MODULE 2

UNIT 1 VOLCANIC HAZARDS (I)

CONTENTS

1.0 INTRODUCTION

As we commence yet another unit on environmental hazards our goal is make thisunit easy for you to comprehend.The environmental hazard for consideration is volcanic hazard and it will bediscussed in two parts as units 6 and 7.

This sixth unit will review fundamental issues on volcanic hazards and relate somereal life experience of the hazards volcanoes have caused in terms of life andproperties.

We like to sound a note of caution that some real life stories and incidences maydisturb you if you are emotional.

2.0 OBJECTIVES

By the end of this unit you should be able to:

- discuss on the three volcanic tectonic settings; and
- listsix substances that are ejected during a volcanic eruption.

2.1 HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.

2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENT

There are about 500 active volcanoes in the world. In an average year, around fifty erupt. Since only about 5 per cent of eruptions result in human fatalities, therelative infrequency of hazardous volcanoes events is one of their most dangerous features.

Traditionally, volcanoes have been classified as active dormant or extinct but in 1951 Mt Lamington erupted in Papua New Guinea killing 5,000 people although considered extinct. To be prudent, all volcanoes which have erupted within the last 25,000 years should be regarded as at least potentially active.Like earthquakes, the distribution and behaviour of volcanoes is controlled by theglobal geometry of plate tectonics, and active volcanoes in every continent,except Australia (Smith, 1991).

They are found in three tectonic settings:

1. Subduction Volcanoes

*They are located in the subduction zones of the earth s crust where one tectonic*plate is thrust consumed beneath another.

They comprise about 80 per cent of the world's active volcanoes and are the mostexplosive type with the typical form of a stratulern, composed of alternatinglayers of ash and lava.

2. Rift Resumes

*They occur where tectonic plates are diverging. They are generally less explosive*and more effusive, especially when they occur on the deep ocean floor.

3. Hat spill Roleames

*They exist in the middle of tectonic plates where a crustal weakness allows*molten material to penetrate from the earth s interior. The Hawaman islands inthe middle of the Pacific plate are a good example.

3.1 Primary Volcanic Hazards

They are associate d with the products ejected by the volcanic eruption. The mostexplosive volcanic eruptions are accompanied by pyrodastic flows, sometimescalled niesardents or glowing clouds. These flows result from the frothing ofmolten magma in the vent of the volcano. The gas bubbles them expand andburst explosively to fragment the lava.

Eventually, a dense dead of lava fragments is ejected to form a turbulent mixtureof;

- hot gases
- pyroclastic material
- volcanoes fragments
- Cystals
- ash
- pumice
- glass and shards

These eventually then flows down the flank of the volcano. Pyroclastic bursts flowdownhill because, with a heavy load of lava fragments and dust, the flow isappreciably denser than the surrounding air.Such clouds may be literally red hot (up to 1,0000C) and may be ejected manytens of kilometres into the atmosphere. However, they pose the biggest hazardwhen they are directed laterally by explosive blasts (Pelean type) and remain close to the ground. These directed blasts are capable of advancing in surges at speeds beyond 30 ms1. In historical eruptions, pyroclastic flows have travelledsome 3010 km from the source. Very little can survive in the path of apyroclastic surge and flows eruption.

During the twentieth century the Mont Pelee disaster on the island of Martiniquethe town of St Pierre, some 6km from the centre of the explosion. The Islandsuffered a surge temperature around 7000C borne by a blast travelling at around33ms, such surges can melt

- plastic
- metal and
- glass.

The surge itself is usually preceded by an air blast with sufficient force to topplesome buildings. Air fall replied comprises all the fragmented material which isejected by the volcano and subsequently falls to the ground.

Volcanic gases are released by explosive eruptions and lava flows. The gaseousmixture commonly includes

- water vapour
- hydrogen
- carbon monoxide
- hydrogen sulphide
- sulphur dioxide
- sulphur trioxide
- chlorine and
- hydrogen chloride in variable proportions.

Measurement of the exact gas composition is made difficult by the hightemperatures near an active vent and by the fact that the juvenile gases interactwith the atmosphere and each other, thus constantly altering their compositionand proportionsCarbon monoxide has caused deaths because of the toxic effects at very lowconcentrations but most fatalities have been associated with carbon dioxidereleases.

Carbon dioxide is dangerous because of the following features:

- it is a colourless
- odourless gas
- density about 1.5 times greater than air
- accumulates in low-lying places
- Commonly found at topographic hollows
- Sometimes detected at basements of house
- Not easily detected
- Once inhaled, it can cause death in 10 -15 minutes at atmosphere concentrations as low as 10 per cent by volume.

REFLECTION

You may wish to consider this awful experience in 1979. About 142 peopleevacuating from a village in Indonesia due to the presence of lava, at nighttried to escape from the threatened eruption simply walked into a densepool of volcanically released carbon dioxide and were immediatelyasphyxiated.

Learn wisdom from this experience.

3.2 Ground Deformation

Ground deformation occurs as often as volcanoes grow from within by magmaintrusion and as new layers of lava and pyroclastic material accumulate on thesurrounding slopes. The deformation is not in itself a hazard but it provides adestabilizing process by over -steepening hill slopesSuch structural failures of a volcano have occurred worldwide, on average, four timesper century over the last 500 years, although few deaths have occurred majorstructural instability is most likely on large polygenetic volcanoes (Smith, 1991).

Lather is volcanic mudflows with the following characteristics:

- at least 50% sediment
- has sand grain size or smaller
- occur widely on the flanks of volcanoes
- Also occur in wet tropics
- the term is of Indonesian origin
- present the greatest threat to human life, after Iron privoclastic surge

- lather may occur in associate with any volcanic event
- large quantities of water are present on the steep sides of a volcano.
- Sometimes this water forms iron violent electrical rainstorms
- most destructive events have been linked to the rapid melting of snow and ice
- pyroclastic flows cause mean-descent lava fragments to fall over a wide area of snow and ice

REFLECTION

For example, about 5,500 people were killed in a mudflow following theerumpent of the Kelut volcanic Lava, in 1919.

The water mixes with soft ash and volcanic boulder to produce a debris-rich fluid,sometimes at high temperatures, which then pours down the mountainside atspeeds which commonly attain 15ms and may reach in excess of 22ms.

The lather threat is prominent along the volcanic chain of the northern Andes.

Andean volcanoes result iron in the Pacific Ocean floor (Nazea plate) descendingbeneath the continent of South America plates. There are at least twenty activevolcanoes in the resulting mountain area which extends for 1,000 km andstraddles the equator from central Colombia in the north to southern Ecuador inthe south.

The highest peaks exceed 5,000m in altitude and are permanently snowcapped.Many of the mountain tops are structurally very week due to the action of hotgases over time. Lathers have caused several historic disasters.

DISCUSSION POINT

Cotopaxi in Ecuador has erupted at least fifty times since 1738. During aneruption in 1877, so much ice and snow was melted that e normous lathers,were released about 160 km long. This was discharged simultaneously tothe Pacific and Atlantic drainage basins.

What is the possible effect of this discharge on the aquatic organism?

Discuss your response with your colleague s in class.

The worst volcanic disaster in the world since the eruption of Mont Pelee occurred is a result of lathers following the 1985 eruption of the NevadodelRuizvolcano in Colombia. Nevadodel Ruiz (5,200m) is the most northerly active volcano in the Andes. It has generated large lathers in the past, notable in 1595 and 1815, and additional settlement has taken place in the surrounding valleys over the last century.

Fresh major volcanic eruption did not take place until one year later. This causedlarge-scale, rapid melting and a huge lather rushed down the Lagunillas valley sweeping up tree, buildings and everything else in its path. Some 50 km downstream it overwhelmed the town of Armero. Over 5,000 buildings were destroyed by a deposit of mud 3-8 m deep and almost 22,000 people lost their lives within a few minutes. Some of the survivors were trapped up to shoulder height in the ash slurry for two days before being rescued.

EXERCISE 6.1

From the above paragraph about 22,000 lives were lost in this volcanic eruption.On the basesof this data search theinternet using any search engine such asgoggle scholar to obtain;

1. The number of lives lost in volcanic eruption in;
   - 2000
   - 2001
   - 2002
   - 2003
   - 2004
2. Identify the countries where each incident occurred and rank each Country based on the number of occurrence.
3. Make a list of the Continents of the world and rank them on the bases of volcanic eruption.

4.0 CONCLUSION

Volcanic eruption is real and it is a very serious environmental hazard althoughthe hazard is alien to our nation, there are many nations around the world thatare plagued by the fear of the possibility of volcanic eruption. Others live in thefear and trauma of seeing a beloved one perish in an eruption.

