Government of Jammu & Kashmir
Higher Education Department

E-CONTENT

A Gateway to all Under Graduate Courses

Subject	Environmental Sciences
Paper Title	Environmental Studies
Course Name	Environmental Hazards: Concept and Management
Course Code	PSESTE 601
Module/Unit No	Understanding Disasters and Their Characteristics; Unit-II (2.4)
Title	**Geological Disasters: Avalanches**
Affiliated Institution: GDC Kishtwar	University of Jammu
Content Developer Name: **Dr. Sehrish Gazal** Designation: Assistant Professor Email: sehrishgazal@gmail.com	**Reviewer** Name: Designation:

TABLE OF CONTENTS

2.4.4 AVALANCHES

I. INTRODUCTION

An avalanche is a rapid flow of snow down a hill or mountainside. An avalanche is a very large slide of rapidly moving granular material, most commonly snow, down a mountainside caused by a buildup of material. When a mass of material exceeds the static friction threshold, a cascading effect takes place and accumulates more material as it travels down the mountainside and causes massive, widespread destruction. There are many different types of avalanches including snow, ice, rock and soil.

The word avalanche is derived from the French word '**avalance**' meaning descent. An avalanche is a mass of snow, often mixed with ice and debris which travels down mountain sides, destroying all in its path. An avalanche (also called a snowslide) is an event that occurs when a cohesive slab of snow lying upon a weaker layer of snow fractures and slides down a steep slope.

What is avalanche?

- Rapid flow of snow down on a slope
- Triggered in starting zone
- Form gravity current
- Triggered by seismic activity, explosion, snow mobile.

Falling masses of snow and ice, avalanches pose a threat to anyone on snowy mountainsides. Beautiful to witness from afar, they can be deadly because of their intensity and seeming unpredictability. Humans trigger 90 percent of avalanche disasters, with as many as 40 deaths in North America each year among which most are climbers, skiers, and snowmobilers.

II. AVALANCHE VULNERABILITY ZONES IN INDIA

Snow and Avalanche problem is a problem of high altitude mountainous regions, which receive heavy snow precipitation and are either inhabited or are used frequently by human beings for communication, winter sports, mountaineering, defense, natural resource exploration, etc.

The avalanche areas of our country lie along the Northern parts of Jammu and Kashmir, Himachal Pradesh, hills of Uttaranchal and up to Sikkim in the Eastern region. These areas, due to communication difficulties and remoteness from the rest of the country, are very thinly populated and under-developed and hence a lot of incidents of this nature in these areas go unnoticed and they do not receive media attention. Nevertheless, there lies a great potential for development, which needs our careful attention for mitigating such disasters. Every year, avalanches in these areas take a heavy toll of lives and cause considerable damage to properly.

Severe snow avalanches are observed during and after snowfalls in Jammu & Kashmir, Himachal Pradesh and the Hills of Western Uttar Pradesh.

1. **Jammu and Kashmir**: Higher reaches of Kashmir and Gurez valleys, Keran, Machhil, Pahalgam, Gulmarg, Naugam, Banihal, Kargil and Ladakh and some of the major roads.

2. **Himachal Pradesh**: Chamba, Kullu-Spiti and Kinnaur are vulnerable areas.

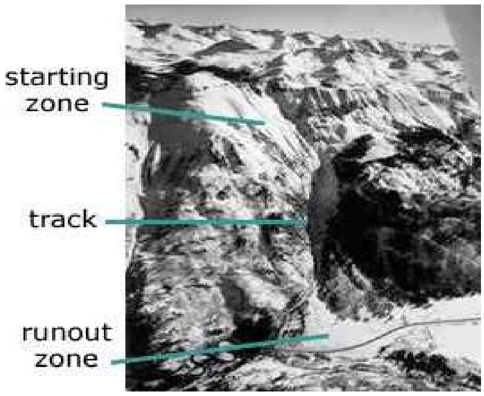
3. **Uttaranchal**: Parts of Tehri Garhwal and Chamoli districts are vulnerable areas.

SNOW AVALANCHE ZONES

- **1. Red Zone**: The most dangerous zone where snow avalanches are most frequent and have an impact pressure of more than 3 tonnes per square metre.
- **2. Blue Zone:** Where the avalanche force is less than 3 tonnes per square metre and where living and other activities may be permitted with connection of safe designs but such areas may have to be vacated on warning.
- **3. Yellow Zone:** Where snow avalanches occur only occasionally.

