Homeowners' policies may not cover flooding from a tsunami. Ask the Insurance Agent about the benefits from Multi-Hazard Insurance Schemes.
- Discuss tsunamis with your family. Everyone should know what to do in a tsunami situation. Discussing tsunamis ahead of time will help reduce fear and save precious time in an emergency. Review flood safety and preparedness measures with your family.

If you are in an area at risk from tsunamis

- You should find out if your home, school, workplace, or other frequently visited locations are in tsunami hazard areas.
- Know the height of your street above sea level and the distance of your street from the coast or other high-risk waters. (Local administration may put sign boards). Also find out the height above sea level and the distance from the coast of outbuildings that house animals, as well as pastures or corrals.
- Plan evacuation routes from your home, school, workplace, or any other place you could be where tsunamis present a risk. If possible, pick areas (30 meters) above sea level or go as far as 3 kilometers inland, away from the coastline. If you cannot get this high or far, go as high or far as you can. Every meter inland or upward may make a difference. You should be able to reach your safe location on foot within 15 minutes. After a disaster, roads may become blocked or unusable. Be prepared to evacuate by foot if necessary. Footpaths normally lead uphill and inland, while many roads parallel coastlines. Follow posted tsunami evacuation routes; these will lead to safety. Local emergency management officials can advise you on the best route to safety and likely shelter locations.

- If your children's school is in an identified inundation zone, find out what the school evacuation plan is. Find out if the plan requires you to pick your children up from school or from another location. Telephone lines during a tsunami watch or warning may be overloaded and routes to and from schools may be jammed.
- Practice your evacuation routes. Familiarity may save your life. Be able to follow your escape route at night and during inclement weather. Practicing your plan makes the appropriate response more of a reaction, requiring less thinking during an actual emergency situation. Use weather Radio or stay tuned to a local radio or television station to keep informed of local watches and warnings.
- Talk to your insurance agent. Homeowners' policies may not cover flooding from a tsunami. Ask the Insurance Agent about the benefits from Multi-Hazard Insurance Schemes.
- Discuss tsunamis with your family. Everyone should know what to do in a tsunami situation. Discussing tsunamis ahead of time will help reduce fear and save precious time in an emergency. Review flood safety and preparedness measures with your family.

If you are visiting an area at risk from tsunamis

- Check with the hotel or campground operators for tsunami evacuation information and find out what the warning system is for tsunamis. It is important to know designated escape routes before a warning is issued.
- One of the early warning signals of a tsunami is that the sea water recedes several metres, exposing fish on shallow waters or on the beaches. If you see the sea water receding, you must immediately leave the beach and go to higher ground far away from the beach.
- Protect Your Property
- You should avoid building or living in buildings within 200 meters of the high tide coastline.
- These areas are more likely to experience damage from tsunamis, strong winds, or coastal storms.
- Make a list of items to bring inside in the event of a tsunami.
- A list will help you remember anything that can be swept away by tsunami water.
- Elevate coastal homes.
- Most tsunami waves are less than 3 meters. Elevating your house will help reduce damage to your property from most tsunamis.
- Take precautions to prevent flooding.
- Have an engineer check your home and advise about ways to make it more resistant to tsunami water.
- There may be ways to divert waves away from your property. Improperly built walls could make your situation worse. Consult with a professional for advice.
- Ensure that any outbuildings, pastures, or corrals are protected in the same way as your home. When installing or changing fence lines, consider placing them in such a way that your animals are able to move to higher ground in the event of a tsunami.

What to Do if You Feel a Strong Coastal Earthquake

- If you feel an earthquake that lasts 20 seconds or longer when you are in a coastal area, you should:
- Drop, cover, and hold on. You should first protect yourself from the earthquake damages.
- When the shaking stops.
- Gather members of your household and move quickly to higher ground away from the coast. A tsunami may be coming within minutes.

- Avoid downed power lines and stay away from damaged buildings and bridges from which Heavy objects might fall during an aftershock.