Irrespective of the experience volcanic eruption releases gases that are dangerousand hazardous to human health, life and properties. This hazard cannot easily becontrolled but humans can avoid living in volcanic zones.

5.0 SUMMARY

We have learnt in this unit that:

Lather is volcanic mudflows with the following characteristics:

- at least 50% sediment
- has sand grain size or smaller
- occur widely on the flanks of volcanoes
- Also occur in wet tropics
- the term is of Indonesian origin
- present the greatest threat to human life, after Iron privoclastic surge

- lather may occur in associate with any volcanic event
- large quantities of water are present on the steep sides of a volcano.
- Sometimes this water forms iron violent electrical rainstorms
- most destructive events have been linked to the rapid melting of snow and ice
- pyroclastic flows cause mean-descent lava fragments to fall over a wide area of snow and ice.

Carbon dioxide released from volcanic vent is dangerous because of the followingfeatures:

- it is a colourless
- odourless gas
- density about 1.5 times greater than air
- accumulates in low-lying places
- Commonly found at topographic hollows
- Sometimes detected at basements of house
- Not easily detected
- Once inhaled, it can cause death in 10 -15 minutes at atmosphere concentrations as low as 10 per cent by volume.

6.0 Tutor – Marked Assignment

1. discuss three volcanic tectonic settings
2. list six substances that are ejected during a volcanic eruption

7.0 REFERENCES/FURTHER READING

Smith, K. (1991). Environmental Hazards: Assessing Risk and Reducing Disaster. London: Routledge.

Other Resources

Enger, E. D & Smith, B.F. (2002). Environmental Science: A study of Interrelationships. New York. McGraw Hill.

Hogan, D.J. &Marandola, E. (2007).Vulnerability of Natural Hazards in population-Environment Studies. Background Paper to the Population-Environment research network (PERN) Cyberseminar on Population and Natural Hazards, 5-19 November.

Lauwerys, J. A (1970). Man s Impact on Nature. New York. The American Museum of Natural History.

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UNIT 2 VOLCANIC HAZARDS (II)

CONTENTS

1.0 INTRODUCTION

This is the second part on the series on volcanic eruption. This unit will treatissues related to lather slides and debars avalanches. Essential environmentalcontrol techniques for diverting and controlling lava flows such as bombing, theuse of artificial barriers and water sprays will be discussed.

2.0 OBJECTIVES

By the end of this unit you should be able to:

- explain the relationship between lather slides and volcanic eruption;
- state three methods for the control and diversion of lava flow; and
- discusson any four ways of forecasting and warning on volcanic eruption.

2.1 HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and

by consulting other relevant materials or internet.

3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.

Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENT

They are a common feature of volcano-related ground failure. They areparticularly associated with eruptions of deictic magma, which is siliceous with arelatively high viscosity and has a large content of dissolved gas.

The experience of volcanic eruption at Mt. St Helens that took place in May, 1980is worth discussing. Mt St Helens is one of at least seven active subductionvolcanoes in the Cascade Range of the Pacific Northwest, USA.

The experience began with swarms of small earthquakes (M = 3.0) and minor asheruptions gave the first signs of a major event and were followed by ground uplift on the north flank of the volcanic cone. Over a two-month period the upliftcontinued at a rate of about 1.5m per day. More than one month before themain eruption the bulge was nearly 2km in diameter and had swelled by as 100m.

Large cracks were evident in the cover of snow and ice. All this evidence wasconsistent with the injection of viscous magma under the volcano at shallowdepth. On 18 May, when the bulge because 150m high, an earthquake (M = 5.1)shook the walls of Mt St He lens summit crater and started many smallavalanches. Then a huge slab of rock and ice on the over-steepened northernslope of the volcano broke away from the main cone along a crack across theupper part of the bulge. The earthquake triggered a debris avalanche containing2.7 km of material and pressure in the shallow intrusion was further relieved byan explosive eruption and massive ash cloud. Volcanic ash blanketed much ofeastern Washington State, 57 people were killed and property damage wasestimated at USI billion (Smith, 1991).

3.1 Environmental Control

There is no known method of preventing volcanic eruption. Similarly, there is no known defence against the pyroclastic flows and comparatively little can be doneto protect standing crops and exposed water supplies from air-fall tephra.Therefore, lava flows moving at comparatively slow speeds are the volcanichazard over which most physical control can be exerted.

The first known attempt to divert a lava flow took place in Sicily in 1669, wheniron bars were employed to try to stop an advancing flow from

Ethareaching thetown of Catania. A breach was opened in the flank of the flow which then beganto take another direction. Unfortunately the new course threatened aneighbouring village and the attempt was abandoned.

Control of lava flows has also been attempted in Hawaii, mainly to protect the city of Hilo, which was reached by a flow in 1881 and is at risk from future events.

3.2 Methods of Diverting and Controlling Lava Flows

There are three possible methods, according to Smith (1999) for diverting andcontrolling lava flows:

3.2.1 Bombing

The use of ground explosives can be useful in three situations.

- First, bombing of lava high on the volcano may cause the flow to spread there andhalt the advancing lava front by depriving it of supply. This method was first triedwith limited success in 1935 on a fluid lava stream advancing on Hilo, althoughsome scientists believe that more modern techniques of aerial bombing couldachieve better results.
- Second, control of how lava has been attempted by breaching the flow out locallyand starve the advancing front of material. This method was tried on the flow ofMauna Loss 1942 eruption and in the 1983 eruption of Etna, when it provedpossible to divert some 20-30 % of the blocky flow from its natural channel.
- The third possibility, not yet tried, is to bomb the walls of the cone at the vent so that the very fluid lava there spills out over a relatively wide area and is unable to contribute to a definite stream. These methods involve an element of risk. Eve n when the topography is suitable, and are best attempted with good atmosphere visibility, which is unusual during volcanic eruption.

3.2.2 Artificial Barriers

It can be used to diver lava streams away from valuable property if thetopography is favourable. Barriers must be constructed from resistant, large-calibre material, such as massive rocks, with a broad base and gentle slopes. Themethod is most appropriate for thin and fluid lava flows which exert a relativelysmall amount of thrust. It is doubtful if diversion would work with more powerfulblocky flows which may attain heights of 30 m or more.

Several diversion barriers have been proposed to protect Hillo, Hawaii. Thetopographic setting is favourable because flows can only approach the citythrough a narrow corridor, allowing intercepting barriers to be located in advanceof an eruption with a high degree of confidence. The walls suggested would bearound 10 m high and the channels created by the barriers would be around 1kmwide, which would hold the volume of lava resulting from any nearby eruptions inhistoric times.

This method has applications else-where. For example, in the Kralla area ofNorthern Iceland, the land has been bulldozed to create two barriers to protect avillage and a factory respectively from the free-flowing lava.

3.2.3 Water Sprays

This technique was first employed to control lava flows during the 1960 eruptionof Kilauca, Hawaii, in a sponteous experiment by a local fire chief. The methodwas used on a large scale during the 1973 eruption of Eldfell to protect the townof Vestmananaeyjar on the Icelandic island of Heimacy. It has been estimated that1 m of water will cool about 0.7 m of lava from 11000C when totally converted tostream.

On Heimacy, special pumps were shipped to the island so that large quantities ofsea water could be pumped from the harbour. At the height of the operation, thepumping rate was almost 1 m s effectively chilling about 60.0000 m. of advancinglava per day. The exercise was expensive, lasting for about 150 day, but itappeared to be successful.

Some days after spraying started, the lava front slowed up into a solid wall some20m in height. Measurements of lava temperature, made is specially drilledboreholes after the eruption was over, confirm that where water had not beenapplied, the lava temperature was 500-7000C at a depth of 5-8 m below thesurface. In the sprayed areas an equivalent temperature was attained until adepth of 12-16 m below the lava surface (Smith, 1991).

3.3 Vulnerability Modification Adjustment: Community preparedness

As with earthquakes, the cost of mentoring volcanic activity and pre-disaster planning is small compare d to the potential losses. Given the existence of a monitoring programme and effective preparation, some warning can usually be given to permit evacuation of the most dangerous areas before the eruption occurs. Until recently, emergency planning in volcanic hazard zones was not well developed in the LDCs.

Before the Nevadodel Ruiz disaster in Colombia in 1985, there was no national policy in place for the systematic monitoring of volcanic hazards or for the management of such hazards. Police failures were compounded by de lays in hazard mapping and the unwillingness of the authorities to accept the economic and political costs of early evacuation.

The length of time available for the alert phase differs widely. In some casesvolcanic activity may start to increase months before a violent eruption; in otherevents only a few hours may be available. For effective evacuation, it is essentialthat the population at risk is clearly informed well in advance about theevacuation routes and the refuge points to which they should go. To some extentthese directions will have to be flexible depending on factors such as the expectedscale of the eruption, which might influence the pattern of lava flow, and thewind direction at the time, which will influence the pattern of ash fall.

