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Chapter 8

Avalanche disaster in India, mitigation and their impacts

Desastre de avalancha en India, mitigación y sus efectos

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ABSTRACT

Avalanche is a natural disaster. It is caused by the melting and sliding of snow from the mountains. The main causes of avalanche disasters are heavy sunlight, human activity, natural, vibration or movement, snowflakes, steep slopes, and temperature. The types of avalanches are slab, loose snow, powder, gliding, and wet avalanches. The avalanche is divided into three zones Red, Blue, and Yellow Zones. Avalanche in India came in Chamoli, Uttarakhand in 2021, Gurez Sector in 2017, Lahaul Valley, Lahaul, and Spiti in 1979. The avalanche-affected areas of India are Jammu and Kashmir, Ladakh, Uttarakhand, Himachal Pradesh, etc. Avalanches cause damage to humans, animals, roads, electric wires, cars, plants, etc. In this review, the causes, types, area, damage, and mitigation, etc. of avalanche disasters have been discussed in detail.

KEYWORDS: Avalanche, causes, glacier breaks in India, effects, guidelines, and mitigation.

RESUMEN

La avalancha es un desastre natural. Es causada por el derretimiento y deslizamiento de la nieve de las montañas. Las principales causas de los desastres por avalancha son la luz solar intensa, la actividad humana, la vibración o el movimiento natural, los copos de nieve, las pendientes pronunciadas y la temperatura. Los tipos de avalanchas son placa, nieve suelta, polvo, deslizamiento y avalanchas húmedas. Avalanche se divide en tres zonas Zonas roja, azul y amarilla. Avalanchas en India ocurrieron en Chamoli, Uttarakhand en 2021, sector Gurez en 2017, Lahaul Valley, Lahaul y Spiti en 1979. Las áreas de la India afectadas por la avalancha son Jammu y Cachemira, Ladakh, Uttarakhand, Himachal Pradesh, etc. Las avalanchas causan daños. Para humanos, animales,

carreteras, cables eléctricos, automóviles, plantas, etc. En esta revisión, se analizan en detalle las causas, los tipos, el área, el daño y la mitigación, etc. de los desastres por avalancha.

PALABRAS CLAVE: Avalancha, causas, ruptura de glaciares en India, efectos, direcciones y mitigación.

INTRODUCTION

An avalanche is a rapid flow of snow down a hill or a mountain. All that is necessary for an Avalanche is a mass of snow on a slope to slide down. Avalanche occurs at a certain slope under particular conditions. Avalanche behaves similarly to rock slides. Snow avalanches are a serious concern for skiers and structures in mountainous areas [1]. Avalanches are major natural hazards in snowy mountain regions and threaten people and infrastructure. Avalanche accidents in the 20th century have been characterized by natural disasters. Either events with several days of intense precipitation, snow, and rain, have triggered numerous catastrophic avalanches in many mountain ranges, affecting inhabited areas and transport corridors [2, 3]. The famous avalanche disaster in Switzerland in 1951 and in the Himalayas in Mar 1979 killed only 98 persons and 200 persons respectively [4, 5]. Avalanches, a well-known threat in snow-bound mountainous terrain, are dreaded for their destructive potential. Thousands of people have lost their lives in avalanches so far. In comparison to the other natural hazards, snow avalanche is relatively less known, on account of the remoteness of the scene of disaster away in the mountains. Nevertheless, they shook the mountains, wreaking havoc on life and property winter after winter. In comparison to earthquakes where destruction can go up to thousands or even up to millions, avalanches are relatively less destructive forces [4]. While the human and infrastructural losses caused by extreme weather and climate events depend upon a complex combination of sequential events, vulnerability, and exposure [6], a timely forecast of these events or at least identification of possible precursors is crucial for the carrying out of disaster mitigation and management processes by disaster management authorities [7].