If you are on land

- Be aware of tsunami facts. This knowledge could save your life! Share this knowledge with your relatives and friends. It could save their lives!
- If you are in school and you hear there is a tsunami warning,
- You should follow the advice of teachers and other school personnel.
- If you are at home and hear there is a tsunami warning.
- You should make sure your entire family is aware of the warning. Your family should evacuate your house if you live in a tsunami evacuation zone. Move in an orderly, calm and safe manner to the evacuation site or to any safe place outside your evacuation zone. Follow the advice of local emergency and law enforcement authorities.

If you are at the beach or near the ocean and you feel the earth shake

- Move immediately to higher ground, DO NOT wait for a tsunami warning to be announced. Stay away from rivers and streams that lead to the ocean as you would stay away from the beach and ocean if there is a tsunami. A regional tsunami from a local earthquake could strike some areas before a tsunami warning could be announced.
- Tsunamis generated in distant locations will generally give people enough time to move to higher ground. For locally-generated tsunamis, where you might feel the ground shake, you may only have a few minutes to move to higher ground.
- High, multi-storied, reinforced concrete hotels are located in many low-lying coastal areas. The upper floors of these hotels can provide a safe place to find refuge should there be a tsunami warning and you cannot move quickly inland to higher ground.
- Homes and small buildings located in low-lying coastal areas are not designed to withstand tsunami impacts. Do not stay in these structures should there be a tsunami warning.
- Offshore reefs and shallow areas may help break the force of tsunami waves, but large and dangerous wave can still be a threat to coastal residents in these areas.
- Staying away from all low-lying areas is the safest advice when there is a tsunami warning.

If you are on a boat

- Since tsunami wave activity is imperceptible in the open ocean, do not return to port if you are at sea and a tsunami warning has been issued for your area. Tsunamis can cause rapid changes in water level and unpredictable dangerous currents in harbours and ports.
- If there is time to move your boat or ship from port to deep water (after a tsunami warning has been issued), you should weigh the following considerations:
- Most large harbours and ports are under the control of a harbor authority and/or a vessel traffic system. These authorities direct operations during periods of increased readiness (should a tsunami be expected), including the forced movement of vessels if deemed necessary. Keep in contact with the authorities should a forced movement of vessel be directed.
- Smaller ports may not be under the control of a harbor authority. If you are aware there is a tsunami warning and you have time to move your vessel to deep water, then you may want to do so in an orderly manner, in consideration of other vessels.

- Owners of small boats may find it safest to leave their boat at the pier and physically move to higher ground, particularly in the event of a locally-generated tsunami.
- Concurrent severe weather conditions (rough seas outside of safe harbor) could present a greater hazardous situation to small boats, so physically moving yourself to higher ground may be the only option.
- Damaging wave activity and unpredictable currents can affect harbours for a period of time following the initial tsunami impact on the coast. Contact the harbor authority before returning to port making sure to verify that conditions in the harbor are safe for navigation and berthing.

What to do after a Tsunami

- You should continue using a Weather Radio or staying tuned to a Coast Guard emergency frequency station or a local radio or television station for updated emergency information.
- The Tsunami may have damaged roads, bridges, or other places that may be unsafe.
- Check yourself for injuries and get first aid if necessary before helping injured or trapped persons.
- If someone needs to be rescued, call professionals with the right equipment to help.
- Help people who require special assistance— Infants, elderly people, those without transportation, large families who may need additional help in an emergency situation, people with disabilities, and the people who care for them.
- Avoid disaster areas.
- Your presence might hamper rescue and other emergency operations and put you at further risk from the residual effects of floods, such as contaminated water, crumbled roads, landslides, mudflows, and other hazards.
- Use the telephone only for emergency calls.Telephone lines are frequently overwhelmed in disaster situations. They need to be clear for emergency calls to get through.
- Stay out of a building if water remains around it.Tsunami water, like floodwater, can undermine foundations, causing buildings to sink, floors to crack, or walls to collapse.
- When re-entering buildings or homes, use extreme caution.Tsunami-driven floodwater may have damaged buildings where you least expect it. Carefully watch every step you take.
- Wear long pants, a long-sleeved shirt, and sturdy shoes.The most common injury following a disaster is cut feet.
- Use battery-powered lanterns or flashlights when examining buildings.Battery-powered lighting is the safest and easiest to use, and it does not present a fire hazard for the user, occupants, or building. DO NOT USE CANDLES.
- Examine walls, floors, doors, staircases, and windows to make sure that the building is not in danger of collapsing. Inspect foundations for cracks or other damage. Cracks and damage to a foundation can render a building uninhabitable.
- Look for fire hazards.Under the earthquake action there may be broken or leaking gas lines, and under the tsunami flooded electrical circuits, or submerged furnaces or electrical appliances. Flammable or explosive materials may have come from upstream. Fire is the most frequent hazard following floods.
- Check for gas leaks.If you smell gas or hear a blowing or hissing noise, open a window and get everyone outside quickly. Turn off the gas using the outside main valve if you can, and call the gas company from a neighbour’s home. If you turn off the gas for any reason, it must be turned back on by a professional.