Some local roads may be destroyed by earthquake-induced ground failures. Steepsections of highway can become impossible with even small deposits of fine ash,which make asphalt very slippery. The evacuation of densely populated areascreates special problems of transportation, including the peak capacity of roadnetworks and the balance of public and private vehicles available (Smith, 1991).

During the 1991 eruption of Mt Pinatubo, the total number of evacuees extendedto well over 200,000 about three times more people than previously evacuated inany volcanic emergency.

In some cases, off-shore evacuation may be necessary for;

- small volcanic islands
- coast of New Britain island
- Papua New Guinea.

The existing road network, extending no more than 50 km from the caldera, couldnot guarantee safe landward evacuation during all eruptions whilst seaborneevacuation was limited by the absence of suitable wharf facilities for large ships.

In small-to moderate eruptions, it was suggested that the best option might beto shelter the population in an extensive system of tunnels which were excaudatein tephra deposits around Rebaul during the Japanese occupation of the areaduring the Second World War.
After evacuees have reached the refuge points, they require support serviceswhich include;

- medical treatment (especially for dust-aggravate d respiratory problems and burns)
- shelter
- food and
- hygiene.

Volcanic emergencies may last for many months as eruptions are repeated. This implies that the temporary arrangements planned for refugees may have to function for some time, perhaps is that, depending on the prevailing windconditions, ash fall has the potential to disrupt communities several hundreds of

kilometres away.
For residents at these sites claimed any prior knowledge of ash fall hazard andwarning messages were largely ineffectual in promoting a response. Hazardmitigation specialists clearly have a difficult task in persuading such distantcommunities that they face a volcanic risk.

Increasing efforts are now made to encourage the local population in seismicallyactive areas to become more involved with disaster preparedness. Evidence fromthe western USA suggests that, whist residents do make responses from the long-term threats, there is little prioritization of the adjustments.

In the Philippines the Institute of Volcanology and Seismology has adopted aprogramme whereby residents are gives a training course and then encouraged tolook for possible precursor y signs of volcanic activity. Such as crater glow, steamreleases, sulphuronsodour and dying vegetation (Smith, 1991).

In Ecuador about 3 million people live within the two main volcanic mountainranges and are at some degree of risk from lather. The principal threat is theChillos and Latacunga on lather deposits from the 1877 eruption.

Again, public education programmes, including field trips and evacuationexercises involving 5,000 people in a simulated eruption scenario, have been usedto raise awareness and encourage better precautionary attitudes.

3.4 Forecasting and Warning

Major volcanic eruptions do not occur spontaneously. They are preceded by a variety of environmental changes which accompany the risk of magma towards the surface. The monitoring of these changes provides the best hope of developing reliable forecasting and warning systems. However, only twenty volcanoes worldwide are monitored by well-equipped local observatories whilst afurther 150 have limited instrumentation, mainly seismometers (Smith, 1991).

UNDRO (1985) classified the various unusual physical and chemical phenomena that have been observe d to occur before eruptions. Unfortunately, suchphenomena do not always appear and the highly explosive volcanic eruptions aregenerally the most difficult to forecast.

The most reliable monitoring techniques are seismic and ground deformation measurements, although lather monitoring by automatic rain gauges and flow sensors on the upper slopes of volcanoes can provide some warning of this hazard.

3.4.1 Earthquake Activity

This occurs commonly near volcanoes, although it is not fully understood whetherearthquakes trigger eruptions or vice versa. For predictive purposes, it isimportant to gauge any increase in activity in relation to local background levels.

This means that it is essential to have good seismograph records, preferably overmany years for the volcano in question.

Immediately prior to an expected eruption these records will be supplemented bydata from portable seismometers. There is some evidence from a percussiveseismic signature which has been incorporated into a tentative earthquake swarmmodel for the prediction of volcanic eruptions.

The onset and subsequent peak of a swarm of high-frequency earthquakesreflects the fracture of local rocks as the magmatic pressure increases. This phaseis followed by a relatively quiet period, when some of this pressure is relieved bycracking in the earth s crust, before a final tremor results in an explosive eruption.

3.4.2 Ground Deformation

This is sometimes a reliable percussive sign of an explosive eruption as magmamoves towards the surface, but the relationships are complex and not easy to fitinto a forecasting mode l. The method is also difficult to employ for the explosivesubduction volcanoes because it erupts so infrequently that it is difficult to obtainsufficient comparative information. In rare cases, such as the 1980 event at Mt St

Helens, the deformation is sufficiently large to be easily visible but it is usuallynecessary to detect movements with standard survey equipment or the use of tilt meters.

These instruments are very sensitive but can only record changes in slopes overshort distances. The use of electronic distance measurement (EDM) techniquesprovides a more accurate picture of relative ground displacement, although it isless usually available and requires a series of visible targets on the volcano. Globalpositioning system (GPS) measurements, obtained from satellites, are now alsoavailable to reveal the surface displacement of volcanoes.

3.4.3 Thermal Monitoring

Thermal Monitoring as magma rises to the surface; it might be expected to produce an increase in temperature. But many volcanoes have erupted without

any detectable thermal change. The temperature of hot springs and steam emission can be fairly easily monitored but it provides only an indirect picture of what is happening beneath the surface.
Also any small rise in surface temperature associated with a greater geothermalheat flux can be obscured by rainfall. There is also a problem of thermal inertiawhen heat conduction may be too slow for forecasting purposes. Where a craterlake exists, thermal changes have been meaningful.

UNDRO (1985) cited the example of the Crater Lake on Taal volcano, in thePhilippines, which increased in temperature from a constant 330C in June 1965 toread 450C by the end of July. The water level also rose during this period and, inSeptember 1965, a violent eruption occurred.

Such observations can increasingly be supplemented by thermal imaging fromsatellites. Heat emission was one of the first volcanic features to sense remotelyand it has proved a valuable means of hazard assessment.

3.4.4 Geodetically Monitoring

This is any predictive interpretation of the chemical composition of the juvenilegases issuing from volcanic vents is a difficult task. Gas samples take only a shorttime, or distance, apart often shows considerable variation. It is, therefore, notusually possible to know how representative any changes in composition might beof more general conditions in the volcano. Visual observations of steam emissionsor ash clouds depend on meteorological conditions of well as volcanic activity, butvolcanic plumes can be monitored by AVHRRs carried on weather satellites.

At present there is no fully reliable forecasting scheme available for volcaniceruptions although some success has been achieved. For example, a high-confidence forecast of the 1991 Mt Pinnatubo eruption allowed the evacuation ofpeople from an area that, at maximum, covered a 40 km radius.

By the time the 1996-7 eruptions on the island of Montserat had destroyed themain town of Phymouth, all the residents had been evacuate to the safer,northern part of the island. But uncertainty often leads to practical problems; thiswas well illustrated by the events at La Soufriere, on the island of Guadaloupe,Lesser Antilles, in 1976.

Abnormal seismic activity over a twelve-month period eventually led to theevacuation of 72,000 people from around the volcano. This evacuation of aroundone-fifth of the population was one of the largest, and most costly, everundertake n for a volcanic emergency and lasted for over three months.

The managerial problems of responding to an uncertain volcanic hazardprediction have also been apparent in the Cascade Range in the Pacific

Northwestof the USA. Following steam discharges at least ten times above the normal levelfrom Mt Baker, Washington, during March 1975, the US Geological Survey foresaw the possibility of a destructive mudflow or avalanche.
The US Forest Service closed public access to the Baker Lake Recreation Area in June 1975. The restrictions remained in force for nearly one year, during which time no hazardous event occurred.
Subsequent survey of both residents and recreationalists shown a wide-spread belief that the authorities had over-reacted and over 70 per cent of residents claimed that they would ignore any future hazard warnings and respond to mandatory controls only.

In comparison, the 1980 eruption Mt St Helens was more accurately forecast butstill took the authorities party by surprise. This was because the main explosion was not immediately preceded by any special abnormal phenomena and the explosive blast was directed laterally rather than vertically. As a result 57 people who had been allowed to enter the danger area were killed. Although the surrounding area was sparsely populated, it has been estimated that perhaps as many as 1,000 lives might have been lost if free access had been allowed to residents and tourists.

4.0 CONCLUSION

The occurrence volcanic eruption is real and it is a very serious environmentalhazard that destroys life and properties although you may not appreciate thetechniques for the control of this hazard because it is alien to our nation.

There are many nations around the world that are plagued by the fear of thepossibility of volcanic eruption. Others live in the fear and trauma of seeing abeloved one perish in an eruption.

Irrespective of the experience volcanic eruption releases gases that are dangerousand hazardous to human health, life and properties. This hazard cannot easily becontrolled but humans can avoid living in volcanic zones.