Figure: 1 An Avalanche strikes Arunachal Pradesh

Source: https://www.skymetweather.com/content/weather-news-and-analysis/an-avalanche-strikes-arunachal-pradesh/

Causes of Avalanches

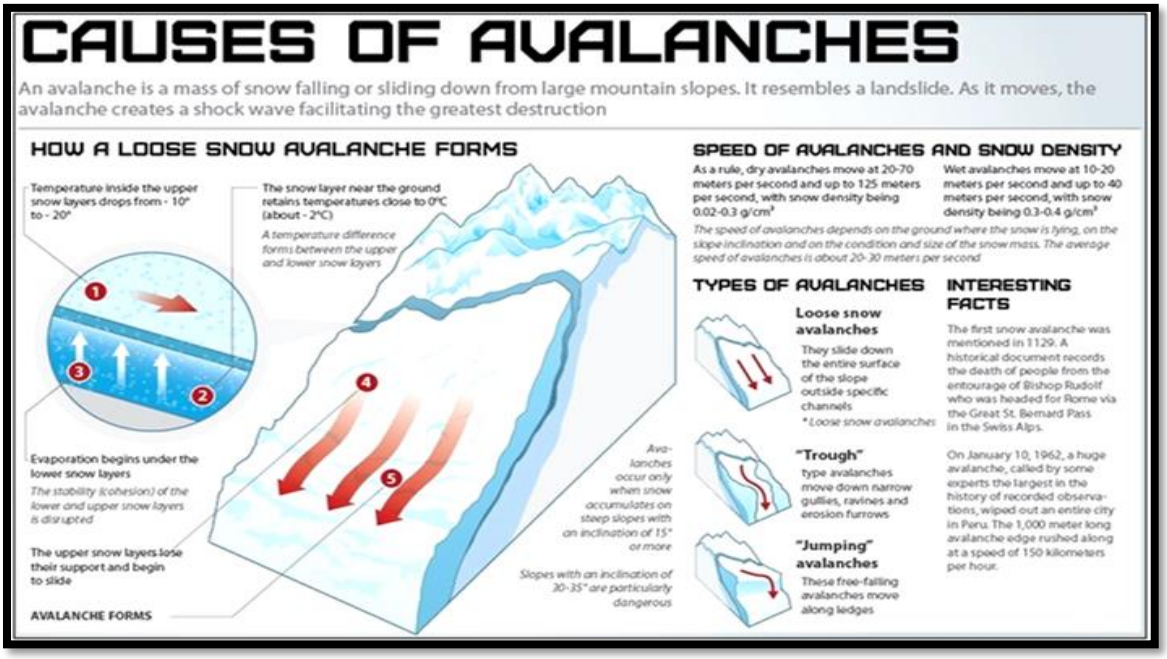


Figure: 2 Causes of avalanches

Source: https://www.iasgyan.in/blogs/avalanches

Heavy snowfall: Heavy snowfall is the first because it deposits snow in unstable areas and puts pressure on the snowpack. Precipitation in the summer months is the main cause of wet snow avalanches [9].

Human activity: Humans have contributed to triggering numerous avalanches in recent years. Winter sports that require steep slopes often put pressure on the snowpack that it cannot support. Combined with the high deforestation and soil erosion in the mountain regions, there is little snow stability during the winter months [9].

Natural causes: These include earthquakes and tremors, as they can often cause cracks in the snowpack. Fresh snow or rain can cause accumulated snow to break off and fall down the side of a mountain. Animal movement is also sometimes known to cause avalanches [9].

Vibration or movement: The use of all-terrain vehicles creates vibrations in the snow that it cannot support. Along with gravity, this is one of the fastest ways to trigger an avalanche. Other artificial triggers are off-piste skiers, gunfire and construction with explosives, which tend to weaken the overall environment [9].

Layers of snow: There are conditions where the mountains already have snow and have turned to ice. Then fresh snow falls on top, which can easily slide down [9].

Steep Slopes - Layers of snow build up and slide down the mountain at a faster rate as steep slopes can increase the speed of snow. A rock or piece of huge ice can shake the snow and cause it to come down [9].

Warm 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 [9].

