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Mining: A Key Human Cause of Landslides

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Abstract - *Landslides are a frequent hazard that are either naturally instigated or caused by human activities. While landslides caused by natural means may hardly be controlled, those caused by human activities may be prevented or at least regulated. This study reviews the contribution of human activities to geo-hazard, otherwise referred to as landslides. Relevant literatures and case studies were analyzed to identify the human activities that catalyze into landslide disaster with a view to evolve the way forward. This study observed that about 50% of human activities that cause landslides are mining activities and that these geo-hazards are experienced as cause of open pit, underground and quarrying systems of mining. However, illegal mining contributes significant proportion of the mining influence on landslides occurrence. It was also observed that 60% of articles that were studied considered mining as main human activity that causes landslides directly and 30% submitted that it can cause landslides indirectly and 10% considered mining as direct and indirect human activity that causes landslides. Whereas 30% of articles reported loss of humans in landslides fatalities caused by mines and 70% reported only loss of properties. This paper concludes that governmental authorities will need to establish mining standards to undertake landslide risk assessment and prediction while mining companies should endeavour to apply scientific principles to their operations.*

Key Words: Landslides, Geohazards, Mining, Slope Stability, Human Activities.

1. INTRODUCTION

Landslides are a result of the failure of soil and rock materials that make up a slope. This failure can result in serious human fatalities, loss of properties and environmental damages. A landslide occurs when stability conditions of the slope are disturbed either by the increase of stress imposed on the slope and / or by the decrease in strength of the earth material building up the slope and it involves a mass downward movement of earth material under the influence of gravity [1]. This movement can occur in many ways. It can be a fall, topple, slide, spread or flow. It is known that landslides are environmental hazards that occur naturally. But recently landslides have increased in many areas as a result of different human activities, where mining is a key activity of among these.

2. METHODS

This paper is a systematic review of scholarly publications such as journal articles, conference proceedings and internet sources that were published between 1986 and 2018 (there was no defined age or place of the articles). These works were accessed from electronic databases via the Internet. The studies were selected based on their relevance to this study and were analyzed in line with its goal. The reviewed works also guided the contents this paper. Different terms related to the topic were used to search in the Internet, like, "Geohazards, landslides, landslides natural causes, landslides human causes, landslides effects, mining effects, mining cause landslides, mining and landslides". These terms led to valuable information that were used in writing the paper. All the information were obtained lawfully and reported accurately. Out of the articles that were studied ten (10) were selected and categorized as studies that are related directly to the topic and were analyzed statistically.

3. RESULTS AND DISCUSSION

3.1 CAUSES OF LANDSLIDES

The basic cause of landslides is the instability of slopes which is mainly a result of weakness in the composition or geological structure of rock or soil formation. This weakness can be caused either by a natural factors or human factors. Several studies have revealed that landslides can result from natural and human factors [2]

- **NATURAL FACTORS**

Many landslides are natural phenomenon that occur independently of any human action [1]. Several natural factors can be a cause of landslides, such as, earthquakes or volcanic activities, heavy rainfall, erosion, changes in climate, deforestation… etc.

Some of the major roles played by natural factors to induce landslides are as follows.

a) Earthquakes or volcanic activities occur when tectonic plates move, which causes slip of slopes resulting in landslides.
b) Heavy rainfall increases the weight of the slope material and decreases the soil strength.
c) Erosion causes the removal of material from the slope mass, which result in the slope instability.
d) Changes in climate causes weathered and weak materials, thus resulting in slope instability.

e) Deforestation is the loss of trees cover. Trees roots can increase the cohesive strength of slopes resulting in better slope stability.

Majority of these natural factors are also caused by human activities indirectly, like, climate changes, deforestation and erosion. But there are human activities that can be considered as factors that cause landslides directly.

- **HUMAN FACTORS**

Human or man-made activities causes of landslides are numerous; including road construction, clear cutting, mining and others. These activities can change the soil state resulting in the instability of the slope. Mining is a key human cause of landslides because of its different operations that produce a huge amount of vibrations, especially blasting techniques and its vibrations that can reach hundreds of meters under the soil surface and poses threat to other areas that are at the risk of sliding. On the basis of analytical study of global database from 2004 to 2016, almost 50% of human activities and some natural factors, excluding rainfall and earthquakes (Non-seismic non-rainfall triggered, NSNR), causing landslides worldwide are from mining (Fig - 1) [3]. They also submitted that all mining techniques either open-pit mines, underground mines or quarries can be capable of causing landslides because of blasting operations that produce vibrations and the huge unfilled excavations that commonly result from ore extraction in the mining sites. Furthermore, it was observed that the increase in landslides caused by mining has become a major concern and if it is properly monitored, the hazard of landslides can be significantly reduced worldwide. Here, emphasis is laid more on the increase of illegal or unregulated extractions (illegal mining). Statistics has shown that illegal extractions (illegal mining + illegal hill cutting) have contributed more than 27% of the human activities that cause landslides[3]. This calls for a need to regulate illegal mining activities and obliging the use of scientific principles in excavating ore materials. Thus, the contribution of mining to the landslide hazards would be reduced globally.