5.0 SUMMARY

In this unit you have learnt that lather slides and debars avalanches are commonfeature of volcano-related ground failure. They are particularly associated witheruptions of deictic magma, which is siliceous with a relatively high viscosity andhas a large content of dissolved gas. The experience of volcanic eruption at Mt. StHelens that took place in May, 1980 is worth discussing.

With regards to environmental control there is no known method of preventingvolcanic eruption. Similarly, there is no known defence against the pyroclasticflows and comparatively little can be done to protect standing crops

and exposedwater supplies from air-fall tephra. Therefore, lava flows moving at comparativelyslow speeds are the volcanic hazard over which most physical control can beexerted.
Three possible methods of diverting and controlling lava flows identified they are

- Bombing
- Artificial Barriers
- Water Sprays

The most important precursors of volcanic eruption are:

- Earthquake Activity
- Ground Deformation
- Thermal Monitoring
- Geodetically Monitoring

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the relationship between lather slides and volcanic eruptions
2. State three methods for control and diversion of lava flow
3. Discuss four ways of forecasting and warning on volcanic eruption

7.0 REFERENCES AND OTHER RESOURCES

Smith, K. (1991). Environmental Hazards: Assessing Risk and Reducing Disaster.London: Routledge.

Other Resources

Enger, E. D & Smith, B.F. (2002). Environmental Science: A study of Interrelationships. New York. McGraw Hill.

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UNIT 3 LANDSLIDE

CONTENTS

1.0 INTRODUCTION

The truth about life is that environmental hazards are inevitable because they are natural but may be naturally induced or artificially as a result of human interference on nature. However the type of hazard experienced in a particular location may be different from another.

The concept for discussion in this unit is not a familiar one with our environment so you may not have a deep appreciation of the hazard as experienced by others except you have the capacity to put yourself in their shoes.

The truth is that landslides are real; you may wish to have a look at pictures to back-up our discussions in this unit.

2.0 OBJECTIVES

By the end of this study you should be able to:

- state five types of landslide terrain;
- discuss on two major factors that determine the strength of the material during a landslide; and
- list five causes of Landslide.

2.1 HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.

Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENT

The down slope movement of large volumes of surface materials under gravitational influences is an important environmental hazard, especially in mountainous terrain. Rapid movements cause most loss of the life and damage; including human-induced land subsidence, have less potential to kill but can be costly.

Depending on the dormant material, these movements tend to be grouped into*landslides (rock and soil) or avalanches (snow and ice). Mass movements may be*triggered by either seismic activity or atmospheric events. To that extent, this hazard lies at the interface between endogenous and exogenous earth processes.

There can be few countries where mass movement processes do not exist, and the landslide risk is increasing worldwide as land hunger forces new development on to unstable slopes, it is an under-recognize d threat because the impacts tend to be frequent and small- scale, whilst the process itself is often attributed to other hazards, such as earthquakes and rainstorms. Mass movements also add considerably to the wide range of hazards found in mountainous areas throughout the world Smith, 1991).

During the early 1970s, an average of nearly 600 people per year were killed byslope failures worldwide but, twenty years later, the figure ranked into several thousand. Perhaps as many as 90 per cent of these deaths occur on the Pacific ocean which is particularly susceptible to mass movements because of thevarying combinations of rock type, steep terrain, heavy typhoon rainfall, rapidland use change and high population density.

The main cause of increased deaths has been the expansion of unregulated townsettlements to unstable slopes in many Third World cities- for example, inCaracas. In Venezuela, the number of urban landslides increased from less thanone per year in 1950 to reach about 35 per year in the 1980s.

The death toll from mass movements is still comparatively low in most MDCs. Inthe USA annual mortality runs at 25 to 50 people and it has been estimated that,for landslides alone, some 22 per cent of the population are exposed to highhazard conditions while another 20 percent are exposed to moderate hazardsconditions. As with many other environmental hazards it is the urban area whichis most vulnerable because of the large populations at risk (Smith, 1991).

3.1 Land Slides Terrain

The term landslides cover most down slope movements of rock and soil debristhat have become separated, from the underlying part of the slope by a shearzone or slip surface. The type of movement, which may include falling, sliding andflowing, depends largely on the nature of the geologic environment, includingmaterial strength, slope configuration and water pressure. The truth is that slopefailure will become an increasingly important hazard, especially in the LDCs.

Five types of landslide terrain have been identified:

1. *Areas subject to seismic shaking. Earthquakes can promote widespread*land sliding, which often occurs in thousands of individual slides, as in the 1950Asian- India earthquake when over 50 billion m of material was displaced over anarea of 15,000 km. Major landslides also occurred after the 1988 Armenian and1990 Iran earthquakes.
2. *Mountainous environment with high relative relief. High energy* terrain, such as the Himalayan or Andean mountain chains, produces perhaps onecatastrophic rock fall per decade worldwide. These spectacular slope failures comprise huge masses of material (up to 100 x 106m) which, at least in the initialstages, travel near-vertically at high velocities over long run-out distances.
3. *Area of moderate relied suffering severe land degradation. Readily*erodible soils on slopes subject to land degradation caused by deforestation or overgrazing have the potential for gully expansion and land shipping. Over the centuries, about 100 villages in southern Italy have been abandoned because of this process.
4. *Areas covered with thick sheets of loss. Any mantling of an existing*ground surface with finely grained deposits, such as wind-blown loess ortephra,is likely to lead to a shear zone at the junction of the two materials and theformation of flow slides in the loose deposits. The loess plateau of central Chinaisa classic location.
5. *Areas with high rainfall inputs. In areas which regularly experience*rainfall from monsoons or tropical cyclones, rock weathering can penetrate tensof meters below the ground surface. For example, in parts of Hong Kongweathered material has moved down slope or cover the bedrock to a depth ofmore than 20 m.

throughout the humid tropics, these deep and porous mantlesare prone to landslides(Smith,1991).

3.2 Landslides: Strength of the Material

Landslides are down slope movements of rock and soil along slip surfaces. Theyare associated with a disturbance of the equilibrium which normally existsbetween stress and strength in material resting on slopes. The relationshipbetween stress and strength in material resting on slopes and the density,strength cohesion and friction of the materials comprising the slope is exceededby a down slope stress.

The strength of the material is the maximum resistance to shear stress anddepends on:

1. Internal cohesion: This is produced by the interlocking, or stickingtogether, of granular particles, particularly in clayey soils and rocks, that enablesthe material to rest at an angle. Some materials, such as dry sand, are cohesionless. Cohesion is independent of the weight of material about the surface.
2. ***Internal friction: This is the resistance of particles of granular soil to***sliding across each other. The friction components of granular soil to depend on the weight of material above the surface.

In turn, these factors will depend on

- the weight or loading on the slope
- the moisture conditionals
- the weight of material in the block
- the angle paralleled to the slope
- the driving force or shear.

Sliding is resisted by the shear strength which is derived from the cohesion ofclay-rich materials and the static friction between the block will remain in place aslong as the driving force does not exceed this combined shear strength. If theslope becomes steeper, the shear stress exerted on potential slip surface becausethe down slope component of gravity increase. If these stresses eventually exceedthe shear strength along a critical slip surface, the mass above the surface willmove down slope.

3.3 Types of Landslide

There are two main types of landslide:

3.3.1 Rotational slides

They exist as curved slip surfaces. The result is a pattern of scars and depositionalfeatures. Of which the most common is the spoon-shaped scar associated withshear failures along arcade plants. The slipped material will be deposited on theslope in either a hummocky or a lobate form depending on the water content.

This type of slope movement can cause a great deal of property damage if theslope has been built upon but warning can often be given for evacuation. A goodexample is the landslide disaster which affected the city of Ancona, central Italy,in 1982.

The major short-term cause was an increase in pore-water pressure associate d with heavy rainfall in the previous month. Apart from losses to road and rail communications, 280 dwellings were damaged. Although the slide occurred in an area of known slope instability, no formed warning was given on this occasion. Nevertheless, about 4,000 people spontaneously evacuated their houses.

3.3.2 Translational slides

Translational slides have relatively uniform, planer surfaces of movement and aresometimes known as block glides and debris slides. Intersecting planner slipsurfaces from wedges of rock, which are relatively common types of translationalslide. The destructive landslide that hit the Vaiontdam in the Piave valley,northern Italy, in October 1963 was a combined natural and technologicaldisaster.

The Vaiont dam, over 260 m high, the key construction in a chain of hydroelectricdams, was completed in 1960 across a narrow canyon set within a broader valley.

The slope of the upper valley were underlain by layered sedimentary rock dippingtowards the valley floor and traversed by fractures parallel to the slope. Thesedimentary sequence included limestones with inter-bedded clays whichbecame significantly weaker when wet.

