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# Changes in Soil Quality in Limestone Mining Area of Meghalaya, India

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## ABSTRACT

Limestone mining in East Jaintia Hills, Meghalaya, India is being carried out extensively for the production of cement. Extraction of limestone is done mainly by adopting opencast method of mining. Mining activities have deteriorated the environment of the area in terms of deforestation, biodiversity loss, water quality and availability, noise pollution, landscape disturbance, soil erosion, generation of spoils and degradation of land. In this paper, we report the results of study conducted on the soil quality in relation to limestone mining. Comparison of soil quality in mining area with that of unmined area shows that soil quality has degraded with respect to most of the parameters analysed during the present study. Remarkable decrease in moisture content, water holding capacity, organic carbon and total nitrogen has been found. Electrical conductivity and bulk density of soil increased in the mining area. On the other hand, there was an improvement in pH from acidic to slightly alkaline soil. However, changes in the values of phosphorus and potassium were not so prominent. The overall changes in soil quality can be attributed due to limestone mining in the area.

## INTRODUCTION

The State of Meghalaya is rich in mineral resources. Limestone is one of the main resources found in the state. It constitutes about 9% of the total limestone reserves of India (IBM 2012). Extensive mining of limestone in East Jaintia Hills, Meghalaya had started a decade ago. Mostly open cast method of mining is used for extraction of limestone at large scale by cement companies and small scale by individuals. Mining activities involved are removal of vegetation, drilling and blasting, excavation, breaking of large size rocks into smaller pieces and finally its transportation to cement plants. Limestone mining and manufacturing of cement by both private and government agencies in the state are the sources of revenue and employment. However, mining has also caused adverse effects on the environment and ecological disturbance in the area.

Generally, both small and large scale mining activities have been found intrinsically disruptive to the environment (Makweba & Ndonde 1996). Worldwide, it has been reported that mining of mineral resources has an adverse impact on various components of the natural environment (Singh 1998, Tiwary 2001, Wong 2003, Kuma & Younger 2004, Swer & Singh 2003 and 2004, Kraus & Wiegand 2006, Sheoran et al. 2011).

Studies have revealed that limestone mining in East Jaintia Hills, Meghalaya has caused environmental degradation in terms of loss of vegetation (Chakraborty & Sudhakar 2014, Somendro & Singh 2015) and degradation of water quality (Lamare & Singh 2014, 2015, 2016). Other impacts include depletion of biodiversity, loss of top soil, silting of streams, disturbance of landscape due to dumping of overburden and waste tailing, blockade, diversion and disappearance of streams, unstable geological setup due to frequent blasting, sprawl of waste land, fragmentation of habitat and noise pollution caused by drilling and blasting. Top fertile soil of the area has also been affected. In this paper, we report the effects of limestone mining on soil quality parameters.

## MATERIALS AND METHODS

**Study area:** The study was conducted in East Jaintia Hills, Meghalaya, India, where more than eight cement plants are in operation and extensive limestone extraction is going on to supply raw material requirements to these cement plants. Mining is spread in a large area starting from Nongsning village to Lumshnong village. Mines are owned by both cement companies and individuals of the local area. Soil sampling in present study was done from the mining area operated by local individuals due to easy accessibility. The locations of the five sampling sites (RR, M1, M2, M3 and M4) and their details are displayed in Fig. 1 and Table 1, respectively.

**Soil sampling:** To study different physico-chemical parameters of soil, soil samples were collected from four different limestone mining sites of East Jaintia Hills, Meghalaya. Soil samples were also collected from the nearby unmined area for comparison. Soil samples were collected randomly from

