ABSTRACT

Meghalaya, a small state in north eastern region of India is abundantly blessed with coal and limestone. About 9% of the country's total limestone reserves are distributed in the state. Mining is carried out by open cast method of mining which is taking place at both large scale and small scale levels. The limestone mined is used chiefly for the manufacturing of cement, lime and edible lime etc. Scientific studies revealed that loss of forest cover, pollution of water, soil and air, depletion of natural flora and fauna, reduction in biodiversity, erosion of soil, instability of soil and rock masses, changes in landscape and degradation of agriculture land are some of the conspicuous environmental implications of limestone mining. In this paper we have reviewed the status of limestone mining and its environmental implications in Meghalaya, India. Results on impact of limestone mining on quality of water, soil and air, degradation of forest and availability of water are summarized and discussed. Based on overall impact of limestone mining in the area it is suggested that all stakeholders particularly the owners of mines and cement plants should give necessary attention to environmental issues prevailing in the area. Initiatives for proper management of natural resources such as water, soil and forest should be taken to halt further loss of forest cover and top soil and to prevent deterioration of water quality, soil degradation, air and noise pollution.

Keywords: Limestone mining, Cement Plants, Environment Issues and Problems, Meghalaya.

INTRODUCTION

India is a diverse country endowed with potentially rich mineral resources. According to the Indian Mineral Yearbook Report (2013), India produces around 90 minerals. Of these, 4 are fuel minerals, 11 metallic minerals, 52 non-metallic and 23 minor minerals (building and other materials). This indicates that the mining industry in India is a very important industry essential for the economic development of the country. Limestone is a non-metallic mineral and is a raw ingredient required for the manufacturing of cement, an important construction material. The total estimated resources of limestone of all categories and grades in India are 184,935 million tonnes. Of this, 14,926 million tonnes (8%) are under reserves category and 170,009 million tonnes (92%) are under remaining resources category. The state of Karnataka alone accounts for about 28% of the total limestone resources in India followed by Andhra Pradesh (20%), Rajasthan (12%), Gujarat (11%), Meghalaya (9%), Chhattisgarh (5%) and remaining 15% by other states.

However in terms of production, the state with maximum production is Andhra Pradesh accounting about 21% of the total cement production, followed by Rajasthan (20%), Madhya Pradesh (13%), Tamil Nadu (9%), Gujarat, Karnataka and Chhattisgarh (8% each), Himachal Pradesh and Maharashtra (4% each) and the remaining 5% is contributed by Odisha.
Meghalaya, Uttar Pradesh, Jharkhand, Kerala, Bihar, Assam and Jammu & Kashmir (Indian Mineral Yearbook Report, 2014). In India, cement industry alone consumed about 76% of the limestone produced, whereas 16% is used by iron and steel industry, 4% by chemical industries and remaining 4% is used in sugar, paper, fertiliser and ferromanganese industries. India is the second largest cement producing country in the world after China. There were 178 large cement plants having an installed capacity of 318.94 million tonnes in 2012-13 in addition to mini and white cement plants having estimated capacity of around 6 million tonnes per annum (Indian Minerals Yearbook, 2014).

Meghalaya, one of the eight states of North-Eastern Region (NER) of India lies between 25002'E - 26007'N latitude and 89049'E and 92050' E longitude. The geographical area of the state is 22,429 sq. Km with a total population of 29, 64,007 (Census, 2011). It comprises of three hill regions namely Khasi Hills, Jaintia Hills and Garo Hills. Currently the state is divided into 11 districts i.e. Garo Hills (5 districts), Khasi Hills (4 districts) and Jaintia Hills (2 districts). Undulating topography dissected by numerous rivers and streams are the characteristic features of the state. The state is blessed with rich and diverse natural resources, both renewable and non-renewable. Major renewable resources include water, forest, a variety of flora and fauna etc. Important non-renewable resources present in Meghalaya are coal, limestone, granite, uranium, kaolin, clay, glass sand etc. Of these, mining of coal and limestone has been taking place at large scale. Mining and exploitation of minerals have provided opportunity for a variety of employment and livelihood options to the local people. Besides, it has also contributed towards industrial and economic development of the state. On the other hand, exploitation of rocks and minerals including limestone has affected the local environment at its various stages of mining, processing and utilisation. In this article an attempt has been made to review the available information on limestone mining and its environmental implications in Meghalaya.

