Mine Waste Management in Nepal: An Overview of Limestone Quarries

Birendra Sapkota\textsuperscript{1}, Kumar Khadka\textsuperscript{2}, Manish Shrestha\textsuperscript{3}, Santa M. Rai\textsuperscript{4}, Ambika Paudel\textsuperscript{5}

\textsuperscript{1}KarmaQuest International, Ottawa, Ontario, Canada
\textsuperscript{2}Department of Mines and Geology, Ministry of Industry, Commerce and Supplies, Kathmandu, Nepal (Email: kumarkhadka26@gmail.com)
\textsuperscript{3}Shivam Cement Limited, Hetauda, Nepal (Email: shrestha.manish2019@gmail.com)
\textsuperscript{4}KarmaQuest International, 941 Goose River Avenue, Gloucester, Ontario, K1V 1T7, Canada (Email: santamanrai1@gmail.com)
\textsuperscript{5}Department of Geography and Environmental Studies, Carleton University, Ontario, Canada (Email: ambikapaudel@cmail.carleton.ca)

Author Note
Correspondence concerning this article should be addressed to Birendra Sapkota.
E-mail: sapkotabirendra@gmail.com
Abstract

The objective of this paper is to evaluate the management of non-metallic mine waste in general, and specifically, limestone mine waste in Nepal. The authors reviewed the policy documents and the regulations, assessed the implementation of the regulations on this issue considering a few selected limestone quarry sites, and discussed how mine waste can be managed more efficiently with reference to existing practices from the developed countries. Our analysis shows that despite the challenges that exist due to complex geology, steep topography, and financial constraint associated with surface mining and waste management, the available management strategies have not been implemented adequately in the majority of the mine/quarry sites. This indicates a need for a relook into the current practices of mine waste management and formulating appropriate mine waste management-related policies of the country. The national demand for cement has been soaring, and more cement industries are operating in recent years. Consequently, the volume of the mine waste will increase in far excess of the liberated resource and it can create environmental degradation if not managed appropriately and in time. The authors recommend legislative reform and suggest the implementation of feasible management strategies at the mine sites.

**JEL Classification:** Q20, O10  
**Keywords:** quarry, mine waste, environmental impact, mine waste remediation, overburden, mine waste reclamation

**Acknowledgements:** The authors would like to thank Mr. Ram Prasad Ghimire, the Director General, Department of Mines and Geology, Nepal, for providing reports and supportive information. Our sincere thanks go to Mr. Sabin Sharma (Mining Geologist from Hetauda Cement Industries Ltd., Nepal) for his help in collecting the field data. The authors also would like to extend thanks to two anonymous reviewers for their sincere advice and comments which helped to improve the quality of this manuscript.
1. Introduction

Mine waste is the unwanted material discarded during the mining of ore or the main source of raw materials. It comes out as an associated material during the processes of excavation and exploitation, and further physical and chemical processing of a wide range of metallic ore minerals and non-metallic minerals (Szczepanska & Twardowska, 2004). Over the last century, the volume of mine waste generated by the mining industries has increased tremendously. Due to the increasing tendency in the demand for mineral commodities, there is a concomitant increase in the exploitation of even slightly lower-grade deposits (Hudson-Edwards & Dold, 2015), thereby generating large amounts of mine waste. In Canada alone, the volume of tailings (residue from the ore concentration process) produced per day has increased 20-fold since the 1960s (Perreault et al., 2015). Although North American mines today operate under stringent environmental regulations (i.e., mine regulators only permit mining if robust waste management plans have been developed) (Prabhakar-Fox & Lottermoser, 2015), managing mine wastes and minimizing environmental and social impacts associated with resource mining, extraction, and refining operations present significant engineering, environmental and safety challenges (Perreault et al., 2015). For example, there is ample evidence that when leachate from sulfide-rich tailings enters the environment, it can severely contaminate groundwater and biota (plants, aquatic animals) (Kossof et al., 2014), and cause ecological degradation (Byrne et al., 2012). Remediating such contaminated areas can become very costly. In developing countries where the environmental regulations are not that stringent, waste management has been an overlooked aspect, and this has created several environmental and social consequences.