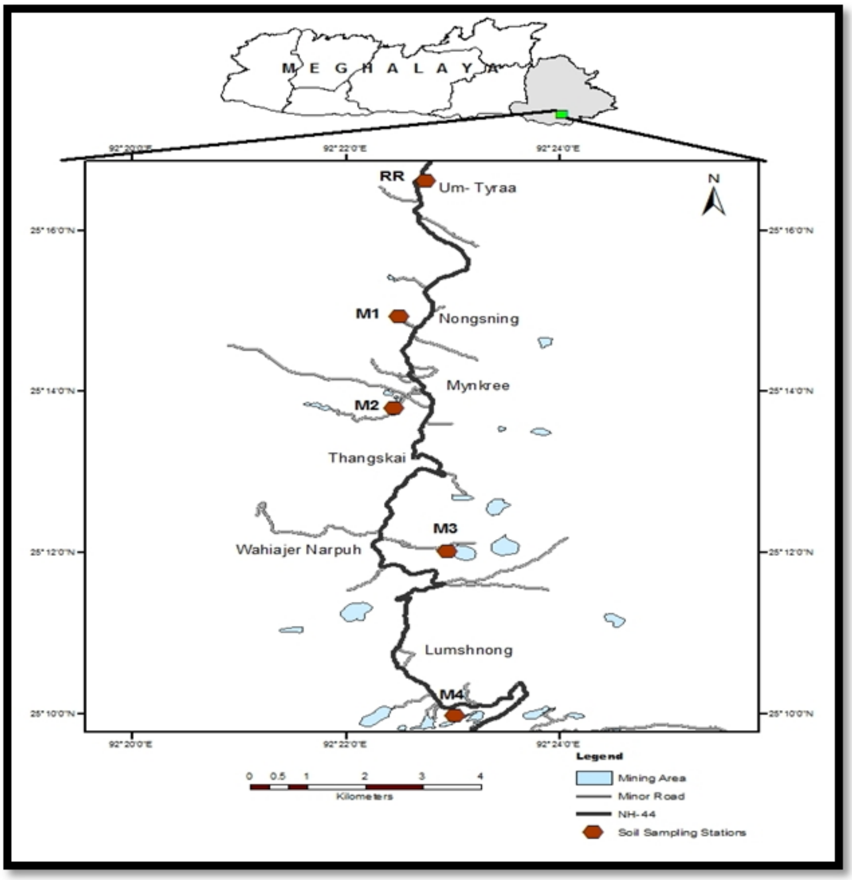


Fig. 1: Map showing sampling sites in East Jaintia Hills, Meghalaya.

a depth of 0-15 cm. Sampling was done in winter, pre monsoon and post monsoon seasons of 2013.

From each location, the bulk samples collected were passed through a 2 mm sieve to remove rocks and pebbles. The soils were then properly mixed by stirring with hands on a clean polythene sheet and ultimately a composite soil sample was prepared following coning and quartering method. Samples were packed in the air tight polythene bags and then transported to the laboratory. The collected samples were air dried, grind and then passed through the 0.2 cm sieve for further analysis of various physical and chemical parameters.

**Analysis:** Soil pH and electrical conductivity were determined in a soil and distilled water suspension (1:2.5) using Deluxe pH-101 meter and Conductivity-601 meter, respectively. Parameters like moisture content, bulk density and water holding capacity were estimated following gravimetric, laboratory and Keen Box-method, respectively (Maiti 2003, Gupta 2005). Walkley and Black rapid titration method was adopted for analysis of organic carbon in soil. Estimation of total nitrogen in soil was done following Kjeldahl method using Pelican Kelplus Model: Classic DX (VA). Molybdenum blue method was adopted for determination of available phosphorus using Systronics UV-VIS Spectrophometer-118 (Allen et al. 1974). 1N ammonium acetate extract solution was used for estimation of available potassium using Microprocessor Flame Photometer (ESICO) Model 1381. SPSS software version 16.0 was employed for assessing the correlation coefficient and analysis of variance (ANOVA) of various soil quality parameters.

## RESULTS AND DISCUSSION

During the present study, altogether nine different physicochemical parameters of soil samples collected from the four sites of the mining area (M1, M2, M3 and M4) and one site from unmined area (RR) in three seasons (winter, premonsoon and post-monsoon) were analysed. The values of moisture content (MC), pH, electrical conductivity (EC), bulk density (BD), water holding capacity (WHC), organic carbon (OC), total nitrogen (TN), phosphorus (P) and potassium (K) are presented in Table 2.