**Geology of Limestone in Meghalaya**

Geologically, the state of Meghalaya comprises of five different rock units namely: Pre-Cambrian gneissic complex with acid and basic intrusive, Shillong Group of rocks, Lower Gondwana rocks, Sylhet Traps and Cretaceous– Tertiary sedimentary rocks.

Limestone is distributed predominantly in the southern fringe of Meghalaya plateau and falls under the rocks formation units of Cretaceous–Tertiary sedimentary rock, which is divided into three groups i.e. the Khasi group, the Jaintia Group and the Garo group. The Jaintia Group is further subdivided into three formations which include the Longpar (lower), the Shella (middle) and the Kopili (upper) formations. The Shella formation is further subdivided into six members: the upper Sylhet Limestone (Prang limestone), upper Sylhet sandstone (Narpur Sandstone), middle Sylhet Limestone (Umlatdoh limestone), middle Sylhet sandstone (Lakadong sandstone), lower Sylhet Limestone (Lakadong limestone) and lower Sylhet sandstone. The limestone deposited in Jaintia Hills possesses all the above three members of Sylhet limestone with alternating bands of limestone and sandstone. However, the limestone deposit in Cherrapunjee belongs to the lower Sylhet member (Lakadong limestone) of Shella formation consisting of limestone layers in the upper part of the hill and dolomite in the lower portion. Thus, the limestone rocks found in Meghalaya belong to the Shella formations of the Jaintia Group of Cretaceous–Tertiary sedimentary rocks of Eocene geological age (Sarma, 2003; DMR Profile, 2016).

**Limestone Reserves in Meghalaya**

Next to coal, limestone is the most abundantly found and extracted mineral in Meghalaya. Various grades and extent of limestone rocks are found in the southern fringe of the state extending for about 200 Km from Jaintia Hills in the east to Garo Hills in the west. According to Tripathi et al. (1996), the maximum limestone reserve in Meghalaya is reported in Jaintia Hills (55%), followed by Khasi Hills (38%) and Garo Hills (7%). Quality of limestone deposited in Meghalaya varies from cement to chemical grade in nature. In the Indian Mineral Yearbook (2012), it is reported that Meghalaya possesses about 9% of the country's total limestone reserve. However, as per the
present status of cement grade limestone reserve report (2014), India possesses about 123,829.64 million tonnes of cement grade limestone. Out of which, about 14959 million tonnes (i.e. 12% of the country reserve) of limestone is present in Meghalaya. The geographical distribution of limestone in Meghalaya is depicted in Figure 1. It is mainly distributed in the districts of East Jaintia Hills, West Jaintia Hills, East Khasi Hills, West Khasi Hills and South Garo Hills.

Fig. 1. Map showing distribution of limestone deposits in Meghalaya

Chemical Composition of Limestone

Limestone rocks are sedimentary in origin and classified as non-metallic mineral with inorganic origin in nature. The two most important constituents of limestone are calcite (calcium carbonate, CaCO3) and dolomite. Limestone often contain small amount of impurities such as magnesium, iron, manganese and lead. Dolomite is a carbonate of calcium and magnesium [CaMg(CO3)2]. Limestone is used in a wide range of industries. It has been utilised by man for thousands of years. However, it is a primary ingredient and raw material for cement manufacturing industries. Besides, it has many uses ranging from building material to white paints and fillers. It is also used as a chemical feedstock for the production of lime having numerous uses.

The limestone found in different parts of Meghalaya varies in chemical composition to some extent and thus differs in quality ranging from cement to chemical grade in nature. Generally, the CaO content of limestone found in Meghalaya is 53% (Kharkongor and Dutta, 2014). The chemical composition of various types of limestone found in Meghalaya is presented in Table 1.