2. Mining Industry in Nepal

Nepal’s mining history is more than 200 years long. However, the actual mining activities, although not that systematic, started only after the establishment of the Nepal Bureau of Mines in 1963 and the Nepal Geological Survey in 1967, both of which amalgamated in 1977 and got renamed as the Department of Mines and Geology (DMG). The mining sector is yet neglected and has remained as the smallest sector of the country’s economy, contributing to about 0.6% of the gross domestic product (GDP) (Central Bureau of Statistics, 2020). In the fiscal year 2019/2020, the royalty and revenue collected from the mining sector was more than NRs.1 billion (NRs. is Nepal's national currency called Nepalese Rupees. 1 billion is equivalent to approximately 860,000 USD; 1 USD = NRs.117 as of May 15, 2021) and the total contribution of the mining sector in national economics is approximately NRs.1.83 billion (equivalent to approximately 1.57 million USD), which is 0.65% of the current GDP. The mines and mineral industries sector contribute to about 2.4% of the national GDP. There are numerous small-scale industrial minerals-mining companies in Nepal, but mineral production has mainly been for domestic consumption. All the mineral resources in the country are owned by the state. DMG, under the Ministry of Industry, Commerce and Supplies, Government of Nepal, is the responsible government organization that has been conducting geological mapping, mineral exploration, and all other investigating activities in different parts of the country (Kaphle, 2020a). The Government of Nepal has authorized DMG to issue mining and prospecting/exploration licenses to the public, private sectors and national and international mining companies registered in Nepal.
In the Fiscal Year 2020, there are altogether 150 mining licenses issued by the DMG for 16 different minerals, including both the metallic minerals (i.e., iron, copper, lead and zinc) and the non-metallic minerals, such as gemstones (tourmaline, kyanite, quartz), industrial minerals (i.e., calcite, limestone, dolomite, magnesite, talc, red clay, coal, quartzite), decorative stones (marble, granite, quartzite) and construction materials (slabstone, slate, sand and gravel). Out of those 150, only 10 mining licenses are of metallic mineral mines, but unfortunately, none of them are in operation at present. Of the remaining 140 non-metallic mineral mines, about 60% of them are in regular operation, of which a few have a low production rate (around 30%), and the remaining mines are either in the developing stage or not in regular production. For example, gemstone mines (23 in total) have not been in operation since 2015 after the Government of Nepal banned the export of gemstones in raw form and mandated them to be processed at least at their initial stage. The lack of processing manpower resulted in the cessation of mining gemstones. Similarly, coal (lignite to sub-bituminous grade) mines (12 in total) are running at their low production capacity as the permission from the Department of Forests and Soil Conservation for clearing forests in mining areas takes a very long time and becomes one of the main obstacles.