As the water stored in the reservoir backed up behind the dam, it entered pre-existing fractures and wetted the vulnerable layers. Following heavy rain and aminor earth tremor, the southern slope of the valley failed. A large volume ofmaterial collapsed into the reservoir and displaced some 200 x 106m3 of water,mud, rock and timber, which fell almost vertically over the dam into the valley below. Although the dam remained intact, several villages were destroyed with the loss of 1.189 lives.

Table 8.1 Classification of landslides

Type of movement	Type of material Bedrock	Engineering soils Predom course	Predom fine
Falls Rock fall	Debris fall Earth	fall	
Topples Rock	Topple Debris topple	Earth topple	
Slides (a) rotational (b) translation	Rock slump Rock block slide Rock slide	Debris slump Debris block slide Debris slide	Earth slump Earth block slide Earth slide
Lateral spreads	rock spread Debris	spread Earth spread	
Flows Rock flow	(deep creep)	Debris flow (soil creep)	Earth flow
Complex	Combination of two or more principal types of movement		

Source: Smith (1991)

3.4 Causes of landslides

Landslides result from a variety of events that may combine either to increase thedriving force or to reduce the shear resistance on a slope. Factors that increaseduring forces on a slope may be either physical or human and include:

- An increase in slope angle which may occur if a stream erodes the bottom of a slope or if the slope is steepened by building work. Jones et al. (1989) have described how the cutting of a road into the basic of a slope during 1984, which left exposed faces 25 m high and colluviums standing at an angle of 550 unsupported by anything other than a 3 m masonry wall, led to the Catak landslide disaster in Turkey in which sixty- six people died in 1988.
- Removal of lateral support at the foot of a slope again caused either by natural mass wasting processes or by building activity.

- Additional weight placed on the slope by the dumping of waste or house construction. Residential development not only adds weight to the slope through the buildings themselves but also through excess water supplied from landscape irrigation and seepage from swimming pools and sewage affluent systems.
- Removal of vegetation by wildfires or through human activities such as logging, overgrazing or construction. Surface materials become looser because of the loss of soil binding by roots and the slope is also more exposed to the erosive action of surface water through the loss of plant cover.
- Local shocks and vibrations which can occur naturally from seismic activityor from the operation of heavy construction machinery.

Factors that lead to a reduction in the shear resistance on a slope are:

- An increase in pore pressure in the slope materials, especially along a slipsurface. This is the most important single factor and explains the closerelationship which exists between shallow-seated landslides debris flows, and rainstorms. Unfortunately, the detailed interaction of rain-water and soilbehaviour is not fully understood and it remains difficult to predict landslides on asite-specific basis.

In unsaturated material that is not totally dry, the internal voids or pore will befilled with gas fair and water vapour and some liquid water. If the slope thenexperiences additional loading, perhaps as a result of building construction, themineral grains will be able to slide into a more compact arrangement. Suchcompression increases the soil density and additional strength will result.

However, if there is resistance to a denser configuration due to water in the voidspace, and rapid surface loading occurs relative to the permeability of the soil,then the additional load is transferred into the pore water causing an increase inthe pore-water pressure. In turn, this reduces the friction component of strengthand down slope movement may occur:

- An increase in slope angle, which often occurs when developed slopes areover-steepened by cutting into the base, a process which increases the driving force. After land slipping on the slope the area has to be re-engineered to a safer2:1 overall angle combined with restoration work includes improve d drainage, reverberation and strengthening of the toe of the slope.

Studies have shown that, several decades ago, 25-30 per cent of landslides in southern California were related to construction activities. Improve d grading codes have reduced the amount of slope movement damage but there is still ageneral trend, in the Los Angeles area and elsewhere, towards building on hill slopes which is driven by the decreasing availability of flat land sites and the fashion for houses with extensive views;

- Weathering processes, which promote the physical and chemicalbreakdown of slope materials. Certain clay materials, such as montmorillonite,expand when water is present and the behaviour of these expansive clays hasbeen implicated in the failure of many southern Californian hillsides. In addition,other natural or soil piping developments on slopes will lead to weakness and thepossibility of land sliding.

In most urban areas, landslides may be attributed to a combination of the abovefactors. One example is the 1979 Abbortsford landslide which created a slopefailure covering 18 ha in a suburb of Dunedin, New Zealand, and severelydamaged sixty-nine houses. In this case the failure was attributed to the removalof some slope support at the toe by excavation for building, the introduction ofadditional water to the site and the extensive removal of natural vegetable allsuperimposed on an unstable geological setting.

The progressive human invasion of landslide hazard zones is not confined to thedeveloped world. The need for improve d transportation leading to new roadconstruction in terrain with a high probability of slope movement throughout theLDCs. In these areas limited resources may lead to inadequate hazard protection.

For example, the 52 km long Dharan-Dhankuta road, completed in 1981, providea key north-south link within Nepal between the Ganges lowlands to the southand the hill villages to the north. The road crosses the unstable Himalayan foothills of East Nepal and is surrounded by long, step valley side slope angled at30-450. Engineering is difficult and expensive in such terrain and the road wasbuilt to a relatively low cost specification. The road has since proved difficult to maintain because of cut-slope failures and the blocking of culverts by debris.

3.5 Rock falls

These are movements of debris (mainly rock) transported through the air. Theyare the simplest type of rock movements and occur on steep faces where bedrockweakness exists such as joints bedding and exfoliation surfaces are present.

Rock falls are presume d to fall directly off cliff faces, rather than to slip along ajoint or bedding plane, although both types of movement may occur. Thepresence of water in clefts and fissures is highly influential, especially in the mid-latitudes where regular freeze-thaw cycles progressively weaken the rock mass byincreasing such openings.

Many of the largest rock falls are induced by earthquake but more spontaneousslope instability also occurs, especially in closely jointed or weakly cementedmaterials on slopes steeper than about 100. The greatest rock fall hazard existswhen joint and bedding planes are inclined at a steep angle as the highly foldedrocks common in major mountain chains like the Himalayas, Andes and Rockies.

The Frank rockslide, which occurred in Alberta, Canada, in 1903, was a classicexample.

In this case the slide took place across bedding planes in a steep anticline formedin the well-jointed limestone of Turtle Mountain, which was subject to miningactivity. Groundwater seeping into the joint dissolved the limestone and enlargedthe fractures. During the winter this water froze and wedged the rock apart,further weakening the structure. The resulting debris destroyed the southern endof the small town of Frank killing about seventy people. The present town hassince been relocated about 2 km north of the original site.

3.6 Debris flows

These are down slope movements of fluidities soil and other material acting as aviscous mass. This occurs when loose slope materials become saturated, resultedin a loss of cohesion and internal friction between the granular particles, as thatan unstable slurry mixture is produced. Debris flows tend to be less deep-seated slope failures than landslides. They are a major feature in the tropics, where theyare triggered by either the prolonged rainfall associated with slow-moving lowpressure troughs or the more intense rainfalls, sometimes exceeding 100 mm h-1,created by tropical cyclones.

The high water content means that the slope material moves faster and furtherfrom the original source than with landslides. Although the course of debris flowsis often guided by stream channels, events mean that they tend to claim morelives than landslides. Because of their high density, up to 1.5 to 2.0 times thedensity of water, debris flows have great destructive force and can remove largeboulders and houses from their path.

Several tropical cities, such as RiodeJaneriro and Hong Kong, are at risk fromboth landslips have been associate d with property development involving earthcuts, fills and retaining walls during major rainstorms in the summer months. In1966, landslides produced in excess of 300,000m3 of debris in the stress of Rioand more than 1,000 people died when many over-steepened for buildingconstruction, failed. One year later, further storms hit Brazil and mudflows causeda further 1,700 deaths and the disruption of the power supply to Rio.

In February 1988 more debris flows in Rio de Janeiro claimed at least 200 livesand made 20,000 people homeless. Most of the victims were living in unplannedsquatter settlements erected on deforested hillsides. Such period in January 1982,some 500-600 mm of rain fell in the San Francisco Bay area and debris flows killedtwenty-six people, ten of whole died in a block glide incident in Sanata CruzCounty.

In most cases the flows followed stream course and began as flow-sides beforeturning into fluidized masses that were able to attain velocities of 10ms. Theflows occurred at night and most victims died in the homes, indicating the needfor effective evacuated as well as better planning controls.

4.0 CONCLUSION

Environmental hazards have continued to challenge the existence of humanity and especially the need to enjoy a comfortable life. In this unit we have discussed in details on landslides the types, causes, rock fall and debris flow. It is important for you to accept this environmental hazard as a natural challenge to human survival, thus provoking our intellectual capacity and skill to control nature for the benefit and survival of the human race.