Table 1. Chemical composition of limestone rocks at different locations in Meghalaya

<table>
<thead>
<tr>
<th>Major chemical compounds in %</th>
<th>Jaintia Hills</th>
<th>East Khasi Hills</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lakadong</td>
<td>Lumshnong</td>
</tr>
<tr>
<td>CaO</td>
<td>42.27-53.89</td>
<td>40.69-54.67</td>
</tr>
<tr>
<td>MgO</td>
<td>1.25-5.58</td>
<td>0.20-11.55</td>
</tr>
<tr>
<td>SiO2</td>
<td>0.14-3.12</td>
<td>0.04-17.20</td>
</tr>
<tr>
<td>Fe2O3</td>
<td>0.26-1.59</td>
<td>0.04---3.87</td>
</tr>
<tr>
<td>Al2O3</td>
<td>0.22-2.61</td>
<td>0.05-5.71</td>
</tr>
<tr>
<td>R2O3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Al</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Cherrapunjee</td>
<td>Komorrah</td>
</tr>
<tr>
<td>CaO</td>
<td>44.33-53.53</td>
<td>51.97-54.95</td>
</tr>
<tr>
<td>MgO</td>
<td>0.33-4.21</td>
<td>0.76-2.98</td>
</tr>
<tr>
<td>SiO2</td>
<td>-</td>
<td>0.46-1.90</td>
</tr>
<tr>
<td>Fe2O3</td>
<td>-</td>
<td>0.28-1.11</td>
</tr>
<tr>
<td>Al2O3</td>
<td>-</td>
<td>0.16-0.56</td>
</tr>
<tr>
<td>R2O3</td>
<td>0.31-2.17</td>
<td>-</td>
</tr>
<tr>
<td>Al</td>
<td>1.43-12.39</td>
<td>-</td>
</tr>
</tbody>
</table>
History of Limestone Mining and Cement Plants establishment in Meghalaya

The history of limestone mining in Khasi Hills of Meghalaya seems very old. As per the Assam District Gazetteers published in 1906, limestone quarrying and trading in Khasi Hills have existed as early as in eighteenth century and it was a lucrative business to the people of Sylhet in Bangladesh and Khasi Hills of Meghalaya. From the earliest days of British rule, it is described that the lime quarries were situated all along the southern face of the Khasi Hills. Limestone was mostly used to make lime by burning it all along the banks of the Surma River. It was also reported that lime transportation from Khasi Hills to Sylhet was done during the rainy seasons by using the natural mode of transportation (i.e. through river) using a flat bottom canoe. This attracted a large number of Europeans who largely controlled the limestone mining, production and trading of lime in this part of India (Allen, 1906). Thus, limestone mining in Meghalaya is taking place for long time, however earlier it was small scale and for local uses only mainly for the production of edible lime.

Later, limestone was used for the production of cement after establishment of cement manufacturing industries in Meghalaya. The Mawmluh-Cherra Cements Limited (MCCL) was the first cement manufacturing unit in the state. It was originally established by some unknown industrialists in Cherrapunjee in 1955 under the banner name of Assam Cements Limited. The company was later acquired by the Government of Assam in 1964 and thereafter by the Government of Meghalaya in 1974 (Dolloi, 1992). This indicates that large scale mining of limestone in Cherrapunjee for the production of Cement started quite early. Later, the Lafarge Umiam Mining Pvt. Ltd., (LUMPL) began extensive limestone mining in Shella-Nongtrai area of East Khasi Hills of Meghalaya for its utilisation in Chhatak, Bangladesh by Lafarge Surma Cement Ltd., (LSC). The limestone mined form Meghalaya is transported to Bangladesh via a 17 Km long cross border Conveyer belt. This activity has been performed in the area since 2005. The LSC start producing and selling cement from 2006. However, mining of limestone was halt in 2007 by the Supreme Court of India in this area due to the pending environmental clearance from the court. However, later in 2011 mining in the area was resumed.

