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Environmental Impact Assessment of Madhyapara Granite Mine, Northwest Bangladesh.

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Abstract

Madhyapara Granite Mine (MGM) is located in Dinajpur district, northwest Bangladesh between latitude 25º23´22´´ N to 25º34´43´´ N and longitude 89º03´34´´ E to 89º05´04´´ E. Estimated reserve of hard rock is about 174 million tons. Production of hard rock (1.65 million tons/year) in MGM is carried out on 5 stopes using room and pillar/sub-level stopping methods. Exploration of hard rock in MGM through full capacity, it has the potentiality to cause serious environmental impacts, mainly probability of subsidence in the mine area, ground water pollution, sound pollution as well as air pollution at the time of drilling and blasting, and lowering of ground water table due to excessive pumping of sub-surface water. Therefore, workers are facing serious health problems like skin diseases, eye diseases, ear complexity etc. The explosion of Ammonium Nitrate Fuel Oil (ANFO) in MGM produces CO_2, NO_2, and CO toxic fumes resulting suffocation, toxicity and dizziness among the workers. Proper use of water spray, water bag, ear blocker and air door during mine operation it can minimize air and sound pollutions. Extraction of hard rock in MGM helps us to save considerable amount of foreign currencies by fulfill the country demand adding to enriched Bangladesh gross national economy.

Keywords: *Environmental impact, Hard rock, Madhyapara Granite Mine, Dinajpur, Bangladesh.*

1. Introduction

Madhyapara Granite Mine (MGM) is the only one underground hard rock mine in Bangladesh under the Petrobangla and the Ministry of Power, Energy and Mineral Resources of Bangladesh. MGM is situated in Madhyapara, Dinajpur district, northwest Bangladesh, with an area of about 1.44 km², between latitude 25º23´22´´ N and 25º34´43´´ N and longitude 89º03´34´´ E and 89º05´04´´ E. In 1974, Geological Survey of Bangladesh (GSB) ran an exploration survey in Madhyapara. In the Madhyapara area, basement rock is encountered at a depth of 130 m [1]. An estimated reserve of 174 million tons of hard rock in MGM consisting of granodiorite, diorite, quartzdiorite and gneiss of the Pre-Cambrian age has been discovered. Mining is a major economic activity in many developing countries [2]. The mining method applied in MGM is room and pillar/ sub-level stoping methods. There are 5 stopes under production of which two are in the south and three are in the north. The length, height and width of each stope are 230 m, 60 m and 20 m, respectively. The long hole drilling is used in MGM and fan pattern is used for blasting operation. Ammonium Nitrate Fuel Oil (ANFO) and power gel are used for blasting purpose. The production of granite is ~1.65 million tons/yr. Mine operations, whether smaller large-scale, are inherently disruptive to the environment [3]. The environmental deterioration caused by mining occurs mainly as a result of inappropriate and wasteful working practices and rehabilitation measures. Mining has a number of common stages or activities, each of which has potentially-adverse impacts on the natural environment, society and cultural heritage, the health and safety of mine workers, and communities based in close proximity to operations [4, 5]. The objective of this study is to find out the environmental impacts caused by the exploitation of hard rock in MGM and its possible remedies and minimization to make MGM a sustainable mine.

2. Tectonic setting

Tectonic evolution of the Bengal basin is related to the orogenic phases of the Himalayas, although the Cenozoic evolutionary history of the eastern Bengal basin is mainly associated to the oblique subduction phases of the Indian plate beneath the Burma plate [6].To the northwest, the basement slopes upward and forms a prominent ridge known as the Rangpur Saddle. The Rangpur saddle and the so called Garo-Rajmahal gap comprise the most uplifted part of the basement in the country, concealed under a thin layer of alluvium. In the Madhyapara area, basement rock is encountered at a depth of 130 m. The Rangpur Saddle represents a block of the Indian shield that connects the Shillong Massif and the Mikir Hills to the Indian Shield in the southwest (Fig. 1). The Shillong Massif is considered a large thrusting block of the Indian shield. Seismic data shows that both northern and southern slopes of Rangpur Saddle are quite gentle. On the southern slope, the basement plunges gently from Madhyapara southeast to the Hinge Zone, an area known as the Bogra Shelf. The stratigraphy of Madhyapara area is listed in Table 1.