Many fatal landslides accidents have been caused by mining activities all over the world, but only a few were recorded especially in non-developed countries. The following examples have shown how dangerous mining induced or related landslides can be. A landslide of gigantic dimensions that took place in the Handlova coal deposit (Central Slovakia) was a result of underground mining excavations without backfilling the extracted spaces [4]. Another disaster that occurred in 1903 in south western Alberta, Canada when a large rock avalanche destroyed the town of Frank, and the open pit coal mine in the area contributed strongly in this huge landslide [5]. The creation of new slope in mining operations is a well-known cause of landslides which can even impact non-mined areas. Also, one of the famous landslides disasters (Aberfan disaster) that occurred in the Wales, in 1966 killing 144 people was a result of the failure of some hills close to a mine that was not properly designed [6].

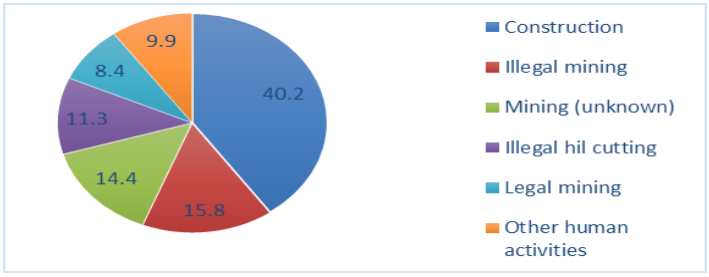

Fig - 1: Distribution of triggers of NSNR landslide events [3]

The authors gathered information from different studies and analyzed them statistically to know the number of studies that considered mining as direct or indirect human cause of landslides and to know the results of landslides studied in those articles. Ten articles were analyzed and out of the ten articles six (60%) considered mining as main human activity that causes landslides directly and three (30%) considered mining as indirect human activity that causes landslides and one (10%) reported that mining can be considered as direct and indirect human activity that causes landslides (Fig - 2). And three (30%) out of the total number of articles reported loss of humans in landslides fatalities caused by mines and the remaining seven (70%) reported only loss of properties (Fig - 3). Which illustrates the engagement of mining directly or indirectly in causing landslides and the effects that result from landslides that are not only loss of properties but can sometimes result in loss of humans.

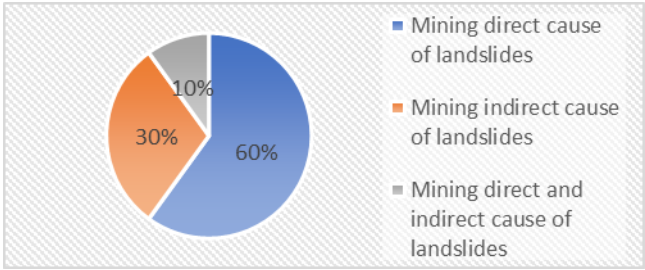

Fig - 1: Results from Selected Studies presenting Mining causality of landslides from selected studies

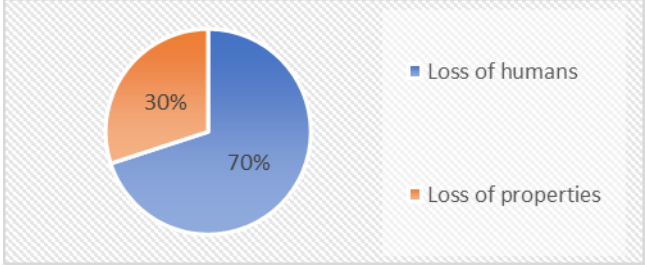

Fig - 3: Results from Selected Studies presenting Loss of humans and properties in mining from selected studies

3. CONCLUSIONS

This review has shown that apart from the natural factors, mining has a major contribution to landslides which is one of the most dangerous global geohazards. This is because mining evolves through legal and illegal activities, and the increase of illegal mining sector is of great concern. Many mines have also not been properly designed or do not operate with designs and most do not apply scientific principles in their operations. The review illustrated that mining causality of landslides is mainly directly but sometimes can cause them indirectly. It also illustrated that majority of landslides cause loss of properties and some can be a cause of human loss. This review has also revealed that landslides pose threat or risk to communities that live close to areas with mining activities and the risk can sometimes be fatal. It thus raises alert to governmental authorities and mining corporations the need to establish standards for developing landslides risk assessment and prediction. This should be based on geologist's skills to examine, analyse and monitor areas that are prone to landslide and the potential mechanism of occurrence as well as their frequency of occurrence.

There would be need for the geologists to generate landslides hazard maps using their field skills to assist the authorities and communities to prepare for landslides in case of their occurrences. There is dire need for governmental authorities to regulate the illegal mining sector to significantly reduce the menace of landslide hazards. Finally, mining companies should apply scientific principles in their operations and employ geomechanical specialists to monitor soil and rock mechanics in the mines and the areas surrounding them. These would hopefully decrease the landslide hazards and hence save many human lives and properties.

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