The origin of limestone mining in Jaintia Hills of Meghalaya is not very well documented. The Jaintia Cement Limited was the first private cement manufacturing plant established in Sutnga Village in 1986. Extensive mining of limestone in Jaintia Hills, Meghalaya started after 2004 after establishment of Cement Manufacturing Company Limited (Star Cement) in Lumshnong and then followed by other privately owned cement manufacturing units in the area. However, utilisation of limestone in Garo Hills for cement production started in 1991. Presently, more than a dozen of cement manufacturing plants are in operation in the state.

**METHOD OF MINING**

Limestone extraction in Meghalaya is carried out by open cast method of mining. It is taking place at both large scale and small scale levels. The large scale extraction of limestone is taking place in Jaintia Hills mainly for the manufacturing of cement. While both large scale and small scale mining are in practice in

<table>
<thead>
<tr>
<th>West Khasi Hills</th>
<th>West Garo Hills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Borsora</strong></td>
<td><strong>Darrang-Era-Aning</strong></td>
</tr>
<tr>
<td>CaO</td>
<td>41.86-53.32</td>
</tr>
<tr>
<td>MgO</td>
<td>0.48-6.10</td>
</tr>
<tr>
<td>SiO₂</td>
<td>0.36-4.52</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.64-5.78</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>1.14-6.55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>West Khasi Hills</th>
<th>West Garo Hills</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₃</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Na₂O</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>K₂O</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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In Sohra (Cherrapunjee), limestone is being extracted both at large and small scale levels. The small scale extraction of limestone is done manually by individuals using minimal machinery and thus categorised as Artisanal and Small Scale mining (ASM). The extraction of limestone from the hillocks in Sohra (EKH) is carried out by several land owners sharing the entire Mawmluh hills. The limestone beds are drilled for blast holes using drilling machines, after which the rocks undergo blasting. The limestone rocks undergo manual sizing, so as to obtain a rock pieces of suitable size for easy transportation and processing in small vertical kilns. Mining is carried out by the people who are directly involved in the production of quicklime and edible lime. The processed lime is exported to the paper industry in the neighbouring states. The processed lime is also used for whitewashing of houses and walls. Other by-products (pulverised form of lime) obtained in the process of production of lime at ASM levels are used as soil conditioner in agricultural fields. Mining of limestone in Meghalaya is also done for other minor uses such as construction of temporary roadbed to the quarrying sites, cement plants and adjacent locality; house construction etc. Large scale mining is also done in Sohra, (EKH) by adopting mechanical methods for production of cement but by MCCL.

Cement Plants in Meghalaya

In last decade a number of cement plants were established in Meghalaya with maximum numbers found in Jaintia Hills alone. Presently, the cement plants are the main consumers of limestone rocks found in the state. The cement manufactured in Meghalaya is utilized in the state as well as transported to other states of the country. A list of cement plants operating in Meghalaya is given in Table 2.

Limestone Mining Leases in Meghalaya

In recent years, Government of Meghalaya has also granted limestone mining leases to several companies for mining of limestone, its utilisation and ultimately
for manufacturing of cement. A list of mining leases granted to different companies operating in Meghalaya is given in Table 3. In addition to leases granted by the government, mining of limestone is rampant because of the unique land ownership in the state. Hence, mining in Meghalaya is predominantly in private hands. The extraction/mining of the rocks and minerals is carried out by the individual land owners in whatever way they deem fit and profitable. In most cases, the method of mining carried out was found unscientific, disruptive and degrading to the environment. Lack of reclamation responsibility and stringent regulated mining procedure further magnify the consequences of mining in Meghalaya.