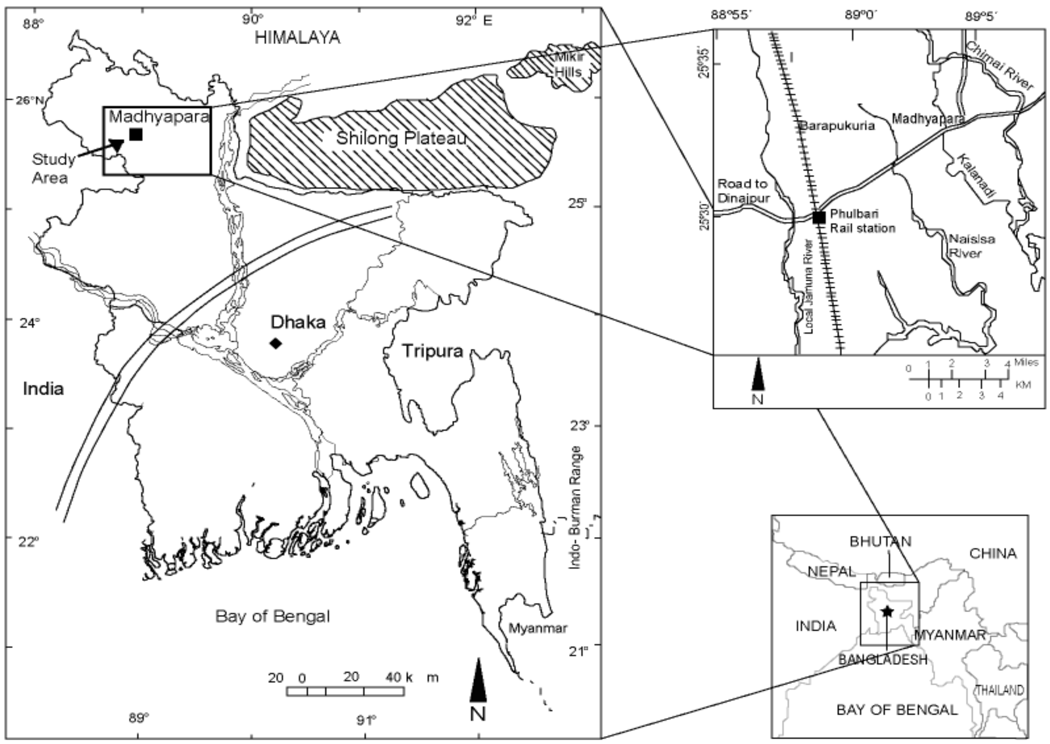

Fig. 1. Generalized map showing location of the study area and major geographic features of the Bengal Basin, Bangladesh [7].

3. Methodology

Fractures and fissures, water inrush and other parameters for the present study were conducted by field observation. Sound vibration was felt upon from the surface, and others relevant data were collected from reports and other literatures.

4. Discussion

4.1. Environmental Impacts

MGM causes several bad impacts on environment. Subsidence in the mine area, pollution of ground water, sound pollution and air pollution at the time of drilling and blasting, lowering of ground water table due to excessive pumping of sub surface water leached inside the mine during production.