III. FEATURES OF AVALANCHES

Avalanches contain three main features:



1. **Starting zone:** Avalanches launch from the starting zone. The **starting zone** is the most volatile area of a slope, where unstable snow can fracture from the surrounding snow cover and begin to slide. Typical starting zones are higher up on slopes. However, given the right conditions, snow can fracture at any point on the slope.
2. **Avalanche track:** The avalanche track is the path or channel that an avalanche follows as it goes downhill. Large vertical swaths of trees missing from a slope or chute-like clearings are often signs that large avalanches run frequently there, creating their own tracks.
3. **Runout zone**: The runout zone is where the snow and debris finally come to a stop. Similarly, this is also the location of the deposition zone, where the snow and debris pile the highest.The avalanche finally comes to a stop at the bottom of a slope, in the runout zone, where the snow and debris pile up.

IV. CAUSES OF AVALANCHES

There are three main factors that contribute to causing an avalanche. If the steepness of the terrain is between 35 to 45 degrees, is shady, has a convex shape and has a rock or slab base with little vegetation the chance of an avalanche is extremely high. Weather is another main factor where everything from temperature to wind and rain can loosen the material pack and cause an avalanche. For a snow avalanche, the snow itself can contribute to the probability of an avalanche. If there is a large amount of new, unbounded snow with little compaction and a large crystal size, the snow can cause an avalanche all by itself.

VIDEO: What causes an avalanche? Britannica

- **https://www.britannica.com/video/179485/Overview-avalanches**

Whenever the gravitational force exceeds the mechanical strength of the snow cover, an avalanche occurs. This process of avalanche is triggered by either natural and artificial factors

Natural triggers for Avalanche	Artificial triggers for Avalanche
• Large mass of fresh snowfall • Blizzards of snow • Global warming and rain • Earthquakes	• Skiing and mountaineering activities • Deforestation along the slopes • Loud sounds and shouts • Machine noises • Sonic booms also trigger avalanches

Human activity: Humans have activated many avalanches in recent years. Seventy percent of snow avalanches worldwide are caused by human activity. There are many athletes from snowboarding, skiing and many other winter sports addition, there are other article factor that contribute to avalanches which include skiers and snowmobiles. Vibrations from snowmobiles and other vehicles place a lot of pressure on top of mountains. The combination of both gravity and vibrations cause the avalanche to occur very quickly.

Contributing factors:

1. **Terrain:**
   a) <u>Steepnes:</u> Slopes under 25 degrees and over 60 degrees typically have a low avalanche risk because of the angle of repose for snow. Snow does not accumulate significantly on steep slopes and does not easily flow on flat slopes. Distribution of avalanches by slope has a sharp peak between 35 to 45 degrees. That peak hazard lies at around 38 degrees. Unfortunately, slopes with the most dangerous steepness are favoured for skiing.
   b) <u>Direction:</u> The three primary variables that influence snowpack evolution are temperature, precipitation and wind. In medium latitudes of the Northern Hemisphere, more accidents occur on shady slopes with northern and north-eastern

aspects. Slopes in the lee of the wind accumulate more snow, presenting locally deep areas and windslabs.

c) Profile: Convex slopes are statistically more dangerous than concave. The reasons lie partly in human behaviour, and the tensile strength of snow layers versus the compression strength.

d) Surface: Full-depth avalanches are more common on slopes with smooth ground cover such as grass or rock slab. Vegetation cover is important for anchoring the snowpack; however in certain snowpack's boulders or buried vegetation may create weak areas within the snowpack.

2. **Snow:** The structure of the snowpack determines avalanche danger. Avalanches require a buried weak layer (or instability) and an overlying slab. Unfortunately relations between easily observable properties of snow layers (strength, grain size, grain type, temperature) and avalanche danger are complex and not yet fully understood. Additionally snow cover varies in space and so does stability of snow.
   - New snow: New snow has not had time to bond with the layers below, especially if it is light and powdery.
   - Snow depth: Snow that is above the layer of boulders and plants on the slope has none of these natural objects to help anchor it to the slope, and is therefore more dangerous. Naturally this is just the type of snow needed for snow sports such as skiing.
   - Snow crystal size: Generally speaking, the larger the crystal, the weaker it is.
   - Snow compaction: Compacted snow is less likely to move than the light powdery layers.

3. **Weather:** Weather determines the evolution of snowpack. The most important factors are heating by solar radiation, radiational cooling, temperature gradients in snow, and snowfall amounts and type. Most avalanches happen during or soon after a storm.