**Soil moisture content (MC):** The soil moisture content (MC)

Table 1: Details of sampling sites.

| Sl. No. | Location | Code | Area | Latitude | Longitude |
|---|---|---|---|---|---|
| 1 | Um-Tyraa | RR | Unmined | 25°16'34.20'N | 92°22'49.18'E |
| 2 | Nongsning | M1 | Limestone mining | 25°15'23.76'N | 92°22'26.36'E |
| 3 | Mynkree | M2 | Limestone mining | 25°13'51.56'N | 92°22'28.50'E |
| 4 | Wahiajer-Narpuh | M3 | Limestone mining | 25°12'0.69'N | 92°22'57.26'E |
| 5 | Lumshnong | M4 | Limestone mining | 25°9'53.67'N | 92°23'12.54'E |

Table 2: The values of various parameters in soil samples collected from limestone mining sites of Meghalaya.

| Loc-ation | Season | MC % | Soil pH | Soil EC (mS/cm) | B.D (g/cm$^3$) | WHC (%) | OC (%) | TKN (%) | P (%) | K (mg/g) |
|---|---|---|---|---|---|---|---|---|---|---|
| RR | WIN | 18.52± | 5.4± | 0.03± | 1.17± | 50.04± | 2.58± | 0.29± | 2.08± | 0.42± |
| | | 1.08 | 0.153 | 0.001 | 0.006 | 0.290 | 0.321 | 0.047 | 0.158 | 0.031 |
| | PRM | 32.50± | 5.5± | 0.03± | 1.06± | 60.30± | 2.59± | 0.37± | 3.55± | 0.61± |
| | | 0.290 | 0.115 | 0.001 | 0.005 | 0.273 | 0.034 | 0.019 | 0.160 | 0.023 |
| | POM | 28.17± | 4.4± | 0.03± | 1.15± | 55.09± | 2.51± | 0.32± | 8.04± | 0.43± |
| | | 0.698 | 0.058 | 0.002 | 0.012 | 0.838 | 0.090 | 0.023 | 1.750 | 0.013 |
| | **Mean** | **26.40** | **5.1** | **0.03** | **1.13** | **55.14** | **2.54** | **0.33** | **4.56** | **0.49** |
| M1 | WIN | 5.53± | 7.4± | 0.45± | 1.37± | 32.00± | 0.21± | 0.04± | 1.93± | 0.65± |
| | | 0.836 | 0.208 | 0.009 | 0.009 | 0.922 | 0.067 | 0.001 | 0.120 | 0.042 |
| | PRM | 9.44± | 7.1± | 0.52± | 1.53± | 29.57± | 0.23± | 0.03± | 3.87± | 0.52± |
| | | 0.340 | 0.200 | 0.011 | 0.042 | 0.995 | 0.090 | 0.002 | 0.129 | 0.009 |
| | POM | 4.88± | 7.4± | 1.04± | 1.58± | 26.99± | 0.29± | 0.03± | 6.35± | 0.42± |
| | | 0.098 | 0.100 | 0.030 | 0.028 | 0.926 | 0.118 | 0.008 | 0.845 | 0.006 |
| | **Mean** | **6.62** | **7.3** | **0.67** | **1.49** | **29.52** | **0.24** | **0.03** | **4.05** | **0.53** |
| M2 | WIN | 4.39± | 7.4± | 0.23± | 1.55± | 32.00± | 0.24± | 0.04± | 2.07± | 0.41± |
| | | 0.027 | 0.173 | 0.003 | 0.014 | 0.527 | 0.000 | 0.007 | 0.080 | 0.014 |
| | PRM | 9.58± | 7.0± | 0.47± | 1.48± | 30.74± | 0.29± | 0.03± | 3.85± | 0.52± |
| | | 0.266 | 0.300 | 0.024 | 0.021 | 0.695 | 0.068 | 0.007 | 0.318 | 0.020 |
| | POM | 3.81± | 7.6± | 0.47± | 1.59± | 27.21± | 0.18± | 0.03± | 6.83± | 0.41± |
| | | 0.075 | 0.058 | 0.006 | 0.010 | 0.105 | 0.102 | 0.002 | 0.917 | 0.006 |
| | **Mean** | **5.93** | **7.3** | **0.39** | **1.54** | **29.98** | **0.23** | **0.03** | **4.25** | **0.45** |
| M3 | WIN | 2.46± | 8.1± | 0.40± | 1.55± | 32.50± | 0.48± | 0.05± | 2.11± | 0.53± |
| | | 0.046 | 0.058 | 0.017 | 0.023 | 0.964 | 0.058 | 0.002 | 0.095 | 0.008 |
| | PRM | 10.18± | 7.1± | 0.32± | 1.54± | 34.85± | 0.46± | 0.06± | 3.19± | 0.64± |
| | | 0.296 | 0.115 | 0.002 | 0.003 | 0.330 | 0.068 | 0.014 | 0.362 | 0.016 |
| | POM | 4.01± | 8.0± | 0.22± | 1.59± | 30.19± | 0.47± | 0.05± | 6.34± | 0.50± |
| | | 0.054 | 0.153 | 0.004 | 0.006 | 0.299 | 0.102 | 0.007 | 0.675 | 0.008 |
| | **Mean** | **5.55** | **7.7** | **0.31** | **1.56** | **32.51** | **0.47** | **0.05** | **3.88** | **0.56** |
| M4 | WIN | 6.64± | 7.5± | 0.36± | 1.51± | 35.47± | 0.34± | 0.05± | 1.98± | 0.27± |
| | | 0.125 | 0.115 | 0.003 | 0.006 | 0.551 | 0.034 | 0.007 | 0.097 | 0.020 |
| | PRM | 11.09± | 7.2± | 1.16± | 1.38± | 36.70± | 0.66± | 0.07± | 2.86± | 0.36± |
| | | 0.233 | 0.058 | 0.042 | 0.021 | 0.770 | 0.068 | 0.021 | 0.226 | 0.023 |
| | POM | 2.86± | 7.8± | 0.58± | 1.73± | 27.70± | 0.14± | 0.03± | 6.44± | 0.24± |
| | | 0.027 | 0.058 | 0.028 | 0.018 | 0.476 | 0.068 | 0.007 | 2.208 | 0.005 |
| | **Mean** | **6.86** | **7.5** | **0.7** | **1.54** | **33.29** | **0.38** | **0.05** | **3.76** | **0.29** |
| **Overall Mean** | | **6.24** | **7.4** | **0.52** | **1.53** | **31.33** | **0.33** | **0.04** | **3.99** | **0.46** |