4.1.1. Subsidence in the mine area

Subsidence is a natural and man-made phenomena associated with a variety of processes including compaction of natural sediments, ground water dewatering, wetting, melting of permafrost, liquefaction and crustal deformation, withdrawal of petroleum and geothermal fluids, and mining of coal, limestone, salt, sulfur and metallic ores [9]. Subsidence in MGM is low relative to BCM (Barapukuria Coal Mine). The load bearing capacity of granite rock is very high where as coal is very low. The strength and stiffness of the overlying and surrounding rock strata, and any pillars left in the mining area are significantly reduced by the effects of water [10]. Drainage gradients may be altered by disturbance of the strata around mine area. Rocks may be weakened by saturation and erosion patterns could be changed. Where surface water is present, it may migrate more easily to fractures and fissures in the strata and into the mine area and may induce subsidence [11]. Cavities formed as a result of mining results in subsidence. Another mining-related phenomenon that also creates subsidence is the withdrawal of water to facilitate underground mining. Two common features of surface subsidence induced from room-and-pillar method such as sink-hole collapse and saucer-shaped depression following pillar failure. In the case of room-and-pillar mining, surface subsidence can occur many years after mining is done [12]. The use of room and pillar technique in hard-rock mining on a large scale is a relatively new and untested method, although it has been carried out as a part of some mining areas where larger ore deposits were encountered with varied success. Leaching water around the mine area through fractures and fissures in MGM can reduce the strength of rock. It can accelerate the rate of subsidence of MGM. Rock quality in terms of fractures or fissures is relatively good in stope-1 to stope-3 and deteriorated towards stope-4 and stope-5 in the southern stopes.

Table 1. Stratigrapic succession of the Madhyapara area, northwest Bangladesh [8].

Age	Formation		Lithology	Average thickness (m)
Recent-Pleistocene	Alluvium-Madhupur Clay		Sand, silt and clay	0.52-6.18
Pliocene to Eocene	Dupi Tila		Sandstone and pebbly sandstone, pebble bed and siltstone, fine to coarse grained sandstone and few dark minerals.	113.27
	Tura Sandstone		Medium to coarse grained sandstone with subordinate claystone and shale	20.14
Permian	Gondwana Group		Mostly feldspathic sandstone with conglomerate, fine to medium grained sandstone and minor dark minerals.	
Archean	Basement rock	Completely and highly weathered zone	Kaolinized weathered rock on the top. Fresh rock: granodiorite to quartz diorite and gneiss, pegmatite, quartz veins.	14.05
		Slightly weathered zone		23.74
		Fresh rock		Unknown

4.1.2. Lowering of ground water table and pollution of ground water

Underground mining can change not only ground water table but also ground water flow paths and the geochemical environment. Mining may increase the permeability of rock units, create fresh rock surfaces, and allow water flow between previously disconnected units or between surface and ground water. This may disturb natural geochemical systems causing dissolution/precipitation reactions and result in disturbances to ground water quality [10]. Ground water quality is affected by depletion of the aquifer when dewatering from underground mining acts as a drain and lowers the water table. When underground mines extend into saturated ground, the seeping water creates a hydraulic gradient and induces flow to the mine, which results in depressed water level. In general, water level will decline more as the mine goes deeper. Permeability increases when fractures reach the ground surface, which may lead to increase ground water recharge and surface water depletion, surface subsidence and mine dewatering and cause compaction of an aquifer unit as water is removed from pore spaces and the weight of overlying rocks causes fissures and cracks in the aquifer unit too close [13]. MGM has also caused the problem of lowering of ground water table and disturbing of water flow path and geochemical environment. The water inrush in the mine is 1200 m^3/day. It is estimated that the average water inrush in May, 2010 was 53.51 m^3/hr [14]. This huge inrush of water from surrounding water bearing formation (Dupi Tila) is responsible for lowering of the water table. Water in MGM is being polluted when mixing with different hazardous substances those are very harmful for human health. This water is pumping out from underground to surface and contamination of this water with surrounding surface water sources i.e. pond, lake, etc. can cause serious effect on drinking and irrigation water. This water contains high concentration of aluminium (Al), antimony (Sb), arsenic (As), cadmium (Cd), lead (Pb), molybdenum (Mo), selenium (Se) and mercury (Hg) relative to WHO's standard. Physical and microbiological parameters like P^H, color, turbidity, total coliform (bacteria) and hydrogen sulphide (H_2S)/odor also have higher value than standard value [14]. Water test result for the sample MGMCL-GHS-W-01 of MGM is listed in Table 2 and the test was conducted by BRTC, BUET [14].

Table 2. Water test result of sample (MGMCL-GHS-W-01) of MGM and test was conducted by BRTC, BUET [14].