AVALANCHE FORMATION

Avalanches have three ingredients - snow, a sloping surface, and a trigger. A weak layer in the snowpack caused by ice, surface or deep frost, faceted crystals, or sleet also contributes. When the weak layer is near the surface, it causes mud - a loose, powdery waterfall of snow in an inverted "V" shape that slides down the mountain. Lava flows are like sand rolling down a dune and usually cause minimal damage to people and property. If the weak layer is deeper in the snow cover, a much more dangerous slab avalanche can occur. In a slab avalanche, a solid, continuous layer of snowpack slides over a layer of snow, like slush sliding off a car windshield. Sometimes the whole snowpack breaks off the mountain and slides on the ground [10]. Avalanches usually start on mountain slopes that form an angle of 25 to 60 degrees to the ground. Slopes below 25 degrees are generally not steep enough to generate avalanches, and slopes above 60 degrees tend to lose snow constantly, making it difficult for slabs to develop. Most avalanches start on slopes of 35 to 45 degrees [10].

AVALANCHE TYPES

Slab avalanches: Slab avalanches have a wide and clear fault line. They can only occur if a bonded snow layer (the slab) lies on a weak layer over a sufficiently large area. Activation requires the application of an additional load and a tilt angle of at least 30 °. The avalanche breaks free through a small fracture that initially occurs in the weak layer (initial failure) and then spreads rapidly. The extent to which the fracture propagates depends on the properties of the weak layer and the plaque lying on it. Once released, the slab slides down the slope. The typical size of a slab avalanche triggered by winter sports enthusiasts is 50 meters wide and 150 to 200 meters long [11].

In dry or wet snow, slab avalanches can occur long after a snowfall. They can be triggered naturally (without human intervention) or triggered at any point inside or even outside (in the case of remote triggering) the perimeter of the disk. Slab avalanches are the most dangerous and are responsible for over 90% of avalanche fatalities. Slab avalanches can be dangerous, although not large. They quickly reach a high speed. A person who drops a plate is often within the perimeter and is captured by the avalanche [11].

Loose snow avalanches: Are frequent on steep slopes and are seen after a fresh snowfall. Since the snow does not have time to settle completely or has been loosened by sunlight, the snowpack is not very solid. Such avalanches have a single point of origin from which they widen as they descend [12].

Powder avalanche: Powder avalanches generally originate from snow slabs. A powder cloud forms at a large change in altitude when there is enough snow floating in the air. Powder avalanches can reach speeds of 300 km/h and cause enormous damage. They most often occur when the avalanche danger is high or very high [12].

Gliding avalanche: Like slab avalanches, Gliding avalanches have a wide and clear fault line, but differ because the entire snowpack is released. They can only occur on smooth ground, usually consisting of flattened grass or boulders. The steeper the slope, the more likely the snow will slide [12].

Gliding avalanches can be a serious problem for transport routes, especially in snowy winters. They are only of minor importance to winter sports enthusiasts, as they cannot be activated by humans. These avalanches are released naturally when the friction decreases at the interface with the ground, as the snow at the base of the snowpack becomes wet [12].

Water can penetrate the lower layer in two different ways:

- In the middle of winter, the snowpack is generally cold and dry. During this period it becomes moist from below, both because the warm ground melts the snow above it, and because the snow absorbs water from the moist ground. In the middle of winter, slip avalanches can occur at any time of the day or night [12].
- At some point in spring, the snowpack reaches a temperature of zero degrees (isothermal) everywhere. This allows meltwater and rain to seep through the entire snowpack and wet the base from above. In these sliding conditions, avalanches often occur during typical wet avalanche periods and increase in frequency in the second half of the day [12]].

Often, but not always, the snowpack slowly begins to slide where voids (slippery cracks) have formed. A slide avalanche can suddenly follow these signs. It is impossible to predict exactly when this will happen, so people should avoid staying under or near sliding cracks longer than necessary [12].