4. **Temperature**: Warm temperatures that can last several hours a day can weaken some of the upper layers of snow and cause it to slide down. If the temperature is high enough for gentle freeze-thaw cycles to take place, the melting and re-freezing of water in the snow strengthens the snowpack during the freeze cycle and weakens it in the thaw cycle. Temperatures rising significantly over the freezing point may cause the whole slope to avalanche, especially in spring. Persistent cold temperatures cause the snow to not gain stability and may contribute to formation of depth hoar, where there is a high temperature gradient within the snow. Thin layers of "faceted grains" may form above or below crusts when temperature gradients become strong through the crust

5. **Wind:** anything more than a gentle wind can contribute to rapid buildup of snow on sheltered slopes (downwind), while the wind pressure can also stabilize other slopes. "Wind slab" is a particularly fragile brittle structure — heavily loaded, poorly bonded. Even on a clear day, wind can quickly shift snow-load to the snow pack. This can occur two ways, by top-loading, where wind deposits snow parallel to the fall-line, or through

cross-loading, which occurs when the wind deposits snow perpendicular to the fall-line of a slope. When wind blows over the top of a mountain, the leeward, or downwind, side of the mountain experiences top-loading. When the wind blows over a ridge that leads up the mountain for example, the leeward side of the ridge experiences cross-loading. Cross-loaded wind-slabs are usually more difficult to spot and also tend to be less stable than top-loaded wind-slabs, and are therefore much more dangerous.

- Heavy snowfall: Heavy snowfall may cause instability, both through the additional weight, and because the snow has insufficient time to bond.
- Rain: In the short-term causes instability through additional load and possible lubrication of lower layers. Avalanche also occurs if the upper snow layer is moved. Rain reduces friction in the snowpack.

V. TYPES OF AVALANCHES

Avalanches have been classified into four types.

1. **Loose Snow Avalanches:** First of these are the Loose Snow Avalanches. They are common on steep slopes and are seen after a fresh snowfall. Since the snow does not have time to settle down fully or has been made loose by sunlight, the snowpack is not very solid. Such avalanches have a single point of origin, from where they widen as they travel down the slope.

2. **Slab Avalanches: T**hese are the most common type of winter avalanche due to the buildup fresh snow. Loose Snow Avalanches, in turn, could cause a Slab Avalanche, which is characterized by the fall of a large block of ice down the slopes. Thin slabs cause fairly small amounts of damage, while the thick ones are responsible for many fatalities. A slab is a compact snow surface layer that can detach from a weaker snow layer underneath. The slab slips forward as a whole block or breaks into pieces.

3. **Powder Avalanches:** Powder Snow Avalanches are a mix of the other forms, Loose Snow and Slab. The bottom half of this avalanche consists of a slab or a dense concentration of snow, ice and air. This often starts from a single point and accumulates snow as it moves down the slope forming a snowball effect. This type is most common following heavy snowfall of one inch per hour or more and often on a smooth surface such as after rain or frost. Without the cohesion with the snow layer underneath the snow is too heavy to settle. This type of avalanche can travel between 62 and 186 miles per hour.

4. **Wet Snow Avalanches:** Finally, there are Wet Snow Avalanches. These are quite dangerous as they travel slowly due to friction, which collects debris from the path fairly easily. Often occurs after a warm spell or during the spring thaw. Snow becomes heavier as it begins to turn into water. Occurs frequently and are generally small and generally easier to predict than the other types.

VI. IMPACTS OF AVALANCHES

There is a little damage to the overall ecological system due to avalanches. However, they are a major natural hazard for the local human population.

1. **Damage to Life and Property:** A large number of casualties take place after avalanches hit heavily populated areas. Infrastructure is damaged, and the blockage caused impacts the livelihood of many. People who enjoy skiing, snowboarding and snowmobiling are at a greater risk of losing their lives. A powerful avalanche can even destroy buildings, and power supplies can be cut off.

2. **Death or Injury:** The biggest way in which avalanches affect people is by causing death or injury. The force from an avalanche can easily break and crush bones, causing serious injury. Asphyxiation is the most common cause of death, followed by death from injury and lastly, by hypothermia—people buried in the avalanche if found within 15 minutes have more than a 90 percent survival rate. The rate drops to around 30 percent if found after 35 minutes.

3. **Flash floods:** When an avalanche occurs, it brings down all the debris with it and can cause havoc in low lying areas. Flash floods are seen to happen after avalanches, which is a long term problem many villagers and townspeople have to deal with. They can also change weather patterns and cause crop failure in farms present in the lower fields.

4. **Property and Transportation:** Avalanches can completely destroy whatever is on its pathways such as houses, cabins and shacks. This force can also cause major damage to ski resorts as well as ski lift towers near or on the mountain. Avalanches also can cause roads and railroad lines to close. A large amount of snow can cover entire mountain passes and travel routes with cars and trains traveling on these routes.

5. **Utilities and Communication:** Avalanches can affect humans by damaging utilities and communication. The power from these snow waves can completely destroy pipelines carrying gas or oil, thus causing leaks and spillage. Broken power lines can cause a disruption in electricity and cause thousands of people to go without power. Communication fields, such as telephone and cable lines, could go silent, causing a panic and a delay in response time and rescue.

6. **Economic Impact:** An avalanche can block anything in its path and even restrict the normal movement of traffic. Various ski resorts depend on tourists to run their business successfully. Ski resorts and other businesses are forced to close until the avalanche decreases, and weather conditions become suitable.