Limestone mines are by far the largest mines in Nepal. Limestone occupies about 7,000 sq. km of Nepal's total land area (DMG, 2017). According to the exploration works carried out to date by the DMG and by some private organizations, the estimated reserve of limestone is more than 1,500 million metric tons (mt), out of which proven reserve is estimated to be more than 750 million metric tons. Few studies (e.g., Sah & Paudyal, 2019; Pandey & Banskota, 2008) have been conducted showing the status of the cement-grade limestone deposits that constitute suitable concentrations of CaO (>42%) and MgO (<2.5%) for ordinary Portland cement production. The country got its first cement industry in 1972 as Himal Cement Industry in Chobhar, Kathmandu, with the production capacity of 120,000 mt per annum, which unfortunately was shut down in 2002 owing to its pollution effect in Kathmandu, the capital city. The industrial policy formulated in 1974-1975 gave a new dimension in the industrialization process leading to the establishment of Hetauda Cement Industry (1976) and then Udayapur Cement Industry (1987), leading to the establishment of first private sector cement company in Nepal in 1996. As per the mining license and production status, limestone is by far the most important mineral resource in Nepal, followed by talc, coal, and dolomite (DMG, 2017). Almost all the limestone mines in Nepal are located in the Mahabharat Range within the Lesser Himalaya, the tectono-stratigraphic unit structurally bounded between the Main Boundary Thrust (MBT) to the south and the Main Central Thrust (MCT) to the north, consisting mainly of the Paleo- and Mesoproterozoic metasedimentary rocks (Upreti, 1999), such as slate, phyllite, schist, quartzite, marble, and unmetamorphosed dolomite, limestone, sandstone, and shale. Kaphle (2020b) highlighted that in many localities, limestone beds/bodies occur together with dolomite in the Mahabharat Range of the Lesser Himalaya, extending from the east (Dhankuta) to the west (Darchula). Cement grade limestone deposits have also been reported by Sah & Paudyal (2019) in different formations of Nawakot Complex of the Lesser Himalaya (e.g., Pre-Cambrian Jhiku Carbonate Beds of the Benighat Slate; Dhading Dolomite and Kerabari Formation/Malekhu Limestone; the Kathmandu Complex/Kathmandu Nappe (Precambrian Bhainsedobhan Marble and Markhu Formation; Ordovician Chandragiri Limestone); and Eocene Gandari Limestone beds). Some of the limestone quarries from these formations have already been exploited as source products for
the cement industries in production. Some parts of the Tibetan-Tethys Himalaya and Higher Himalaya contain limestone/marble beds; however, they have not been used for the cement industry due to inaccessible and rugged topography in the northern and higher altitude terrain of the country.

The number of limestone mining licenses is increasing in the recent decade, from 37 in 2013 to 72 in 2020, consistent with the increasing demand for cement used in infrastructures, such as roads, bridges, dams, irrigation canals, housing complexes, and multi-storey buildings, etc. According to an economic survey conducted by the Ministry of Finance, there is a direct relationship between the amount of cement production and the GDP of Nepal; for example, if the GDP increases by one percent, the consumption of the cement will increase by 4.8% (Economic Survey, Government of Nepal (2020). This clearly signals the heightening use of cement with the country’s economic growth. The limestone quarries supply limestone to about 65 cement industries in Nepal, out of which 29 are large cement plants and 36 are medium to small plants, and together they have the capacity of 14 mt of cement production per annum, which covers nearly 83% of the national cement demand. Due to the installation of newly integrated and grinding units in the past few years, the import of cement into the country has decreased considerably from 65% during 1990-2000 to 16% in 2015 and less than 10% in 2020. However, as the country is in the developing phase, the demand for cement is expected to increase significantly in the next five years. With the increase in mined limestone, the associated mine waste generated from the quarry operations will also increase. According to the mining scheme submitted to DMG, the stripping ratio of limestone to waste on average is 1:0.6. In addition, the mining loss is generally about one-third of the total geological reserve. Thus, the waste generated from each mine is at least about 30-35% of the total excavated material. In light of the increasing demand for mining limestone deposits and the increase in associated mine waste, this study explored the potential environmental and social impacts due to mines/quarries in Nepal. Concerns have been raised on the overall impact of cement industries in the environment and human health. However, there is no reported literature dealing specifically with mine waste management in Nepal. Therefore, an overview of the existing practices of waste management from limestone quarries/mines in Nepal is presented in this study.