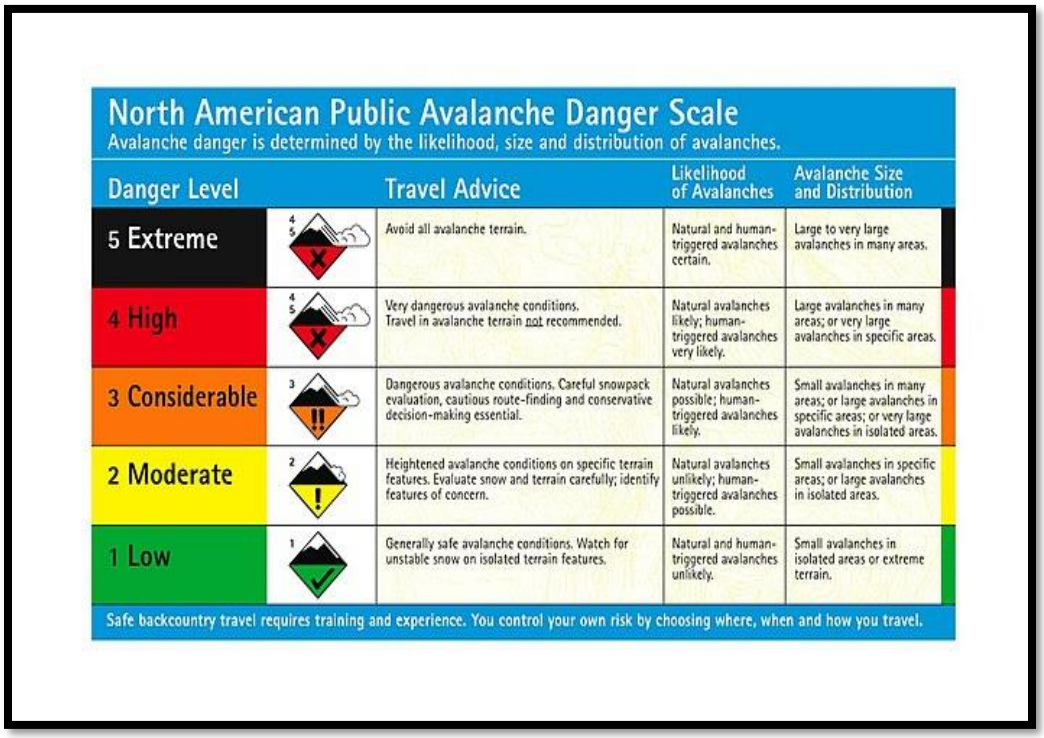
Wet snow avalanches: These are quite dangerous as they move slowly due to friction, making debris from the path quite easy to pick up. The avalanche initially consists of water and snow, but understanding avalanches have shown us that they can easily increase in speed [12].

THERE ARE THREE TYPES OF SNOW AVALANCHE ZONES;

Red Zone: The most dangerous zone where snow avalanches are most frequent and have an impact pressure of more than 3 tonnes per square meter [13].

Blue Zone: Where the avalanche force is less than 3 tonnes per square meter and where living and other activities may be permitted with the connection of safe design but such areas may have to be vacated on warning [13].

Yellow Zone: Where snow avalanches occur only occasionally [13].



North American Public Avalanche Danger Scale

Avalanche danger is determined by the likelihood, size and distribution of avalanches.

Danger Level	Travel Advice	Likelihood of Avalanches	Avalanche Size and Distribution
5 Extreme	Avoid all avalanche terrain.	Natural and human-triggered avalanches certain.	Large to very large avalanches in many areas.
4 High	Very dangerous avalanche conditions. Travel in avalanche terrain not recommended.	Natural avalanches likely; human-triggered avalanches very likely.	Large avalanches in many areas; or very large avalanches in specific areas.
3 Considerable	Dangerous avalanche conditions. Careful snowpack evaluation, cautious route-finding and conservative decision-making essential.	Natural avalanches possible; human-triggered avalanches likely.	Small avalanches in many areas; or large avalanches in specific areas; or very large avalanches in isolated areas.
2 Moderate	Heightened avalanche conditions on specific terrain features. Evaluate snow and terrain carefully; identify features of concern.	Natural avalanches unlikely; human-triggered avalanches possible.	Small avalanches in specific areas; or large avalanches in isolated areas.
1 Low	Generally safe avalanche conditions. Watch for unstable snow on isolated terrain features.	Natural and human-triggered avalanches unlikely.	Small avalanches in isolated areas or extreme terrain.