Environmental Impact of Limestone Mining

Exploitation of rocks and minerals affect environment at its various stages of mining, processing and utilisation irrespective of its scale of mining. Denudation of forest, water depletion, pollution of water, soil and air, depletion of natural flora and fauna, reduction in biodiversity, erosion of soil, instability of soil and rock masses, changes in landscape and degradation of agriculture land are some of the conspicuous environmental implications of mining. The severity of environmental problems depends on the extent of mining and ecological sensitivity of the mining site. Both terrestrial and aquatic ecosystems are affected and the effects could extend beyond the boundaries of the mining area and be for a long term. Narrey et al. (2012) also reported that limestone quarrying in the Manya Krobo District of Ghana do have some negative effects on the environment. Impacts includes lowering of water tables, habitat destruction, encroachment of waste into agricultural land, destruction of buildings due to cracks, pollution of rivers, loss of biodiversity, destruction of crops, unclean rain water harvested from roofs and health related problems include inhalation of dust resulting in respiratory tract infections.
Scientific studies on impact of coal and limestone mining on different aspects of the environment have been done in both Khasi and Jaintia Hills regions of Meghalaya. Water quality deterioration (Swer and Singh, 2003); reduction in aquatic biodiversity (Swer and Singh, 2004; Mylliemngap and Ramanujam, 2011); diminishing plant diversity due to change in land use land cover (LULC) (Sarma and Kushwaha 2005; Sarma et al, 2010); forest cover changes (Lele and Joshi, 2009; Somendro and Singh, 2015) and degradation in agriculture field and its productivity (Gupta et al, 2002) due to coal mining have been extensively studied in Meghalaya. Recently, Chabukdhara and Singh (2016) reviewed the environmental issues of coal mining in northeast India. Similarly, impact of limestone mining and its processing for cement manufacturing has been investigated with reference to general environment and LULC change (Chakraborty and Sudhakar, 2014; Somendro and Singh, 2015) and water and soil quality (Lamare and Singh, 2014, 2015 and 2016a, b).

The vital ecological issues related to mining of limestone rocks are discussed below and various environmental problems observed as the results of limestone mining in Meghalaya are shown in Figure 3.

**Changes in Land Use and Land Cover (LULC)**

Geographic information system (GIS) combined with remote sensing (RS) has been widely used as a powerful and cost-effective tool for detecting and analyzing the spatio-temporal changes in LULC. In Meghalaya, Chakraborty and Sudhakar (2014) analyzed LULC changes in Jaintia Hills to focus the impact of limestone mining and cement manufacturing activities leading to the loss of forest cover during 2005 and 2011.

They observed striking changes in LULC which were implicated with limestone mining and expansion of the cement manufacturing units. The conversion of

### Table 3. Limestone mining leases granted by Government of Meghalaya

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>District</th>
<th>Name of Lessee</th>
<th>Location</th>
<th>Lease Period (Years)</th>
<th>Area in Hectare</th>
<th>Year Granted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>East Khasi Hills</td>
<td>Mawmluh Cherra Cement Ltd.</td>
<td>Mawmluh</td>
<td>20</td>
<td>139.67</td>
<td>2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Komorrah Limestone Mining Co.</td>
<td>Komorrah</td>
<td>20</td>
<td>240.55</td>
<td>2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lafarge Umiam Mining Pvt. Ltd</td>
<td>Nongtrai</td>
<td>30</td>
<td>100</td>
<td>2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M/S K. Singh Wann &amp; Son</td>
<td>Ichamati Mawkilain</td>
<td>20</td>
<td>4.56</td>
<td>2006</td>
</tr>
<tr>
<td>2</td>
<td>Jaintia Hills</td>
<td>M/S Adhunik Cement Ltd.</td>
<td>Mootang</td>
<td>20</td>
<td>4.9</td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thangskai Block -1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Block -2</td>
<td>20</td>
<td>4.9</td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Block -4</td>
<td>20</td>
<td>4.9</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M/S JUD Cement LTD</td>
<td>Wahiajer Narpuh</td>
<td>30</td>
<td>4.76</td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cement Manufacturing Co. Ltd</td>
<td>Lumshnong</td>
<td>20</td>
<td>4.96</td>
<td>2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td>4.7</td>
<td>2006</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td>4.85</td>
<td>2006</td>
</tr>
<tr>
<td>3</td>
<td>West Khasi Hills</td>
<td>Anderson Mineral Pvt. Ltd</td>
<td>Lalghat Cherragoan</td>
<td>20</td>
<td>60</td>
<td>2007</td>
</tr>
</tbody>
</table>