NB: WIN=Winter; PRM=Pre Monsoon; POM=Post Monsoon; Overall Mean value is the average of all seasons and locations in mining area.

is the amount of water that the soil contains and expressed in terms of percentage. The MC in soil samples collected from limestone mining area was found in the range of 2.46% to 11.09% with annual average values of 6.62% (at M1), 5.93% (at M2), 5.55% (at M3) and 6.86% (at M4). The overall average value of all seasons and sampling sites was found 6.24%. However, MC at the unmined site was found to be 26.40%. Comparison of mean values of moisture content in soil samples collected from mining and unmined areas show a remarkable difference. The soil samples from unmined area contains 4 times more MC than that of the mining area. The less soil moisture content in the limestone mining area can be attributed to the absence of vegetation cover and dumping of spoils and overburden during the process of

Table 3: Correlation matrix of various soil parameters.

| | M C | pH | EC | BD | WHC | OC | TN | P | K |
|---|---|---|---|---|---|---|---|---|---|
| M C | 1 | | | | | | | | |
| PH | -0.921** | 1 | | | | | | | |
| EC | -0.485** | 0.502** | 1 | | | | | | |
| BD | -0.909** | 0.869** | 0.454** | 1 | | | | | |
| WHC | 0.952** | -0.890** | -0.582** | -0.928** | 1 | | | | |
| OC | 0.910** | -0.911** | -0.572** | -0.894** | 0.957** | 1 | | | |
| TN | 0.937** | -0.900** | -0.580** | -0.900** | 0.971** | 0.972** | 1 | | |
| P | 0.087 | -0.145 | 0.050 | 0.135 | -0.045 | 0.059 | 0.076 | 1 | |
| K | 0.235 | -0.115 | -0.279 | -0.317* | 0.179 | 0.122 | 0.152 | -0.233 | 1 |

NB: **p< 0.01 level and *p< 0.05 level (2-tailed)

Table 4: Results of ANOVA test for various soil parameters collected from limestone mining area of Meghalaya.