The Mines and Mineral Act 1985 and Mines and Mineral Regulation 1999 of the Government of Nepal, enable the DMG for exploration, promotion, and issuance of licenses for mine operations, and regular monitoring and inspection of mines. Section 19 of the Mines and Mineral Regulation (1999) emphasizes that mining activities should be conducted with minimal environmental impact. Similarly, the Environment Protection Act 1996 (amended July 19, 2019) and the Environment Protection Regulation 1997; amended June 15, 2020), and Nepal Environmental Policy Action Plan 1993 have provisions to inspect environmental issues associated with mining activities. Unfortunately, provisions related to mine waste management and pollution prevention are inadequate in these legislations that constitute a legal framework for mine operation, inspection, regulation, and administration of the mineral development of Nepal, and yet no measures are in process to update them in line with the current international standards (discussed later). This study, therefore, recommends the policy improvements that could be implemented for mine waste management in Nepal. Some insights from the developed countries are also provided to illustrate the best management practices. This study is, however, a preliminary evaluation of environmental and socio-economic impacts due to mining activities, especially mine waste management in Nepal. It is expected that the present
findings will be useful for mine excavation and operation, mineral industries, policymakers, and researchers to understand the current status and challenges of mine waste management in Nepal, as well as to adopt feasible waste management policies and strategies.


The location and general geology of limestone quarries (Table 1) considered for this study were obtained from the DMG records/reports. A total of 13 active limestone mines/quarries and one abandoned quarry (Fig. 1 and Fig. 2) were taken as representative of the general geology and area of the quarries in the country. Details of quarry sites and waste management practices were collected during field inspection and monitoring visits. The existing waste management practices in Nepal are compared with the best available management practices in the developed countries, and recommendations are made to make waste management more effective, environment-friendly, and sustainable in Nepal.

About 90% of the country’s total individual limestone quarries constitute less than 5 ha quarry area. As per the Environment Protection Regulation 1997 (amended in 2020), such small-sized quarries (<25 ha) and those that are outside the forest area require only initial environmental examination (IEE), but not the detailed environmental impact assessment (EIA) of the mining project. This criterion also applies to mines that exploit less than 4800 tons of limestone per day. In order to skip the EIA study that requires a full environmental assessment, a costlier process than IEE, mine owners/miners often select mines/quarry areas that can fulfill IEE criteria and conduct a quick, preliminary environmental review of the reasonably foreseeable impacts of the proposed mine. As a result, a large number of small-size mines are operated in the country, and consequently, this has generated a large volume of mine waste that has not yet been accurately recorded by the concerned authority.

Field site observations by the authors revealed that the mine waste management in most cases is done by storing them in nearby dump yards, creating stacks and berms from the same waste materials. However, the berms are often created haphazardly (Fig. 3; B, D, E, and F) irrespective of the waste management directives. Figure 4 shows two examples of active quarry sites (Siddheswor and Dobhan limestone quarries in Palpa) that are close (<1 km) to the residential areas. There is no mine waste management plan in place for both sites. Such mine sites are the immediate sources of air pollution to the nearby residents from the wind-blown dust present in the non-cohesive material, and once left inactive, they pose a higher risk for erosional and landslide activities which can damage cultivated lands, roads, settlements, drinking water sources, pipelines, electricity pole, and even kill people. To reduce the volume of the waste materials stored on-site, mined waste can be used in road construction, gabion wall construction, road paving, etc.

At few other quarry sites (e.g., Dubidanda limestone quarry in Rolpa, and Kalwan limestone quarry near Hetauda), an attempt has been made to mitigate erosion of mine waste and prevent the potential mass wasting by creating benches (Fig. 5; A and D) and placing gabion walls at the foot of the quarry slope (Fig. 5; B and C). However, such protective measures are not constructed to the full extent required; rather, they evolve as a continuous process directed by the need of the mine owner or at the request of the local community/local government.
Table 1

Some Representative Active Limestone Mines/Quarries with their Location, Mining Reserve (in tonnage) and Geological Units