due to its location near the cement plants; (i, j) - Blue

Fig. 3. Photographs showing (a) – Loss of forest cover; (b) – Creation of waste land by siltation; (c) - Encroachment of overburden into the forest area; (d) – ASM waste disposal forming a hill of lime waste dumping area; (e) – removal of top soil and landscape deterioration; (f) – encroachment of ASM waste into the nearby local streams; (g) - intrusion of mine waste such as rocks, pebbles and sand into the nearby streams; and (h) - local streams showing high turbidity due to its location near the cement plants; (i, j) - Blue colour of water of Lukha River during winter months.

forest area into non-forest area was observed. The total loss of forest in the area was found to be around 1265.36 ha from 2005 to 2011 within a radius of 5 km. They suggested for immediate necessary steps to control conversion of forest land into non-forest land. It is also known that forest depletion and land degradation have inevitable associations with extensive loss of habitat and biodiversity. Forest depletion is also intimately linked with loss of top layer of fertile soil and productivity. Recently, LULC was analyzed by Somendro and Singh (2015) in Jaintia Hills, Meghalaya during 1987 to 1999 and 1999 to 2013.

The study reported loss of forest cover and change in forest categories caused by various human activities such as mining of coal and limestone, industrial expansion, infrastructural development and built up area etc.

Further, a study covering north eastern region (NER) using satellite data was carried out during 1972 to1999 by Lele and Joshi (2009) to analyse the change in forest cover. They reported highest changes in forest cover in Meghalaya, Nagaland and Tripura. Reduction of forest cover in Meghalaya was attributed to extensive mining and shifting cultivation. Sarma and Kushwaha (2005) investigated the impact of mining on land use/land cover in Jaintia Hills during 1975–2007 and revealed extensive loss of vegetation and forest cover due to mining.

Similar studies have also been done in other parts of the country. Rajwar (1982) reported that unscientific and uncontrolled method of limestone mining in Mussoorie mountains have caused various adverse environmental impacts on the surrounding area leaving the region appeared scarred with irregular patches, loss of vegetation cover, emergence and growth of xerophytes, instability of the mountains and aesthetic degradation of the area. Likewise, limestone mining in Dehradun district was also reported to have consequences on forest cover. Depletion in plant diversity due to the stripping off, random digging and quarrying in the hills has also been reported (Sikka et al., 1984).

Degradation of Soil

Mining of rocks and mineral has an irreversible impact on soil both in terms of its quantity and quality. Excavation of land leads to loss of top fertile soil and alters the quality of soil in surrounding areas in terms of its physical, chemical and microbiological properties (Ghose, 2004). Removal of top soils is the basic operations involved in mining processes resulting into elimination of seed bank and root stocks (Parrotta et al., 1997), depletion of
of limestone mining on soil quality. Lamare and Singh (2015) reported land degradation and alteration of landscape topography by dumping of overburden/spoils and lime waste material due to artisanal and small scale limestone mining in Meghalaya. Further, excavation of limestone resulted in removal of fertile top soil and generation of spoil and overburden deteriorated the aesthetic beauty of the proximate landscape.

Sharma et al. (2013) emphasised that continuous mining of limestone in Solan District of Himachal Pradesh has induced dilapidation of the land environment of the area and deterioration of soil quality. This is chiefly due to the negative effects of mining activities such as deforestation, mining, and dumping of mining waste etc. Intensive quarrying of limestone in Mussoorie Mountains was reported to have led to loss of top soil and consequently acceleration of soil erosion in the area resulting into siltation of nearby rivers and streams and agricultural fields (Rajwar, 1982). Similarly, the soil regime of Madukkarai Limestone mine was also reported to be affected either directly or indirectly indicating low nutrient content compared to the soil in agricultural areas (Ravichandran et al., 2009). Hanief et al. 2007 reported alteration in soil texture due to limestone mining in Sirmour district of Himachal Pradesh. They found high percentage of sand and drastically low percentage of silt and clay in the mining affected soil. Sulphate content in the soil near limestone mines and cement plants in Rajasthan was reported to be high (GSI, 2009).