7. **Crop Failure:** If the snow from an avalanche accumulates on farmland located at the lower altitudes, it can completely destroy the crop, causing crop failure and heavy economic losses for the farm.

VII. AVALANCHE WARNING SYSTEM

In India, the responsibility of dealing with the different aspects of avalanches rests with the SASE. The BRO, with a vast network of roads in the high altitude snow-bound areas of Leh in Jammu and Kashmir, Sikkim, Arunachal Pradesh, Himachal Pradesh, and Uttarakhand, plays a major role in the operation of snow-avalanche clearance. The BRO strives to keep vital lines of communication open in these snow-bound regions through a slew of measures like the use of modern snow cutting equipment/snow cutters/snow sweepers, conventional dozers, experienced work-force, total station survey instruments, etc. Summer snow clearance is carried out every year on a 50 km stretch across the Zojilla-Pass on the Srinagar-Leh road (the approximate road length that remains closed to traffic from mid-November to mid-May every year) and on a 100 km stretch on the Manali- Leh road across the Rohtang Pass and Baralachla Pass. These two routes have many avalanche prone zones, which are cleared with the utmost caution. In addition, it clears the Khardungla Pass at an altitude of 18,300 ft in the Ladakh region, the Nathula Pass in Sikkim, and numerous other passes in the Great Himalayas.

Defence Research & Development Organization (DRDO):

DRDO was formed in 1958 with the amalgamation of the then already functioning technical development establishments of the Indian Army and the Directorate of Technical Development and projection with the Defence Science Organization. DRDO was then a small organization with 10 establishment or laboratories. Over the years it has grown as multi directionally in terms of the Variety of disciplines, number of laboratories, achievements and stature.

Today network of more than fifty laboratories are deeply engaged in developing Defence technologies. Center for Snow and Avalanche Study Establishment **(SASE)** is one of the laboratories of the DRDO located at Chandigarh with its primary function to do research in the field of snow and avalanches and to provide avalanche control measures and forecasting support to Armed forces. The SASE is the nodal agency for issuing advisories and warnings about the avalanche in the country.

VIII. AVALANCHE CONTROL STRATEGIES/ MITIGATION MEASURES

Since avalanche prone areas can be identified, the safest and probably best mitigation procedure is to avoid construction of buildings or any type of structure involving winter use in these areas. Agricultural and recreational activities that take place during the non-avalanche months are relatively safe. Other uses that could be considered are those that do not involve permanent unprotected structures in the avalanche path or those that could be moved or closed down during high avalanche-risk periods. Engineering structures for the control of snow avalanches are of the following four types:

i) Supporting structures: in the starting zone built on the upper part of the avalanche path to prevent avalanches from initiating, or to retard movement before it gains momentum. Massive earth or stone walls and terraces; rigid structures made from wood, steel, aluminium, prestressed concrete, or a combination of these materials; and flexible supporting structures called 'snow nets' constructed of steel cables or nylon straps and held up by steel poles, are examples of these.

ii) Deflecting and retarding structures: in the run-out zone to keep the moving snow of an avalanche away from structures in critical locations. These are massive structures usually made of earth, rock, or concrete located in or near the avalanche track or run-out zone.

iii) Retarding structures: are usually earth mounds or large concrete structures called breakers or tripods. The additional roughness and cross currents set up by these structures usually stop all but large, dry snow avalanches.

iv) Direct protection structures: are built immediately adjacent to the object to be protected, or in a few cases, incorporated into the design of the object itself. Avalanche sheds or shelters are merely roofs over roads or railroads that allow avalanches to cross the road/railroad without interrupting or threatening the traffic.

IX. ASSESSMENTS-SHORT QUESTIONS

1. List the regions and seasons prone to snow avalanches in India, and discuss the causes for the formation of snow avalanches.
2. List and discuss the essential elements of preparedness to meet the avalanche hazard.
3. Describe the role and work of the Snow and Avalanche Study Establishment (SASE)
4. What are the various contributing factors which lead to formation of avalanches?

X. REFERENCES

- http://science.howstuffworks.com/nature/natural-disasters/avalanche.htm
- https://www.nationalgeographic.com/environment/natural-disasters/avalanches/
- https://www.conserve-energy-future.com/types-causes-effects-of-avalanches.php
- http://www.utm.edu/students/thodmart/avalanche.htm
- https://www.nationalgeographic.com/environment/natural-disasters/avalanches/
- https://www.n-d-a.org/avalanche.php
- National Disaster Management Guidelines—Management of Landslides and Snow Avalanches, 2009. A publication of the National Disaster Management Authority, Government of India. June 2009, New Delhi.
- https://www.youtube.com/watch?v=kjMonaUIJuY