Safe backcountry travel requires training and experience. You control your own risk by choosing where, when and how you travel.

Figure: 3 North American public avalanche danger scales

Source: https://en.wikipedia.org/wiki/Avalanche

MAJOR GLACIER BREAKS IN INDIA

Chamoli, Uttarakhand (2021)

On February 7, 2021, a major disaster occurred in the Chamoli district of Uttrakhand. A glacier broke after an avalanche in the Joshimath area of the Chamoli district. There have been reports of missing persons and property damage. On February 7, around 10:30 am, a huge amount of water started entering the Rishiganga River. Two energy projects, namely NTPC's Tapovan-Vishnugad hydel project and the Rishi Ganga Hydel project, were severely damaged. According to experts, the drop in snowfall this winter in Uttarakhand seems to have played a role in the disaster [15].

Gurez sector avalanche (2017)

The Gurez avalanche accident was a series of four avalanches observed in the Kashmir valley. It claimed the lives of 24 people, including 20 soldiers and 4 civilians. In January 2017, several snowfalls occurred in the Kashmir Valley which triggered the avalanche. It was snowing heavily before the accident. The first avalanche struck on the morning of January 25, 2017, killing a family of four civilians. The second avalanche occurred at the same time as Sonmarg, where a military camp was located. In the evening, two avalanches hit the Gurez valley again, where the bodies of 10 soldiers in the area were recovered. On January 28, 4 other bodies were found, bringing the death toll to 15 soldiers [15].

Lahaul Valley, Lahaul and Spiti (1979)

75 people died in devastating avalanches in the Lahaul Valley. 40 people died in the villages of Udaipur, Hansa, Bardang, and Shakoli. 12 people were injured. Three villages, Warring, Gardung, Ley Gardung, and 9 km. by Keylong were completely razed. The death toll in the district reaches 200. A dispensary and a Sarai attached to the famous temple of Trilokinath in the Udaipur region were also destroyed [16].

Avalanche-prone areas in India

The Himalayas are known for the occurrence of snow avalanches, especially the Western Himalayas i.e. the snowy regions of Jammu and Kashmir, Himachal Pradesh, and Western Uttar Pradesh [18].

Jammu and Kashmir: Upper reaches of Kashmir and Gurez, Kargil and Ladakh valleys and some of the main roads [18].

Himachal Pradesh: Vulnerable areas of Chamba, Kullu-Spiti, and Kinnaur [18].

West Uttar Pradesh: Parts of Tehri Garhwal and Chamoli districts are vulnerable areas [18].

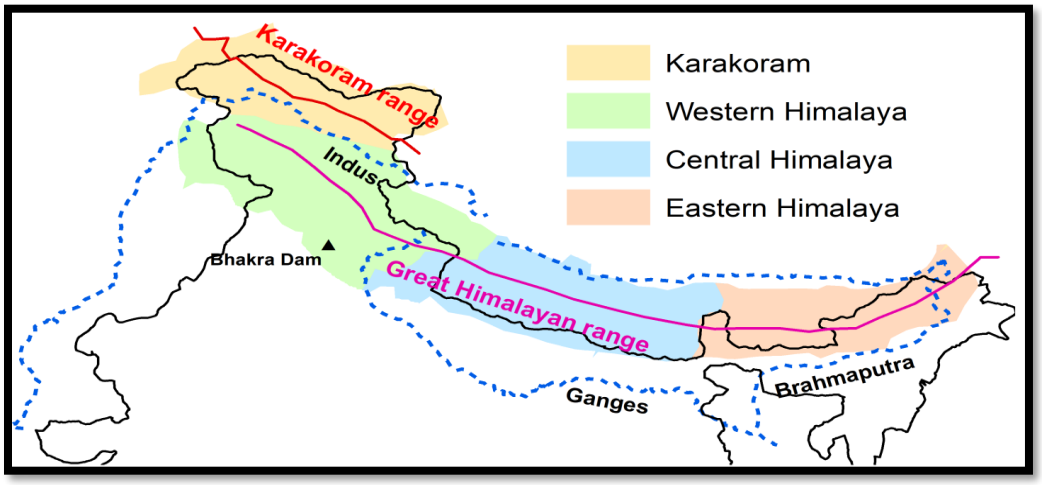


Figure: 4 The various regions of the Himalayas. Map by [20].