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Limestone quarry location</th>
<th>Size, status</th>
<th>Geological units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Complex/Group</td>
</tr>
<tr>
<td>1.</td>
<td>Nigale Mine (Mahalaxmi Municipality, Dhankuta)</td>
<td>2,759,000 tons MR; 350 tons PDPC; active</td>
<td>Lesser Himalaya (Nawakot Complex) (Andrew, 1985)</td>
</tr>
<tr>
<td>2.</td>
<td>Maruti Mine (Dudhouli, Sinduli)</td>
<td>20,340,000 tons MR; 4800 tons PDPC; active</td>
<td>Lakharapa Group, Lesser Himalaya (Tater et al., 1983)</td>
</tr>
<tr>
<td>3.</td>
<td>Suja Mine (Ghorahi, Dang)</td>
<td>14,700,000 tons MR; 1500 tons PDPC; active</td>
<td>Lakharapa Group, Lesser Himalaya (Tater et al., 1983)</td>
</tr>
<tr>
<td>4.</td>
<td>Phoply Mine (Naubahini, Pyuthan)</td>
<td>10,200,000 tons MR; 1200 tons PDPC; active</td>
<td>Nawakot Complex*/Upper Nawakot Group (Stöcklin, 1980)</td>
</tr>
<tr>
<td>5.</td>
<td>Dubidanda Mine (Runtigadhi, Rolpa)</td>
<td>5,360,000 tons MR; 800 tons PDPC; active</td>
<td>Lakharapa Group, Lesser Himalaya (Tater et al., 1983)</td>
</tr>
<tr>
<td>6.</td>
<td>Narpani Mine (Arghakhanchi)</td>
<td>500,000 tons MR; 1000 tons PDPC; active in Quarry II, abandoned in Quarry I</td>
<td>Lakharapa Group, Lesser Himalaya (Tater et al., 1983)</td>
</tr>
<tr>
<td>7.</td>
<td>Siddheswar Mine (Palpa)</td>
<td>1,202,000 tons MR; 600 tons PDPC; active</td>
<td>Kaligandaki Supergroup, Lesser Himalaya (Sakai, 1985)</td>
</tr>
<tr>
<td>8.</td>
<td>Dobhan Mine (Tinau, Palpa)</td>
<td>11,928,050 tons MR; 3000 tons PDPC; active</td>
<td>Kaligandaki Supergroup, Lesser Himalaya (Sakai, 1985)</td>
</tr>
<tr>
<td>9.</td>
<td>Jyamire Mine (Hongshi, Palpa)</td>
<td>254,290,000 tons MR; 10000 tons PDPC; active</td>
<td>Kaligandaki Supergroup, Lesser Himalaya (Sakai, 1985)</td>
</tr>
<tr>
<td>10.</td>
<td>Udayapur Mine (Jalpa, Udayapur)</td>
<td>72,000,000 tons MR; 1200 tons PDPC; active</td>
<td>Nawakot Complex*/Upper Nawakot Group (Stöcklin, 1980)</td>
</tr>
<tr>
<td>11.</td>
<td>Lele Mine (Lalitpur)</td>
<td>5,150,000 tons MR; 400 tons PDPC; active</td>
<td>Kathmandu Complex#/Phulchowki Group (Stöcklin, 1980)</td>
</tr>
<tr>
<td>12.</td>
<td>Kalwan Mine (Hetauda)</td>
<td>13,200,000 tons MR; 4000 tons PDPC; active</td>
<td>Kathmandu Complex#/Bhimphedi Group (Stöcklin, 1980)</td>
</tr>
<tr>
<td>13.</td>
<td>Khortar Mine (Hetauda)</td>
<td>19,760,000 tons MR; 2500 tons PDPC; active</td>
<td>Kathmandu Complex#/Bhimphedi Group (Stöcklin, 1980)</td>
</tr>
<tr>
<td>14.</td>
<td>Okhre Mine (Hetauda)</td>
<td>7,000,000 tons MR, 1050tons PD; active</td>
<td>Kathmandu Complex#/Bhimphedi Group (Stöcklin, 1980)</td>
</tr>
</tbody>
</table>

*Note: Data were obtained from the mining scheme submitted to the DMG for limited quarry area. Abbreviations are: MR = mineable reserve, PDPC = per day production capacity.