| Parameters | Between Locations | | Between Seasons | |
|---|---|---|---|---|
| | F value | P value | F value | P value |
| Moisture Content | 47.97 | 0.000 | 2.85 | 0.069 |
| Soil pH | 74.38 | 0.000 | 0.454 | 0.638 |
| Soil EC | 15.30 | 0.000 | 1.85 | 0.169 |
| B D | 37.82 | 0.000 | 2.15 | 0.129 |
| WHC | 99.16 | 0.000 | 0.90 | 0.414 |
| O C | 43.80 | 0.000 | 0.071 | 0.931 |
| TKN | 267.43 | 0.000 | 0.127 | 0.881 |
| P | 0.173 | 0.951 | 128.85 | 0.000 |
| K | 16.549 | 0.000 | 5.20 | 0.01 |

NB: Significant value is p<0.05

limestone extraction. Earlier studies found that the presence of high contents of stone particles and sand and very low organic matter in soil lead to the reduction in soil moisture (Sadhu et al. 2012). Relatively higher moisture content in soil during the pre monsoon season found in this study may be due to rainfall the area receives during this season.

**Soil pH:** Soil pH determines whether the soil is acidic or alkaline in nature. In the present study, pH of soil from the four different limestone mining sites was found in the range of neutral to slightly alkaline, with values varying from pH 7 to pH 8.1 with an overall average pH of 7.4. The soil pH in unmined area was found in the range of 4.4 to 5.5 with an annual average of 5.1. Acidic pH of soil in the area has also been reported by other researchers (Swer et al. 2011). The slightly alkaline nature of the soil in the limestone mining area could be due to accumulation of limestone particles in the top layer of the soil dispersed during the process of limestone extraction. Similar finding has been reported from the limestone mining areas of Himachal Pradesh (Sharma et al. 2013). In addition, significant input of organic matter into the soil of the unmined area could be responsible for decease in pH of the soil (Richardson et al. 1971, Banerjee et al. 2004).

**Electrical conductivity (EC):** Soil containing an elevated amount of soluble salts when comes in contact with water will display elevated levels of electrical conductivity. In other words, the presence of significant amount of ions in soil raises its electrical conductivity. Soil samples collected from the mining sites exhibited EC values between 0.22 mS/cm to 1.16 mS/cm with an overall annual mean value of 0.52 mS/cm. However, annual mean EC in soil samples of the unmined site was found to be 0.03 mS/cm. The study showed that EC level in soils of the mining sites is many times more than that of the unmined area. This indicates that limestone mining activity has inevitably added excessive amount of soluble salts and ions in the soil leading to higher levels of EC. It is reported that calcium carbonate, the main constituent of limestone, on dissolution is mainly responsible for an increase in EC value (Rai et al. 2011).

**Bulk density (BD):** The bulk density of soil is the measure of particles contained in a unit volume of dry soil including pore spaces. Minimal disturbances coupled with vegetation growth accounts for higher bulk density. The annual mean BD of soil samples of unmined area was found to be 1.13 g/cm$^3$. However, the same in soils of the limestone mining area was found between 1.37 g/cm$^3$ and 1.73 g/cm$^3$ with an overall annual mean of 1.53 g/cm$^3$. The BD of mining area was found a little more than that of unmined area. Less organic matter and higher compactness lead to higher BD. Soils of high bulk density inhibit the growth of plant roots and soil organisms, thereby leading to less vegetation growth (Grossman et al. 2001, Andrews et al. 2004, Rahman et al. 2012).

**Water holding capacity (WHC):** The water holding capacity is defined as the amount of water that a saturated soil can hold and expressed in percentage. The study showed relatively lower WHC values in the limestone mining area compared to that in the unmined area. In limestone mining area the WHC was found in the range of 27.21% to 33.29% with an overall average WHC of 31.33%. However, soil of unmined area possesses a relatively higher level of WHC ranging in the range of 50.04 % to 60.30 % with an annual average of 55.14%. Significantly less WHC in the mining areas is attributed to limestone mining activity which has remarkably changed the soil texture and composition.