- Look for electrical system damage. If you see sparks or broken or frayed wires, or if you smell burning insulation, turn off the electricity at the main fuse box or circuit breaker. If you have to step in water to get to the fuse box or circuit breaker, call an electrician first for advice. Electrical equipment should be checked and dried before being returned to service.
- Check for damage to sewage and water lines. If you suspect sewage lines are damaged under the quake, avoid using the toilets and call a plumber. If water pipes are damaged, contact the water company and avoid using water from the tap. You can obtain safe water from undamaged water heaters or by melting ice cubes that were made before the tsunami hit. Turn off the main water valve before draining water from these sources. Use tap water only if local health officials advise it is safe.
- Watch out for wild animals, especially poisonous snakes that may have come into buildings with the water. Use a stick to poke through debris. Tsunami floodwater flushes snakes and animals out of their homes.
- Watch for loose plaster, drywall, and ceilings that could fall.
- Take pictures of the damage, both of the building and its contents, for insurance claims. Open the windows and doors to help dry the building.
- Shovel mud before it solidifies.
- Check food supplies.
- Any food that has come in contact with floodwater may be contaminated and should be thrown out.
- Expect aftershocks. If the earthquake is of large magnitude (magnitude 8 to 9+ on the Richter scale) and located nearby, some aftershocks could be as large as magnitude 7+ and capable of generating another tsunami. The number of aftershocks will decrease over the course of several days, weeks, or months depending on how large the main shock was.
- Watch your animals closely. Keep all your animals under your direct control. Hazardous materials abound in flooded areas. Your pets may be able to escape from your home or through a broken fence. Pets may become disoriented, particularly because flooding usually affects scent markers that normally allow them to find their homes. The behaviour of pets may change dramatically after any disruption, becoming aggressive or defensive, so be aware of their well-being and take measures to protect them from hazards, including displaced wild animals, and to ensure the safety of other people and animals.

Learning to cope with disasters:

What can we do now:

1. Disaster Management Information System must be built in every district of the country linked with each other, available on the web and also in public libraries. We should know where are the inventories available of critical equipments, skills, resources and information and how can one access them on voluntary or payment basis. The database of various services and infrastructure in private, public and voluntary sectors should be updated regularly. Every college should take responsibility for collecting and updating information about certain categories of services or equipments. Simple information such as about ham radio operators can be put on the web without fail.
2. Just as we have national services scheme, we must now think of national disaster management volunteers who would receive training and be empowered to organize themselves as effective teams for helping local communities around them. No amount

of state help can substitute for community based structures for self help. Supreme Court had passed judgments and given advice for starting courses on disaster management in various educational institutions. Have we ever monitored how many such courses exist and what quality of preparedness has been achieved?