Landslides, rock fall and debris flow will continue to take place as long as humans exist on earth. The challenge is to check the excessiveness of this environmental problem especially through technology that will be environmentally sustainable.

5.0 SUMMARY

In a nut shell what we have discussed in this unit is that down slope movement oflarge volumes of surface materials under gravitational influences is an importantenvironmental hazard, common in mountainous terrain. Rapid movements causemost loss of the life and damage; including human-induced land subsidence, haveless potential to kill but can be costly. Depending on the dormant material, thesemovements tend to be grouped into landslides (rock and soil) or avalanches(snow and ice).

There can be few countries where mass movement processes do not exist, andthe landslide risk is increasing worldwide as land hunger forces new developmenton to unstable slopes. Mass movements also add considerably to the wide rangeof hazards found in mountainous areas throughout the world.

Wealso learnt that, during the early 1970s, an average of nearly 600 people peryear were killed by slope failures worldwide but, twenty years later, the figureranked into several thousand.

Five types of landslide terrain were mentioned in this unit;

- Areas subject to seismic shaking.
- Mountainous environment with high relative relief.
- Area of moderate relied suffering severe land degradation.
- Areas covered with thick sheets of loss.

- Areas with high rainfall inputs.

Recall that the strength of the material in a landslide is the maximum resistanceto shear stress and depends on:

- Internal cohesion
- Internal friction

In turn, these factors will depend on

- the weight or loading on the slope
- the moisture conditionals
- the weight of material in the block
- the angle paralleled to the slope
- the driving force or shear.

There are two main types of landslide:

- Rotational slides
- Translational slides
  Causes of landslides are;
- An increase in slope angle
- Removal of lateral support at the foot of a slope.
- Additional weight placed on the slope by the dumping of waste or house construction.
- Removal of vegetation by wildfires or through human activities such as logging, overgrazing or construction.
- Local shocks and vibrations

6.0 TUTOR-MARKED ASSIGNMENT

1. State five types of landslide terrain.
2. Discuss two major factors that determine the strength of material during a landslide.
3. List five causes of landslide.

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UNIT 4 SNOWS AVALANCHES

CONTENTS

1.0 INTRODUCTION

Welcome to the ninth unit of this course. Our discussion will be centred on Snow and how the fall affects humans and the environment in general. We are aware that most of us in Nigeria have never had a firsthand experience of what we are about to discuss in this unit. But it may be appropriate to say that most of us are aware of snow at least through motion pictures.

2.0 OBJECTIVES

By the end of this unit you should be able to;

- list three elements that the path of a snow avalanche follows; and
- discusson three types of snow avalanche motion.

2.1 HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.

Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENT

Just as it is with slope failures in rock and soil, a snow avalanche results from anunequal contest between stress and strength on an incline. The strength of thesnowpack is related to its density and temperature. Compared to other solids,snow layer has the unique ability to sustain large density changes.

Thus, a layer deposited with an original density of 100kg m^{-3} may density to 400km m^{-3} during the course of a winter, largely due to the weight of overlying snow,pressure melting and the recrystallisation of the ice. On the other hand, the shearstrength decreases as the temperature approaches 00C. As the temperature risesfurther and liquid melt water exists in the pack, the movement of the snowblanket grows.Snow avalanches are a special type of mass movement. They are commonfeatures of mountainous terrain throughout arctic and temperate regionswherever snow is deposited on slopes steeper than about 200. The USA alonesurface 7-10,000 potentially damaging avalanches per year, although with onlyabout 1 per cent harm on humans or property. In the past, most casualties weresuffered either by travellers passing through the mountains or by miners locatedin permanent, but human sited, mining settlements.

The Andean countries are notable for avalanches related mining disasters. Theworst avalanches disaster in the USA occurred in 1910 in the Cascade Range ofWashington, when three snowbound trains wereswept into a canyon with theloss of 118 lives.

Historically, the avalanche problem has always been more severe in Europe thanNorth America because the population density is higher in Europe than NorthAmerica because the population density is higher in the Alps than in the Rockies.

Switzerland has a relatively large number of avalanche deaths amounting to some20-30 fatalities per year.

Snow avalanche problems have risen in recent decades. This is mainly due to thegreater use of alpine areas for winter recreation and the associated developmentof ski centres and other holiday resorts. For example, the town of Vail, Colorado,located at an elevation of 2,500m. was founded as a resort community only in1962. The construction of alpine facilities often required the removal of tumblefrom the surrounding slopes. If left intact, the trees would help to stabilize thesnow cover and protect the new roads, railways and power lines which areinvading these areas.

Avalanche problems in the Rockies beset the Canadian Pacific Railway and theTrans-Canada Highway together with sections of US Highway 2.The Trans-CanadaHighway alone crosses nearly 100 avalanche tracks in the 145 km section betweenGolden and Revel stoke in the vicinity of Roget s Pass and it has been estimatedthat at least one motor vehicle is under a major avalanche path at any given time.

Studies have shown that annual avalanche deaths had been on the increase in theUnited States since the early 1950s but there is some evidence that, in the wintersports area of North America and Europe, the annual loss of life may havereached a peak in the mid-1980s (Smith, 1991).

Most snow loading on slopes occurs slowly. This gives the pack some opportunityto adjust by internal deformation because of its plastic nature, without anydamaging failure taking place. The most important triggers of pack failure tend to be heavy snowfall. For a hazardous snowpack failure to occur there must be sufficiently steep to allow the snow to slide.

Avalanche frequency is thus related to slope angle, with most events occurring on intermediate slope gradients of between 300-150. Angles below 200 are generally too low for failure to occur and most slopes above 600 rarely accumulate sufficient snow to pose a major hazard. Most avalanches start at fracture points in the snow blanker where there is high tensile stress, such as a break of ground slope at an over-hanging cornice or where the snow fails to bond to another surface, such as a rock outcrop.

3.1 Snow Avalanche Path

Whatever their individual characteristics, all avalanches follow an avalanche pathwhich comprises three elements;

- the starting zone where the snow initially breaks away
- the track or path followed and
- the run out zone where the snow decelerates and stops.

Science avalanches tend to recur at the same sites, the threat from future eventscan often be detected from the recognition of previous avalanche paths in thelandscape. Clues in the terrain include breaks of slope and eroded channels onthe hillsides and evidence from damaged vegetation. In heavily forestedmountains, avalanche paths can be identified by the age and species of trees andby sharp trim-lines separating the mature, undisturbed forest from cleared slope.

Once the hazard is recognized, a wide range of potential adjustments is available,some of which are shared with landslide hazard mitigation.
In practice, avalanches result from two quite distinct types of pack failure:

1. loose snow avalanches occur in cohesion less snow where inter-granular bonding is very weak, thus producing behaviour rather like dry sand.
   Failure begins near the snow surface when a small amount of snow, usually lessthan $1m^3$, slips out of place and starts to move down the slope. The sliding snowspreads to produce an elongate d, inverted V-shaped scar.
2. Slab avalanches occur where a strongly cohesive layer of snow breaks away from a weaker underlying layer, to leave a sharp fracture line or crown. Rain or high temperatures, followed by refreezing, can create ice-crusts which may well provide a source of instability when buried by underlying topography produces some

upward deformation of the snow surface which leads to high tensile stress and the creation of associate d surface cracking of the slab layer. Theinitial slab which breaks away may be up to 10,000 m2 in area and up to 10m inthickness. Such large slabs release considerable amounts of energy and represent the most dangerous type of avalanche (Perla and Martinelli, (1976). When a slab breaks loose, it may bring down as mush 100 times the initially released amount of snow which is then deposed in a rather chaotic heap.

3.2 Character of Snow Avalanche Motion

The character of avalanche motion also depends on the type of snow and theterrain. Most avalanches start with a gliding motion but then rapidly accelerateon slopes greater than 300.

It is common to recognize three types of a valanche motion.

1. *Power avalanches are the most hazardous are formed of an aerosol of fine,*diffused snow behaving like a body of dense gas. They flow in deep channels andare not influenced by obstacles in their path. The speed of a powder avalanche isapproximately equal to the prevailing wind speed but, being of much greaterdensity than air, the avalanche is much more destructive than wind storms. At theleading edge its typical speed is 20-70 m s-1 and victims die by inhaling snowparticles.
2. *Dry flowing avalanches are formed of dry snow travelling over steep or* irregular terrain with particles ranging in size from power grains to blocks of up to0.2 m diameter. These avalanches follow well-defined surface channels, such as gullies, but are not greatly influenced by terrain irregularities. Typical speeds atthe leading edge range from 15 to 60 m s-1 but can reach speeds up to $120ms^{-1}$whilst descending through free air.
3. *Wet-flower, avalanches occur mainly in the spring season and are*composed wet snow formed either of rounded particles (from 0.1 m to several meters in diameter) or a mass of sludge. Wet snow tends to flow in stream channels and is easily deflected by small terrain irregularities. Flowing wet snow has a high mean density (300-400 kg m-1 compared to 50-150 kg m-3 for dry flows)and can achieve considerable erosion of its track, despite reaching speeds of only 5-30 m s-1.