**Organic carbon (OC):** One of the vital parameters essential for determination of soil productivity and fertility is soil organic carbon. Saxena (1987) classified soil of good quality when OC is greater than 0.8% and low quality if it is less than 0.4%. The OC content in the soils collected from limestone mining area varied between 0.14% and 0.66% with an overall mean of 0.33%. However, the same in unmined area was found between 2.51% and 2.59% with an annual average of 2.54%. OC content in soils of mining area was found about 7 times more than that in unmined area. Significant amount of OC at the undisturbed area may be attributed mainly by the presence of natural vegetation cover integrated with continuous decomposition process of plant litter. In contrary, depletion of vegetation cover in mining area has resulted in less organic carbon in soils of the limestone mining area.

**Total Kjeldahl nitrogen (TKN):** Nitrogen is one of the vital macronutrients in soil essential for the proper growth of plants. The TKN concentration was found relatively higher at the unmined site when compared to the limestone mining area. The TKN varied between 0.03% and 0.07% in the mining area with an overall annual mean of 0.04%. The annual average TKN in unmined area was found to be 0.33%. Based on the results, it is evident that limestone mining has drastically reduced the TKN in the soil. Rich content of TKN in the unmined area may be due to diverse vegetation growth leading to sufficient litter fall and their transformation into inorganic nitrogen by various microbial activities occurring in the soil. However, limited vegetation growth accompanied with significantly low organic carbon content and loss of nitrogen fixing microorganisms in the mining areas are the major causes of less nitrogen content in soils of the mining area (Rai et al. 2010, Aghasi et al. 2011).

**Available phosphorus:** Of the total phosphorus found in the soil, not all are readily available rather only a fraction may be available to the plants (Maiti 2003). Analysis of phosphorus in soils of unmined and mining areas revealed annual average values of 4.56% and 3.99%, respectively. The soil samples from the unmined area possessed little more phosphorus than in the mining area.

**Available potassium (K):** Concentration of potassium in the soils of the mining area ranged between 0.24 mg/g and 0.65 mg/g with an overall average of 0.46 mg/g. The same in unmined area exhibited about 0.49 mg/g annual average. No significant seasonal and location variation was observed during the study period.

**Statistical analysis:** To determine the closeness of association among the 9 soil parameters studied, the Karl Pearson correlation matrix was calculated using SPSS and the correlation matrix output obtained is tabulated in Table 3. The correlation coefficient (r) lies between -1 to +1.

From the data it was found that 36 pairs of data output were generated. Out of which only 22 pairs are statistically correlated with one another. Nine of the 22 pairs are positively correlated and the rest (i.e. 13) are negatively correlated. Significant positive correlation with $p<0.01$ was found between MC with WHC ($r = 0.952$), OC ($r = 0.910$), and TN ($r = 0.937$). A significant positive correlation was observed between pH and EC ($r=0.502$) and also with BD ($r = 0.869$) at 1% level of significance. WHC was also found to be positively correlated with OC (0.957) and TN (0.971). However, pH was found to have maximum weak correlation with most parameters except EC and BD. The highest negative correlation was seen between BD and WHC ($r = -0.928$, $p<0.01$). No significant statistical correlation ($p>0.05$) was found between phosphorus and potassium with the rest of parameters studied. A significant correlation among different soil parameters was noticeable indicating the associations between parameters which signify an increase or decrease in the values of parameters will affect the corresponding parameter values as well.

The results for analysis of variance obtained among different parameters with respect to variation between locations and seasons was assessed and represented in Table 4. The variations in values of different soil parameters were found to be statistically significant (ANOVA, $p<0.05$) for all parameters between locations except for available phosphorus ($p>0.05$). However, no significant differences were found between seasons except for available phosphorus and available potassium which was statistically significant at 5% level of significance.

## CONCLUSION

Based on the results of the present study, it can be concluded that limestone mining has degraded the soil quality to a certain extent. This deterioration is evident by the significant changes in moisture content, water holding capacity, electrical conductivity, bulk density, organic carbon and total nitrogen in soils of limestone mining areas compared to that of the unmined area. Limestone mining increased the soil pH from acidic to neutral or slightly alkaline nature when compared with unmined soil. Increase in soil pH can be considered a positive change. However, it was found that changes in the values of phosphorus and potassium were not so prominent. Therefore, to a certain extent we can conclude that limestone mining activities have a negative impact on soil quality and this can be observed by the reduction in concentration of various important soil physical and chemical properties.

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