Etim and Adie (2012) reported that mining of limestone supported leaching of metals from the top soil into the surrounding area. Soil samples were found to range from uncontaminated to moderately contaminated categories in terms of heavy metal contamination coupled with low organic matter content. In contrast to these findings, Afeni et al. (2012) reported no significant adverse impact was observed on quality of soil in Nigeria, due to limestone exploitation.

Changes in Water Quality

Mining is known to affect water resources severely both in terms of its quantity and quality. Changes in water levels and flow, availability of potable and irrigation water, changes in sediment flow and deposition, degradation of water quality, reduction and degradation of habitat of aquatic flora and fauna and decrease in abundance and diversity of aquatic species are some of the adverse impacts of mining. Miller (1999) pointed out that water resources, undoubtedly are being polluted, diverted and disturbed from their natural conditions as a result of mining activity. As any other mining, the mining of limestone rocks is also reported to cause alteration in the quality of surface water and shallow groundwater (Naja et al. 2010). Iwanoff (2006) found high content of calcium, bicarbonates, sodium and chloride salts in the water of streams and rivers receiving a significant volume of mine water generated from open cast limestone mining areas in Northern Germany.

Deterioration of water quality due to limestone mining is also reported from India. Ravichandran et al. (2009) reported deterioration of water quality in Madukkarai limestone mine which was found responsible for exceeding the standard limit for water quality parameters like total dissolved solids, total hardness and chloride. However, no significant adverse impact of limestone mining on water quality was found in lower Himalayas (Prasad and Bose, 2001), Biramitrapur, Orissa (Mishra et al. 2004) and Vijayraghovgarh village, Madhya Pradesh (Ahmed et al., 2007) and Chandrapur, Maharstra (Soni, 2007).

Assessment of water quality in limestone mining areas of Meghalaya was carried out in East Jaintia Hills (Lamare and Singh, 2014, 2016a, b) and East Khasi Hills (Lamare and Singh, 2015). In East Jaintia Hills, water samples of streams near limestone mining and cement plants were analysed. It was found that both limestone mining and cement plants have negative impact on the physicochemical characteristic of water of the area. Study found
elevated levels of pH, conductivity, dissolve solids, hardness, calcium and sulphate in affected streams. It was also reported that Cement plants have contributed more towards water quality degradation than the limestone mining in East Jaintia Hills, Meghalaya.

Further, seasonal variation in water quality of Lukha River (Wah Lukha), a major river in East Jaintia Hills, Meghalaya was reported (Lamare and Singh, 2016b). For last 7-8 years water of the river turns deep blue in appearance during winter months. Activities such as mining of limestone and coal, manufacturing of cement, deforestation etc. occurring in the catchment were found responsible for seasonal changes in water quality of Lukha River. Acid mine drainage (AMD) from coal mining areas and powdery sediment, most likely originating from cement plants were suspected causing precipitation of aluminum and such other compounds which give deep blue appearance to water colour due to scattering of light. Physicochemical analysis revealed that river water possesses low pH and high electrical conductivity, turbidity, total solids and high concentration of calcium and sulfate.

Impact of Artisanal and Small Scale Mining (ASM) of limestone rocks in Sohra, Khasi Hills, Meghalaya was found to be localized near the limestone mining area (Lamare and Singh, 2015). High pH, EC and sulfate values were found remarkably above the standard range of water quality and recognized as the factors responsible for deterioration of water quality. Based on water quality index analysis, water at some locations was found not fit for drinking and other domestic uses throughout the year. CGWB (2012) also reported that coal mining; limestone quarrying and cement factories are the main anthropogenic activities causing problems to the environment of Meghalaya and in particular, chiefly the water bodies.

**Impact on Air Quality**

The main issue with mining in relation to air quality is generation of dust particles (Ghose and Majee, 2000). In mining or quarrying, different activities taking place are known to have an impact on air quality. Long term exposures to various air pollutants have significant health related problems (Sunyer, 2001).