Snow avalanche movements translate into extremely high external loadings on structures. Using reasonable estimates for speed and density, it can be shown that maximum direct impact pressures should be in the range of 5-50 t m2, although some pressures have been known to exceed 100 t m2 (Smith,1991).

Table 9.1 provides a guide to the relationships which exist between avalanche impact pressures and the damage to man-made structures. In addition to thedirect impact, avalanches may exert upward and downward forces some of whichhave been known to lift large locomotives, road graders and buildings.

The Galtur disasters in Austria, which occurred in February 1999, were the worstin the European Alps for thirty years and illustrated many of the features ofmassive powder avalanches. In this event, thirty-one people were killed and sevenmodern buildings were demolished in a winter sports village previously thoughtto be located safely at least 200 m from the largest avalanche run out tracks.

However, a series of major storms earlier in the winter deposited nearly 4m ofsnow in the starting zone. This previously unrecorded depth was further increase din places by snow redistributed over the upper slopes by strong winds. By thetime the highest level of avalanche warnings were issued, the snow mass in thestarting zone had grown to approximately 170.000 tonnes. During its track downthe mountain, at an estimated speed in exceed of 80 m s-1, the avalanche pickedup sufficient additional snow to double the original mass. By the time it reachedthe village the leading powder wave was over 100 m high and had sufficientenergy to cross the valley floor and reach the village with destructive force.

Table 9.1 Relationships between impact pressure and the potential damage from snow avalanches

Impact (tones m2)	Potential damage
0.1	Break windows
0.5	Push in doors
3.0	Destroy wood-frame houses
10.0	Uproot mature trees
100.0	Move reinforced concrete structures

4.0 CONCLUSION

Snow avalanche are common in temperate countries and they are the result of an unequal contest between stress and strength on an incline. This natural hazard has continued to result into the loss of life and properties especially in Europe and North America. Houses and other important facilities are not expected to be built on the snow avalanche path to avoid loss of life and properties.

5.0 SUMMARY

In this unit we have learnt that, snow avalanches are a special type of massmovement. They are common features of mountainous terrain throughout arcticand temperate regions wherever snow is deposited on slopes steeper than about200. The USA alone surface 7-10,000 potentially damaging avalanches per year,although with only about 1 per cent harm on humans or property.

We also mention that whatever their individual characteristics, all avalanchesfollow an avalanche path which comprises three elements;

- the starting zone where the snow initially breaks away
- the track or path followed and
- the run out zone where the snow decelerates and stops.

Finally we stressed that it is common to recognize three types of avalanchemotion they are;

- Power avalanches are the most hazardous are formed of an aerosol of fine, diffused snow behaving like a body of dense gas.
- Dry flowing avalanches are formed of dry snow travelling over steep or irregular terrain with particles ranging in size from power grains to blocks of up to 0.2m diameter.
- Wet-flower, avalanches occur mainly in the spring season and are composed wet snow formed either of rounded particles (from 0.1m to several meters indiameter) or a mass of sludge.

6.0 TUTOR MARKED ASSIGNMENT

1. Outline three possible ways that the path of a snow avalanche is likely tofollow.
2. Discuss on three types of snow avalanche motion.

7.0 REFERENCES/FURTHER READING

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UNIT 5 ACID RAIN

CONTENTS

1.0 INTRODUCTION

This is the last unit in this course. Our concern in this unit is to discuss on anotherenvironmental hazard- acid rain. Acid rain may be regarded as the mostdangerous of all airborne pollutants.

Am sure most of our families and friends in the Niger-dealt can testify to thisstatement based on their experience.

Unlike smog, it is invisible; unlike chlorofluorocarbons (CFCs) the damage is not inthe upper reaches of the atmosphere, but right here on earth. Acid rain serves asperhaps the best example of how pollution is formed and how it causes globalenvironmental damage, as well as trans-boundary strife.

This unit explores the causes, effects and some way of preventing acid rain.

2.0 OBJECTIVES

By the end of this unit you should be able to:

- outline three common gases that have potential of inducing acid rain;
- describe the effects of acid rain on living and non-living components of the environment;
- identify cities in Nigeria where acid rain could possible occur;
- outline ways of ameliorating the problem of acid rain; and
- carryout an investigation to determine the acidity level of water in your neighbourhood.

2.1 HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.

Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENT

There is a residual debate over the effects of acid rain, its origins are now certain;

- Sulphur (IV) oxide and
- Nitrogen oxides are the chief contaminants.

Seventy percent of the sulphur (IV) oxide in the air is emitted by coal-fired powerplants, which annually pump 200 million tons of the gas out of their tall stacksinto the atmosphere. The tall stacks used by power plants just send the chemicals high into the sky, where stronger are big contributors as are garbage incinerators.

Nearly half of the nitrogen oxide pollution comes from the growing fleet ofautomobiles worldwide. (It is also a residue of the emissions of coal and otherfossil-fuel-burning power plants).

The increase d focus on alternative fuels-like

- methanol and
- natural gas-

is aimed at reducing nitrogen oxides role in both smog and acid rain. But nitrogenoxides do not pollute just the air.

Deposits of nitrogen oxides are one of the key pollutants stimulating algal growthin some rivers and seas. This proliferation of algae has become so extensive inrecent years that it is;

- killing fish
- killing shellfish, and
- rapidly accelerating the ageing of the water bodies.

Natural causes include

- forest fires

- volcanic eruptions
- bacterial decomposition and
- lighting.

These natural causes pump an additional 75 to 100 million tonnes of nitrogenoxides into the air each year.

But acid rain s major contributors are still human-made: a large coal-fired plantcan emit in a single year as much sulphur (IV) oxide as is blown out in a volcaniceruption!

Part of the problem in studying air pollutants is that they are difficult to visualize.

If one were to stare at the stacks of a local electric company power plant all day,or watch the cars tailpipe for several hours, a single particle of sulphur (IV) ornitrogen oxide would not be seen.
Although they are invisible, these particles however are above the city orindustrial plant that spawned them, and crease clouds that settle locally. Most,however, are sent spiralling high into the atmosphere; their fight many last daysand take them thousands of kilometres away (Akpan, 2000).

EXERCISE 10.1

Which Nigerian cities would you expect to produce high quantities of sulphur (IV)oxide and nitrogen oxides? Give reasons for your answer.En route, the pollutant molecules interact with sunlight, moisture, oxidants and catalysts, to change into new, acid-laden compounds of sulphur and nitrogen. After travelling considerable distances, the now highly acidic chemical return to earth in the form of rain or snow, fog, frost, or dew-sometimes they can contain30 times more acid than normal.

It can;

- damage vegetation
- damage wildlife
- ruin painted finishes on cars and homes, and
- tarnish buildings.

Tracing acid rain back to its source is difficult, which is one reason for government s reluctance to respond to the problem. No doubt all air pollutantshave a negative impact on wildlife; it is contended that ozone created by carexhaust is more damaging to forests and trees than acid rain.

Sceptics (especially industries not eager to make large financial investments incleaner technologies) prefer to blame drought, disease, and insects for the recentdevastation of lakes and forests.

Unfortunately, the destruction is often evident only after the damage is extensiveand before a specific chemical can be indicated. But After decades of study,scientists are convinced that acid rain is high on the list of man-made chemicalcombinations devastating the world's ecosystem.

3.1 Effects of Acid Rain

The effects of acid rain are diverse. Some of the effects are;

- Lakes and streams are no longer able to sustain many kinds of aquatic life
- Under continual acid precipitation, a lake gradually loses its buffering capacityagainst acidity, pH value of its waters begins to drop, and its ecosystems arethreatened
- Spawning waters are threatened
- Acid-heavy water leaches important plant nutrients out of the ground
- Activities of heavy metals such as cadmium and mercury contaminate water supplies
- Status and tables made of bronze, limestone, marble, and sandstone are slowly wearing away
- The multi-trillion naira global timber industry has been hurt by weakened forests and both commercial and recreational fishing businesses have been affected
- Mountain forest- those closest to the acidic clouds best illustrate the long-termeffects of acid rain; growth is stunted, leaves and needles drop inexplicably,frailer species die
- Sulphur (IV) oxide and nitrogen oxide emissions have been linked to increases inoccurrence of asthma, heart disease, and lung disease, primarily among children and the elderly
- It is estimated that about N4, 000 billion is spent annually worldwide on illnessesdirectly related to air pollution.