3. The major tragedy will begin when the media will get interested in new issues, fight among some other politicians or corporate games. Resources would be required for repairing and building the primary school buildings, primary health centres, livestock, clinics, tree climbing devices for palm workers, herbal and other medicines, mat making machines, and machines which can use materials from damaged trees and bio waste, old bamboo scrap, processing machine for various edible and non-edible oilseeds, etc. A proper rehabilitation plan will have to be built for each village affected by the disaster with proper accountability structure. The accounts of every investment must be made public and people should be able to know how much funds were mobilized by which NGO or government agency and how were they used for the purpose.
4. In cases where fishing communities or island based indigenous / tribal communities have been affected very severely, long term rehabilitation plans have to be initiated. These plans must learn from the mistakes made in earlier rehabilitation projects.
5. There is very important need to document the experience of the damage caused and ensuing suffering along with the coping strategies of local communities and administration. Some novel lessons would emerge.
6. One of the major problems in relief is that what is needed where is often not known to the people who want to provide support. The result is that lot of materials get wasted or misdirected. We need to put a spreadsheet immediately on the web pointing out village wise needs, contact persons' names and addresses so that civil society efforts can be targeted more efficiently. We had tried to put an inventory management system in place after Gujarat earthquake with the help of our students and faculty. The students had stacked the relief material received from all over the country in Kutchh and given assorted sheets to the Relief Commissioner. Where we failed was to link this system with GIS so that one could track the deliveries, collect the response and also avoid pilferages. It will be useful if some of the IT firms in Chennai would volunteer to create such a GIS so that people can update the demand and supply information and every unit of material is optimally utilized.
7. The psychological rehabilitation is no less important. The children affected the by the shock and tragedy are particularly vulnerable. The arrangements for adoption of orphan children with proper community care have to be put in place.
8. It is very disheartening to hear that in large number of cases of dead people, the Public Health authorities have been reportedly hesitant in maintaining proper records. It might save the state and central governments some money from the compensation fund but it would certainly inflict damage on the social conscience of the society. If the rehabilitation funds reach late, they are as good as not given. Unless central government ensures delivery of compensation through community control systems within next 24 hours, the fairness in the system will become more and more difficult to achieve with every passing day. While we still need immediate help, the long term rehabilitation must be simultaneously planned.

AGRICULTURAL TECHNOLOGIES FOR TSUNAMI DEVASTATED AREAS - NAGAPATTINAM DISTRICT

On 26 December 2004, Tsunami waves wreaked havoc on the coastal regions of the Indian Ocean and claimed around 400,000 lives. In Tamil Nadu the worst affected district is Nagapattinam district. The scheme "Resilience of agricultural lands in tsunami devastated coastal areas of Nagapattinam district of Tamil Nadu" is operating for development of sustainable livelihood of affected farmers through better crop production and allied agricultural activities and the management strategies drawn were as detailed below:

1. Soil management

- **Incorporation of sea mud:** The sea mud deposited in the agricultural lands will be low in salinity due to the action of rain water and hence the farmers are advised to incorporate it into the lands.
- **Chisel ploughing:**To break the subsoil hard pan and improve the water infiltration rate, chisel ploughing is recommended. This facilitates leaching process.

- **Leaching:** Leaching the excess salinity.
- **Tank silt:** To counteract the soil salinity and increase the soil fertility tank silt is recommended.
- **Green manuring:** Green manuring with Sesbania sp. and sunhemp was recommended. Between these daincha is progressing well.

2. Water management

- **De-silting of ponds:**The silt deposited ponds are desilted for two consecutive years to increase the capacity and remove the salined water.
- **Micro irrigation:** Drip and sprinkler irrigation systems are advised to the farmer.

3. Crop management

- **Rice varieties:**Suitable rice varieties are identified through field experiments. They are

  Transplanting : CO 43, TRY 1 and ADT 43
  Direct sowing : ADT 43, CO 43 and ADT 38

- **Vegetables:**Suitable vegetable crops and varieties are identified through field experiments. They are brinjal, gourds, cluster bean, pumpkin and amaranthus.
- **Plantation crops:**Mango, sapota, amla, pomegranate and guava are suggested for the Tsunami affected regions.
- **SRI:** SRI should be introduced.
- **Coconut root tonic:** Coconut root tonic is introduced through regular field demonstrations and the farmers are applying the tonic to their palms.

4. Livelihood management

- **Vermicompost production:**Trainings should be organized to the farmers for commercial Vermicompost production.

- **Mushroom cultivation:**Field demonstrations should be organized for the farmers and landless people to start commercially production.
- **Livestock management:**

Telicherry breed of goatsis introduced to this region.

- **Cumbu Napier grass** is introduced.
- **Guinea grass**and**subabul**are suggested for fodder management.