* The Nawakot Complex (Stöcklin, 1980) is an equivalent geological unit of the Lesser Himalaya.
# The Kathmandu Complex (Stöcklin, 1980) consists of lower Bhimphedi Group (equivalent to the Higher Himalaya) and the upper Phulchowki Group comparable with the Tibetan-Tethys Himalaya affinity rocks. It overlies the Lesser Himalayan rocks along the Mahabharat Thrust (MT).
Figure 1
Locations of Licensed Limestone Mines/Quarries in Nepal and 14 Selected Limestone Mines for this Study

Figure 2
Geological Map of Nepal (after Dhital, 2015) and Geological References to the Studied Quarry Sites
Similarly, at some locations (e.g., Kalwan limestone quarry near Hetauda), a gabion wall is constructed few kilometers downstream of the mine site upon the request of the local community as a protective measure against future flooding events. While this seems to address community concerns, it will not address the stability measures that are on the mine site. It is imperative to have properly constructed protective measures on-site that can prevent soil and water erosion, sediment loss, and siltation problems before the sediment enters the nearby watercourses.

**Figure 3**

*Limestone Quarry Sites and their Waste Management Practices: Nigale Mine, Dhankuta – (A) Limestone Band and (B) its Waste Yard; Suja Mine, Dang – (C) Limestone Band and (D) its Waste Yard; (E) Waste Yards in Maruti Mine, Sindhuli, and (F) Uncontained Waste in Phoply Mine, Pyuthan*

It seems customary that several mines/quarries in Nepal remain inactive during a certain period (a few years or months) as long as the owner holds the license for future mining operations. With the intent of future mining, such temporarily inactive mines do not have waste management plans. As can be seen, such mine sites not only provide ugly sights to the landscape but also pose future safety challenges. This is imminent mainly in abandoned mines. For example, the Narapani limestone quarry (Fig. 6) has waste material piled up at the periphery of the quarry, and signs of erosion downstream are evident. If enough precipitation accumulates
in the pit, then there is a potential for a landslide in the near future, which can have consequences such as river damming and the subsequent impacts on the settlements, cultivated land, and aquatic life in the local freshwater ecosystem.

**Figure 4**

*Active Mines without Waste Management Practices: (A) Siddheswor Limestone Quarry, and (B) Dobhan Limestone Quarry, Palpa*

**Figure 5**

*Protection Mechanisms (Benches and Gabion Walls) for Mine Waste Containment: (A & B) - Dubidanda Limestone Quarry in Rolpa, and (C & D) - Kalwan Limestone Quarry in Hetauda*
3.1 Socio-Economic Impacts

The present study shows positive impacts of mining in general, and mainly on the socio-economic aspects in the communities nearby the mine areas. Many remote areas immensely benefitted from the mining, with access roads for transportation, electricity, and job opportunities (as labourers, equipment operators, etc.). This was evident mainly in the Hetauda region, central Nepal. The establishment of local markets and communication services grew there rapidly with the onset of mining and the establishment of the cement industry as well as many other industries in Hetauda industrial area. Reduction in migration of youth in search of jobs in the city areas or abroad is another advantage. In Palpa area, most of the local youth have owned trippers and machinery for mining, which has helped mine industries, both in terms of using local resources and in gaining local support to keep the industries running. Similarly, the reuse of mine wastes has allowed for their beneficial application, such as construction material in building gabion walls, masonry walls, backfill for open voids, landscaping, and as soil components and soil additives. Such waste management strategies can promote a circular economy, a resource efficiency concept aimed for efficient use of natural resources throughout their life cycle (Tayebi-Khorami et al., 2019). While the extraction industry in Nepal has a positive contribution to society and the economy, it has not demonstrated best practices to reduce impacts on land degradation, and potential landslide and erosional activities. Also, quarries that use blasting leave dust and toxic gases to the neighbouring residence, and these may pollute soil and local water resources. This, however, has so far been a minor issue as only Udayapur Cement Industry practices mining by blasting that occurs in 15 days intervals. Other cement industries mine by using mechanical breakers and rippers.