The Ph scale measures how many hydrogen ions are in a substance. The morehydrogen ions, the lower the pH value corresponds to a tenfold increase inacidity. Acid rain has a pH of less 5the first signs of acid rain s long-rang ecological damage appeared inScandinavian lakes during the 1960s. Fish population were dwindling, and in somelakes disappearing entirely. Similar evidence of devastation continued to grow annually. But it was not until the early 1980s that scientists realise that the acid rains-as well as ozone and other human- made pollutants-were beginning to kill off the upper reaches of forests.

A word has been created to describe the devastation: Waldsterben, or forest death. The effect of pollution on trees has been compared to human physical exhaustion- they are weakened and moresussed. Thus scientists feel that air pollution does not kill trees directly, but rather weaken them to the point where they are no longer able to withstand normal periods of moderate drought, insectinfestation or disease.

Scientists working in western Africa have discovered alarmingly high rates of acidity in rains over some parts of the region, caused by human-made fires that rage for months across thousands of kilometres of savannahs.

For years, farmers and herdsmen have set fires to clear shrubs and stimulate thegrowth of crops and grass.

Now, added to already slightly polluted skies, smoke from those fires has raise d the level of acidity in soil and rain water. While scientists and governments ponder this new source of pollution-and ways of dealing with it-the first, burn on!

3.2 Prevention of Acid Rain

Ittadpoles should begin be you die noted that chemical pH7- compounds naturally present in lakes, streams,and watersheds can neutralist acids, often for many neutralizers are depleted will a lake begin to gainyears. Only when those acidity. Similarly, forestdestruction can take years to surface.

pH8⁻ Scientists have learned that visible symptoms of forest destruction becomewater obvious only after damage is well underway and in some cases Lakes can rebuild themselves once input drops. But the recovery of a lake depends on the extent ofdamage. If sufficiently weakened, the lake s natural recover y mechanism is overwhelmed by increasing amounts of acid and other pollutants.
Bakingthesoda latency period pH9⁻ between acid rain pollution and the manifestation of its consequences has provided a fascinating case study of the relationship between environmental science and environmental policy. As evidence mounts against acidmilkrain pollution, the following ways are being suggested for its control:

- Liming: This involves the addition of acid neutralizing lime to the lakes. It offers avery to stave off permanent harm until there is a solution. It can also restore thehealth of lakes and streams where life has already been destroyed byacidification, though it works best and is least costly in small water systems. Yetwhile inexpensive, liming remains a stop-gap effort, not a solution.
- Washing: The most promising technology, one which coal and utility industry representative are watching anxiously, is the washing of sulphur from high sulphur coal. If it works as well as experiments suggest, it could allow coal-burningelectric utilities to cut air pollution linked to acid rain without installing costly scrubbers. Instead of filtering sulphur (IV) oxide from smokestacks, the process removes the potential for pollution before the coal is burned. Tests suggest that90 percent or more of all sulphur could be removed by such washings.
- Use of low-sulphur fuels: This is one of the government initiatives which are pointed in new directions around the globe. Many countries have issued stringentsulphur fuels. The Nigerian crude oil has been of very great value because of its low sulphur content.

EXERCISE 10.2

Make a list of other countries producing low-sulphur petroleum.But the fact that acid rain recognizes no boundaries remains a stumbling block tosolutions. For every acid raindrops saved in one country through tough government laws, two more may be created in another country where laws are lax. Thus solutions must be hammered out simultaneously in every nation if the problem is to be resolved. Acid rain does not carry a passport its ignorance of borderlines has governments have roles to play in the control of acid rain.

3.2.1 Individuals Efforts Towards Control of Acid Rain

Individuals can help by;

- using fossil fuels more wisely
- Car pools and mass transit help; so do fuel-efficient cars and trucks
- Using smart, efficient appliances at home and work helps, as well as turning off lights and appliances when not in use.
- Acid rain is a pollution that industry needs to address, but that individuals need to help keep in the public eye.
- One simple way to draw attention to the problem is by monitoring the acid levels in the rainfall in your own backyard. The tools required for at-home testing aresimple, and thought the results may not stand up in a scientific laboratory; they should give an indication of whether or not there are high levels of acid in your community' s rainfall.

EXERCISE 10.3

A simple pH test on pond or stream water can be conducted by using pH (litmus) paper, which is available at some stores. Take the following steps;

- Use a clean glass jar or container to collect the water sample; collect the water from the middle of the pond or mid-depth in a stream to get a representative sample
- Dip a piece of pH paper into the sample
- Immediately compare the colour of the wet pH paper to the colour chart that is provided with pH paper to determine the approximate pH value.

3.2.2 Government Actions towards control of Acid Rain

Companies that reduce the amount of emissions contributing to acid rain shouldbe given incentives.Laws to reduce nitrogen oxide emissions from cars should betoughened. Scrubbers should be mandatory on all coal- and oil-burning powerplants and ore smelters.

EXERCISE 10.4

Base on your experience and skills in the previous exercise; carry out similar testswith samples of water from several localities in the country. Are there anydiscernible trends? Comment critically on your results.

4.0 CONCLUSION

In this last Unit, you have learnt the causes, effects and ways of controlling acidrain. Though the phenomenon is not grave in Nigeria, aside from some spots inthe Niger-Delta. However it is still a matter for concern for environmentalists andindeed, the people of Nigeria.

The world's 500 million cars (as at year 2000) are among the main culpritscontributing to the growing problem of acid rain. Each year, automobiles and the thousands of electricity-producing utilities around the globe pump over a hundredmillion tonnes of acidic particles into the atmosphere.

Nearly invisible, the dust-like particles of sulphur (IV) oxide from power plants andnitrogen oxides from car exhaust combine with the water vapour in the sky toform acid-laden clouds. These new compounds can travel hundreds of kilometers thought the air-across national boundaries before returning to Earth in the form of dangerously acidic fog, dew snow, and rain.

While acid rain may look harmless, it is not. It can destroy lakes, forests, and ruinthe health of humans. Absorbed by the soil, acid rain dissolves nutrientsnecessary for plants and trees to grow. Acid rain dissolved harmful metals fromthe soil at lake and river bottoms and excess acidity will encourage algae growth,both of which will harm aquatic life and their systems. Acid raincan also affectour drinking water.

When acid rain finds its way into reservoirs or seeping into groundwater, it caneventually pollute the water that comes from the kitchen tap. This polluted watercan also corrode plumbing. Toxic metals are then dissolved into the water wedrink and bathe in. Acid rain contributes to lung cancer and there in mountingevidence of links to respiratory illnesses such as asthma, especially in children.

The only real solution is reducing our reliance on the sources of acid rain. Non-pollution, alternative forms of energy may be best hope.

5.0 SUMMARY

Sulphur(IV) oxide and nitrogen oxides are the chief contaminants. Seventypercent of the sulphur (IV) oxide in the air is emitted by coal-fired power plants,which annually pump 200 million tonnes of the gas out of their tall stacks into theatmosphere. But acid rain s major contributors are still human-made: a large coal-fired plant can emit in a single year as much sulphur (IV) oxide as is blown out in avolcanic eruption!

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If one were to stare at the stacks of a local electric company power plant all day,or watch the cars tailpipe for several hours, a single particle of sulphur (IV) ornitrogen oxide would not be seen. Although they are invisible, these particleshover above the city or industrial plant that spawned them, and crease cloudsthat settle locally. Most, however, are sent spiralling high into the atmosphere;their fight many last days and take them thousands of kilometres away.

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- Activities of heavy metals such as cadmium and mercury contaminate water supplies
- Status and tables made of bronze, limestone, marble, and sandstone are slowly wearing away
- The multi-trillion naira global timber industry has been hurt by weakened forests and both commercial and recreational fishing businesses have been affected
- Mountain forest- those closest to the acidic clouds best illustrate the long-termeffects of acid rain; growth is stunted, leaves and needles drop inexplicably,frailer species die
- Sulphur (IV) oxide and nitrogen oxide emissions have been linked to increases inoccurrence of asthma, heart disease, and lung disease, primarily among children and the elderly
- It is estimated that about N4, 000 billion is spent annually worldwide on illnessesdirectly related to air pollution.

Strategies for controlling acid rain include;

- Liming
- Washing
- Use of low-sulphur fuels

But importantly individuals can help by

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- Using smart, efficient appliances at home and work helps, as well as turning off lights and appliances when not in use.
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6.0 TUTOR MARKED ASSIGNMENT

1. List four common gases that have the potential of causing to acid rain.
2. With the aid of your Atlas identify five locations in the Niger-Delta that is currently experiencing acid rain.
3. What are the effects of acid rain on both living and non-living things
4. Discuss ways of eliminating the problem of acid rain.

7.0 REFERENCES/FURTHER READING

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