SL No.	Water Quality Parameter	Unit	Concentration Present in Sample: MGMCL-GHS-W-01	Bangladesh Standard for Drinking Water (ECR, 97)	WHO Guideline Value, 2004
01	P^H	--	9.54	6.5-8.5	6.5-8.5
02	Color	Pt-Co	242	15	15
03	Turbidity	NTU	115	10	10
04	Total Alkalinity (as $CaCO_3$)	mg/liter	…	…	…
05	Chloride (Cl^-)	mg/liter	46	150-600	250
06	Iron (Fe)	mg/liter	…	0.3-1.0	0.3
07	Nitrate- Nitrogen (NO_3-N)	mg/liter	4.8	10	50
08	Fluoride (F)	mg/liter	…	1	1.5
09	Total Dissolved Solids (TDS)	mg/liter	362	1000	1000
10	Fecal Coliform (FC)	CFU/100 ml	Nil	0	0
11	Total Coliform (TC)	CFU/100 ml	15	0	0
12	Total Hardness (as $CaCO_3$)	mg/liter	18	200-500	500
13	Electrical Conductivity (EC) at 25^0	µS/cm	510	…	…
14	Nitrite- Nitrogen (NO_3-N)	mg/liter	0.013	<1	3
15	Silica (SiO_2), Colloidal silica	mg/liter	59.9	…	…
16	Sulphate (SO_4)	mg/liter	45.4	400	250
17	Total Suspended Solids (TSS)	mg/liter	27	10	…
18	Hydrogen Sulphide (H_2S)/ Odor	mg/liter	0.03	Odorless	…
19	Mercury (Hg)	mg/liter	0.002	0.001	0.001

The chart mentioned above shows that this water contained very high p^H value and also contaminated with H_2S, Hg, suspended solids, Fe, Cl and F, inferring that it is not safe for drinking purpose.

4.1.3. Air pollution

From the environmental point of view, the various gases, which are by-products of blasting operation, are dangers to human health. These noxious gases produced in blasting operation are known as blasting fumes. The production of these noxious gases can be directly related to the type of explosive used. Carbon monoxide (CO) and oxides of nitrogen are the most important toxic products of blasting. Other gases present may be N, CO_2, water vapor, methane, H_2S etc. Oxides of nitrogen are more toxic than CO at a given concentration. Even a simple mixture of ammonium nitrate and fuel oil can produce very bad fume situations. In MGM, ANFO (oxygen balanced) is used for blasting. In ANFO, if part of the oil is lost by evaporation or settles out to accumulate at the bottom of the container, the product remaining in the top of the container will be deficient in fuel and high oxides of nitrogen will be produced. At the same time, the bottom of the container will contain excess fuel and hence will produce high quantities of CO.

$3NH_4NO_3 + CH_2 \rightarrow 3NO_2 + CO_2 + 7H_2O + 930$ KCal/kg [15]

The production of dust during the blast is directly related to the geology of the area and the charge concentration. This dust polluted air of the mine which is more hazardous to human health. The air dust can cause eye problem, allergy and skin diseases. Besides, the polluted air is released to the atmosphere that pollutes the environment more considerably.

4.1.4. Noise pollution and vibration effect

According to DoE (Department of Environment, Bangladesh) acceptable noise level for industrial areas are 75 dB at day time and 70 dB at night. During blasting and drilling of rock in MGM, a massive noise is generated which exceeds the tolerable level of industrial areas. The pneumatic rock drill is one of the severe noise sources in mining operations. The operation of these drills produces A-weighted noise levels in range of 100 to 120 dB at the operator location [16]. There is bound to be a big sound due to two reasons- firstly, release of gases from the confinement area displacing the massive air pocket and secondly, throw/dump of the huge material on the ground from a great distance. During secondary blasting operation massive amount of noise is produced that causes acoustic pollution. Also the machines and equipment installed at the shafts, inclines, compressor houses, workshops, etc. generate noise, which tends to become ambient noise as it is generated on the surface. Sound pollution in the mine causes reduction of hearing power and ear problems to the mine workers. The ground vibrations induced by blasting are one of the fundamental problems in the mining industry and may cause severe damage to structures and plants nearby [17]. When explosives detonate in rock, energy is generated in the form of various surface and body vibration waves which can damage upper constructions and structures if the vibration wave level is too high.