Relatively, less work has been done on air pollution in relation to limestone mining. Rajwar (1983) found that the limestone quarrying elevates dust concentration and consequently affects physiology of plants. In addition, health related problems were reported by Mishra *et al.* (2004) as a result of limestone mining.

Activities involved during limestone extraction like drilling, blasting, loading and transportation generate dust into the surrounding area causing air pollution mainly suspended particulate matter (SPM). The gaseous pollutant released into the air are attributed by the motorized machine involved during the entire processes i.e. bulldozer, drilling machines, dumper and transportation vehicles. No data is available to on air quality of the limestone mining areas of Meghalaya. But, wide spread limestone mining and presence of large number of cement plants in Meghalaya are likely to have significant impact on air quality of the area.

**Noise and Vibrations Problems**

Extraction of limestone involves activities like drilling of blast holes, blasting of rock beds using explosives and transportation. These activities generate hefty and annoying noise pollution to the inhabitants and likely to have an adverse health impacts. In addition, multiple undesirable effects such as geological displacement and destabilisation of the area, drying up of spring water, decrease of water table, weakening of the rocks formation leading to slopes failures and increase probability of landslides. No information is available on noise pollution in limestone mining areas of Meghalaya.

**Water Scarcity**

Region with Karst topography are reported to have problems of water scarcity due to absence or lack of surface streams and availability of groundwater at a greater depth (Legard, 1973). In Meghalaya, only a few surface water bodies are present in limestone deposit areas. Some water bodies are found above ground for certain distances and then they disappear due to flowing underground and then again emerge at some point somewhere else. Such phenomena lead to
water scarcity in the area. Mining of limestone and establishment of cement plants in the region have further aggravated the water scarcity in the area. The small natural streams near the mining vicinity are seen to have been deviated or covered with rocks, gravels, pebbles and sand. Excessive silting in all water bodies was also found in the area. Water bodies near the cement plants were found contaminated and water is not fit for human consumption (Lamare and Singh, 2014, 2016a).

Based on the field observation and feedback received from the local inhabitants, it was found that area is facing the problem of water scarcity particularly in winter months. The main causes are drying up of water sources and their contamination. However, in some villages due to limited access to portable drinking water, people have no choice but to use the polluted water for drinking and other domestic purposes. Many perennial streams and rivulets, in recent years have turned seasonal.

Other concomitant Problems

In East Jaintia Hills, Meghalaya various other concomitant problems were viewed due to the limestone mining and cement plants operating in the area. This area was formerly known for orange cultivation and production. However, due to land use land cover changes taking place in the area many orchards of oranges were found destroyed. Further, it was found that due to unknown reasons the orange trees in this area no longer bear healthy flowers and fruits and thus many farmers have stopped orange cultivation.

People residing in the hilly areas have the practice of harvesting rain water for drinking purposes. However, after the establishment of cement plants in the area, this practice has declined drastically due to the daily deposition of dust on the roof top causing the contamination of collected water. Decline of traditional agricultural practices to certain extent due to the quick revenue obtained from mining of limestone is another serious problem in the area. The locality situated adjacent to the cement plants experience deposition of thick dust throughout the year especially during dry season. Thus, the vegetation cover found here is no longer lush green and shows reduced plants growth. Cement dust falling on the soil are known to have effects such as change in the soil pH making it more alkaline and unfavourable for certain plants species and also causing leaf injury or death in plants due to blocking of light for photosynthesis (Darley, 1966; Lerman and Darley, 1975). Local inhabitants are also of the opinion that caves in this area possess very less number of fishes in recent years leading to drastic decline of cave fishing by the local people.

CONCLUSION

Based on above information it can be concluded that limestone mining in Meghalaya has impacted various components of environment and the life and livelihood of the local population. It is therefore attention of all concerned stakeholders; particularly the owners of mines and cement plants are drawn for proper management and conservation of the environment in order to halt further loss of forest cover and top soil and to prevent deterioration of water quality, soil degradation, air and noise pollution for the healthy environment and sustainable development of the region.

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