Source: https://india.mongabay.com/2018/04/warmer-winters-in-the-himalayas-triggering-avalanches/

Hazardous impacts of Avalanches

- Avalanches can cause great loss of human and animal life. Asphyxiation is the first cause of death by avalanche. People and animals buried deep in snow suffocate from lack of oxygen. The force of an avalanche can also easily break and crush bones. People can also freeze to death if buried under several feet of snow.
- Avalanches can cause significant property damage by destroying buildings and other structures in their path. Homes, cabins, cottages, colonies, resorts, etc. are destroyed in an avalanche.
- Avalanches cause major traffic disruptions as they can completely cut off high mountain settlements from the rest of the world. Due to damage to transportation infrastructure from the avalanche, railroads and

roads may need to be closed. Roads can be covered in heavy snow from the avalanche, preventing vehicles from moving for days before the snow is cleared.

- Telephone and cable lines are also down, preventing people from communicating with others or seeking help. Such problems can also delay rescue operations.
- Oil, gas and water pipes can burst, leak or be crushed, resulting in a lack of supply of these vital necessities.
- If snow from an avalanche accumulates on farmland at low elevations, it can destroy crops, resulting in crop failure and serious economic loss to the farm.
- If snow and ice falling during an avalanche succeed in disrupting the flow of a river or displacing water from a lake, water from these bodies of water can flood surrounding areas immediately after the avalanche.
- Avalanche These flash floods are called flash floods and can be extremely dangerous.
- Avalanches harm the local economy. Huge avalanches cause significant damage to property and people. Immediate rescue operations and disaster management funds should be organized by the government of the affected area. Many local businesses, especially those involved in the tourism industry, are suffering greatly. Millions of dollars of private property are also lost in the disaster [1].

Approach to the Guidelines

While a good deal of work has already been done to improve the management of landslides and snow avalanches, many areas require special focus and emphasis in the future. Important among these are:

a. Hazard Zonation Mapping.
b. Geological and Geotechnical Investigation.
c. Landslide Risk Treatment.
d. Monitoring and Forecasting of Landslides.
e. Regulation and Enforcement.
f. Awareness and Preparedness.
g. Capacity Development.
h. Response.
i. Research and Development.
j. Implementation of the Guidelines— Preparation of Landslide Management Plans [19].

AVALANCHE RISK MITIGATION MEASURES

Following are the measures to mitigate the risk of avalanches

Structural Measures

- Planting trees on mountain slopes.
- Stepped terraces on steep slopes.

- Avalanche control pillars on slopes of mountains. Avalanche control fences should be installed.
- Snow cornice (cover hanging edge of snow on the crest of a mountain and along the sides of gullies) control structures in avalanche risk zones.
- Protection structures such as stopping, deflecting, and retarding structures [1].

Non-structural measures

- Forecasting avalanches and evacuating people from endangered areas.
- Removing snow deposits on slopes by blasting [1].

CONCLUSION

Avalanche is a natural disaster. It is caused by the melting and sliding of snow from the mountains. In India, avalanches occurred in 2021 in Chamoli, Uttarakhand, Gurez Sector 2017, Lahaul Valley, Lahaul, and Spiti in 1979. The avalanche-affected areas of India are Jammu and Kashmir, Ladakh, Uttarakhand, Himachal Pradesh, etc. Avalanches cause damage to humans and animals, roads, electric wires, cars, plants, etc. An awareness campaign should be conducted in the affected areas and all activities of Avalanche should be taken care of.

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