4.1.5. Ecological disturbance

Mining is often a heavy industrial activity that involves road construction and the use of heavy machinery, wildlife can be dislocated and habitat can be damaged or destroyed. Birds and other wildlife can be poisoned after drinking contaminated water in tailings ponds. In MGM, the topography of the mine has a little vegetation which is not suitable habitat for wildlife and other ecological demands.

4.1.6. Soil pollution

Soil contamination or soil pollution is caused by the presence of xenobiotic (human-made) chemicals or other alteration in the natural soil environment. It is typically caused by industrial activity, agricultural chemicals, or improper disposal of waste. There are several different types of waste materials produced during both the hard rock mining operation itself and the subsequent mineral processing activities which aim to concentrate the minerals of value from the surrounding waste rocks or gangue minerals. Close to an old mine site there may be spoil heaps composed of large blocks of rock. These spoil tips are commonly poorly vegetated as lack of soil, and easily drain and also have high levels of metal contamination either locked within mineral grains or through contamination of the water.

4.2. Remedy and recommendation

4.2.1. Remedy

Ore strength can be reduced by the influence of water that will results in pillar failure after mining. In MGM, a large quantity of water is leaching out from the surrounding geological formation. This can cause to collapse pillar to accelerate subsidence. So, it is necessary to investigate and determine the quantity of pillar strength reduction due to water inrush for planning of proper next stope development and counting the number of pillars necessary for the support or any other necessary of extra artificial support like bolting, wire-meshes, etc. As massive water inrushes in MGM, it creates a big problem for the working condition. Hence it is needed to be pumped out of the mine. But to prevent the harmful effect of the contaminated water, a water treatment plant has to be established and the treated water can be used for drinking and irrigation purposes. It can also be used for various underground workings i.e. water spray, water bags etc. during drilling and blasting.

Proper planning and management is essential for waste disposal or dumping yard to protect environment from being polluted by rainwater that washes the dumping yard.

Gaseous pollution that is produced by drilling and blasting can be reduced by proper ventilation system (i.e. proper implementation of air door). Water spray during drilling can reduce dust that can prevent the air pollution. Ear blocker and proper utilization of air door can be used to reduce the sound effect. Water bags can also be used to minimize the vibration (that causes noise) during blasting.

4.2.2. Recommendation

In stope-1 to stope-3, less fractures/fissures are seen. So, more drilling holes and much quantity of explosives can be used. Conversely, in the stope-4 and stope-5, more fractures and fissures are seen. More water inrush happens in this zone than stope-1 to stope-3. So, less number of drilling holes and fewer explosives should be used. So, further extension of stopes should be towards northern part. Implementation of water treatment plant in MGM can produce vast amount of drinking water for workers and the purified water can be supplied to surrounding areas. As we know about 1200 m³ (120000 liters) water inrushes per day, these water can be purified in the plant. Recently, there is huge demand of purified water in the country with huge population problems. So purified water can also be marketed and it may be very much profitable. This is an extra income for the company. These water can be exported and earn foreign currencies, and it also saves the environment from being polluted.

5. Conclusions

Mining is one of the major economic activities in many developing countries. MGM serves the country by providing with hard rocks which is used in various purposes. But there are some problems which cause bad impacts to the environment like subsidence in the mine area, ground water pollution and lowering of ground water table due to excessive pumping of sub-surface water, noise pollution, vibration effect and air pollution during drilling and blasting, soil pollution in the mine area, etc. Appropriate environmental policy and management can reduce these impacts. Policies and managements like adopting suitable supporting system throughout the mine, establishment a water treatment plant, proper management of dumping yard, implementation of proper ventilation system and air doors which can be taken as remedy of the impacts. By adopting these remedies this mine can be both sustainable and environment friendly. Extraction of hard rock in MGM helps us to save considerable amount of foreign currencies. So to improve socio-economic infrastructure of our country this mine can play a vital role in improving gross national economy of Bangladesh.

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