3.2 State-of-the-art Mine Waste Practices

Mine site reclamation is typically guided by the site characteristics, immediate surroundings, and economic viability of the land being used. A possible way of solving the problem should be laid out with contemporary benefits. There are several successful examples of rehabilitation measures, such as creating a botanical educational garden or recreational park,
transforming the quarry site into progressively agricultural land, constructing community spaces, new settlement areas, playgrounds, etc. For example, the Royal Botanical Garden in Hamilton, Ontario, the largest of its kind in Canada that was built in a gravel pit site, is an impressive attraction. Similarly, Kerncliff Limestone Quarry in Ontario, Canada, is another excellent example of mine site rehabilitation and how revegetation can contribute to local biodiversity conservation (The Ontario Aggregate Resource Corporation, 2008).

Post-closure mine site management requires careful planning with a specific objective of an end-use after its rehabilitation. Surface treatments, such as corrugation, ripping, vegetation to localized rills, can prevent erosion and protect topsoil. Revegetation with different functional groups (fast-growth vs. slow-growth) favours a quicker establishment of species and promotes microclimatic conditions favourable for colonisation by other species (Correia et al., 2001). Innovative approaches suitable to the locality can be adopted based on societal interest and stakeholder input (e.g., local community, interest groups, local government) but with due consideration of topography, drainage, relief, geological condition, and suitable time frame.

In Nepal, all the mines remain in operation within the licensing period. The prospecting and mining license holders must renew their licenses every fiscal year. Ghimire et al. (2006) reported in their monitoring and inspection report that most of the mine operators did not follow the directives of the DMG and their licenses had been warned, fined, and even canceled as per the Mine and Minerals Act and Regulation. In a recent environmental audit report of the DMG, Banskota et al. (2020) have mentioned several issues in the operating limestone quarries/mines, such as lack of waste management plan, failure of retention wall in waste yard, the boundary of quarry area not being properly marked, improper drainage, and inadequate safety measures. They have also highlighted the importance of scheduled monitoring of the mines by the DMG, and maintenance of efficient mining with minimal environmental impact. These reports indicate that the mining activities are not carried out as per the directives of the DMG. Such issue was also evident in the majority of the mine sites considered for this study. Although a need for regular inspection and monitoring of mining activities and their environmental impacts is clearly stressed in the DMG reports, rehabilitation options, which are the measures to create suitable landforms for other purposes from the disturbed land, that are compatible with the existing landscape, are not discussed and are in fact never practiced. Similarly, although the approved mining schemes should comply with mining under the supervision and instruction of a mining engineer as stated in the policy, this is a rare practice due to the lack of manpower, and in the majority of the mines, the excavation is done at the contractor’s convenience, which creates additional risk for mine workers, and additional environmental problems.

The government is planning to utilize the security funds from the miners to rehabilitate the mine sites once they cease operation and are closed. However, there is no set guideline to restore mine sites to the condition in which it is visually acceptable to the local community. In developed countries, the mine site rehabilitation hierarchy guide is followed once the mining operation ceases (Lottermoser, 2011; EPA, 2008) with ‘leaving site unusable or potential to cause environmental harm’ as the least favoured option. In Canada, for example, depleted pits and quarries must be rehabilitated by law (Corry et al., 2008), and few rehabilitation attempts have been made to restore ecological functions as well. In fact, plans for rehabilitating a quarry site must be submitted to the responsible Ministry/Department along with the original application for mining, following the minimum reclamation requirements that are clearly set out in the Guideline (e.g., BC Reclamation Handbook, 1995).

3.3 Challenges of Mine Waste Management in Nepal

Limestone deposits and quarry sites in Nepal are often located in remote and physically inaccessible places. In many locations in the hilly areas, site topography, drainage and land use
pattern remain as some of the biggest challenges to secure mine waste and for in-situ waste containment. The temporary storage of waste within berms or yards cannot prevent erosion of loose, unconsolidated material and its transport by the local water channels during heavy monsoon rainfall. Such transport and erosion processes degrade landform along their flow path and may cause channel blockage due to sedimentation during flooding and debris flow events. In particular, quarries located in the Mahabharat Range, which gets extensive rainfall mainly during the monsoon season and with steep slopes, are prone to soil slips, debris flows and shallow landslides (Dahal, 2012). Even if permanent structures, such as masonry walls, are built at the foot of the quarry site, they are still liable to slope failures in such situations.

The best approach would be to utilize the unused quarry products (mine waste) from the limestone mine as construction material and aggregates. The stripped material/topsoil could be used for rehabilitation and plantation during the reclamation stage. However, if the waste cannot be timely utilized and securely stored on-site, then it could pose problems. Haulage of waste from one mine site into another safe discharge point (dumping yard) is also a commonly practiced method of secure waste storage. It, however, involves a succession of events, such as finding an appropriate site nearby the quarry site for secure storage and feasible transportation route, and is a costlier approach for small-scale mining companies. Transportation cost for mine waste is an additional cost for mine owners to go beyond the mining for remediating or rehabilitation purposes. Moreover, non-metallic mines are often resources with a high bulk but low unit value, and the overall mining cost is high. Thus, the financial condition becomes another major challenge, particularly for small-scale mining companies in Nepal. Considering these challenges and yet a need to effectively manage mine waste, a collective effort of the mine owners, stakeholders, local communities, and local governments is essential to make the rehabilitation plan sustainable, technically feasible, socially acceptable, and successful to the desired endpoints. To put this into action, it is critical to include such waste management plans, and if possible, restoration measures in the Mines and Minerals Act of Nepal. This would enhance the directives from the DMG to all mining license holders for optimum use of resources and zero waste mining.

It is strongly recommended that regular inspection and monitoring of mines and correct reporting should be factored into the entire restoration plan. Policymakers can discuss with aggregate and cement industries in delivering a positive ecological legacy to local citizens after the quarry operation is completed (Ministry of Natural Resources, Quebec, 1997). There is no universal method that fits everywhere to manage waste and it primarily depends on local geology, topography, drainage, climatic condition, vegetation, land use pattern, human settlements, etc. Therefore, each site must have a site-specific program that can provide adequate considerations of risk for sound environmental management. Efforts should be geared towards the sustainable use of resources with minimal environmental and social impacts.

While the mine waste management is entirely the responsibility of the mine owner and must be done in accordance with the applicable regulations, restoration should be a cooperative effort between the local government, stakeholders, and local citizens to prepare the site that is visually, ecologically, and structurally acceptable and blending with the surrounding landscape. Preparation of an operation guide/manual that gathers and uses the local community concerns prior to mining would be great practice as it can avoid confrontations and post-mining issues raised by the community. There is no universal ‘best management practice’ appropriate for all sites, so each site should conduct a site-specific program that provides adequate considerations of risk for sound environmental management.
4. Conclusions and Recommendations

With a large and potential prospect of the cement industry in Nepal, limestone mining is in an increasing trend. This raises a potential environmental threat from the waste generated from mining and related activities. The current situation shows that the best available mine waste management strategies have not been applied adequately in the majority of the mine sites in the country, thereby creating risk in those sites and making the local people vulnerable to man-induced hazards. Even large cement industries such as Hongshi, Shivam, Hetauda, Maruti, and Udaypur, have not applied proper environmental protection methods in their quarries/mines. This indicates an immediate need for further investigations into the current practices of mining, mine waste management, as well as an urgent need for formulating appropriate mine waste management-related policies to be prepared and strictly regulated by the DMG. However, very little has been done in legislating proper waste management and site restoration in Nepal.

The comparative importance of mining and contribution to the nation’s GDP shows that Nepal’s economic growth is dependent on the mining of potential mineral resources in the country. With a prospect of rapid mining (including base metals, iron, rare elements, battery metals, precious metals, oil and gas, coal, gemstones, decorative stones, limestone, dolomite, magnesite, talc, phosphorite, gypsum, construction aggregates, etc.), it is recommended that more stringent mining practices be adopted that guide future mining projects to meet societal and developmental needs and be less damaging to the environment.

References


