Conventional and unscientific mining poses severe threat to life, public property and continuation of mining in the area. Incompatible land uses, huge waste dumps and large scale land transformation have resulted in land degradation, ponding, flooding, water contamination and health hazards in Makrana mining area. Segregation of dumps, compatible land use and research and development activity for use of marble slurry are suggested measures for reclamation and restoration of the degraded land.

INTRODUCTION

Makrana (Lat. 27°02'25" N; Long. 74°43'44" E) is situated at eastern margin of the Thar desert and has an ancient marble mining history. The Makrana marble has made a perceptible dent in marble industry because of its blockability, whiteness, (high CaO 50-56 %, low MgO 0.90-1.77 %), good polishing character and lustre. It is fine grained and exhibits stable, well distributed colours, pleasing and attractive designs and patterns. The translucent varieties of Makrana marble are preferred over other marbles for monumental and sculptural work (IBM, 1993).

GEOMORPHOLOGICAL AND GEOLOGICAL SET-UP

Geomorphologically, the area is represented by strike ridges, sand sheets, anthropogenic overburden mounds, slurry dumps and deep pits. Drainage in the mining area is mostly internal. Major part of the area is covered by mobile to semi stable, NNW-SSE to NE-SW trending sand dunes which overlie calcareous sand, pseudo-conglomerate, kankar or gypsite beds of Quaternary period. Marble is exposed on surface in the central part, whereas overburden varies upto 15 m in the northern and the southern part of the area.

General slope in the mining area is towards west and northwest. Mining at present is below the water table in old mines. Water table in the area is 30-40 m below ground level. Groundwater from the mines is released into open lands and agricultural fields.

Makrana marble deposits belongs to the Ajmer Formation of Kumbhalgarh Group of the Delhi Supergroup (Pareek, 1984; GSI, 1997). According to Sinha Roy et al. (1998) Makrana marble is northeastern extension of the Ras marble and its stratigraphic position is debatable. The Alwar Group of rocks towards east are overlain by the Ajmer Formation (Ajabgarh Group) comprising of medium to coarse grained, cherty, ferruginous and/or micaceous quartzite (Fig.1). The Ras Formation of the Kumbhalgarh Group, considered coeval with the Ajmer Formation, comprises greyish white to pink marble and dolomitic marble and is exposed west of Makrana. Marble occurs as thin parallel bands associated with calc-silicate rocks and calcareous quartzite having NNE-SSW strike and steep easterly dips. The rocks of Bombolai Formation of Punagarh Group are the youngest rocks of the Delhi Supergroup in the area. These consist of biotite gneiss, quartzite and calc-silicate having NNE-SSW strike and steep easterly dips. The exact interrelationship of these rocks is not known due to paucity of outcrops. Rocks of the Delhi Supergroup have been intruded by the Erinpura Igneous suite comprising porphyritic granite, biotite granite, pink granite, leucogranite and pegmatite.

Five prominent marble bands occur in the area west of Makrana. From east to west these are known as: (1) Devi-Gunawati range, (2) Dungri range, (3) Pink range, (4) Makrana Kumhari range, and (5) Borawar Kumhari range with band I and U (Natani, 2001). The different marble bands have formed due to tight isoclinal folding. The exact ranges are known by different names in different blocks (Fig. 2). At present mines extend from Matabhar in the north to Bilu-Mored in the south (approximately 13 km) along the strike and from Gunawati in the east to Borawar in the west (about 16 km) across the strike. Matabhar, Kalanada, Kolhadungri and Bilu-Mored are new mining areas.
Fig. 1. Geological map of area around Makrana, Nagaur District, Rajasthan.

LEGEND

- **4** Aeolian mobile sand intermixed with calcareous clay or silt with polymictic conglomerate and grit
- **3** Biotite granite, Pegmatite Amphibolite
- **2** Phyllite, impure limestone, calc-silicate rock
- **1** Makrana marble and Dolomitic limestone / Quartzite at places Cherty micaceous and ferruginous
- **O** Well section

Source: GSI, 1997

Quaternary
Upper Proterozoic
Lower to Middle Proterozoic

Bombolai Formation
Ras / Ajmer Formation
Punagarh Group
Kumbhalgarh Group
Delhi Supergroup

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MINING RELATED ACTIVITIES AND THEIR IMPACT ON ENVIRONMENT

Open cast mining, marble processing, solid waste generation and its disposal, trading and transport of marble blocks, slabs and irregular marble pieces (khandas), and art and craft work are important activities in Makrana mining area. Quarrying is by conventional rope and bucket method and the quarries run along the strike and dip of marble bands. Large scale land transformation, unscientific mining, unsegregated waste dumps, incompatible land uses and improper waste disposal have caused land degradation, ponding and flooding of water, visual impact, loss of aesthetics, pollution, health and safety hazards.

Safety Hazards and Loss of Public Property

Blasting of rocks mass is done to detach blocks of marble and remove hanging wall strata. Undercutting, side cutting and removal of safety pillars thus make the hanging wall strata unstable. Dewatering of mine pits and under cutting of loose aeolian sand by water released from processing plants results in failure of hanging wall strata and consequent mine collapse and loss of public property. Instances of unsystematic, unscientific and adhoc mining like rat hole mining, mining on small rent cum royalty lease holds of the size 3 m x 5 m (in Bapi mines) as against the norm of a minimum 2.25 ha laid down in the marble policy (Govt. of Rajasthan, 1994), undercuts and removal of safety pillars are quite common in the area.

Casualty figures provided by Makrana Police Station and Parbatsar Police station reveal 20 persons died of mine accidents during the period January 1999 to April, 2000. A major accident occurred in the area few years back in Chuck dungri range mines near Makrana railway station. Nearly 500 m of Makrana Parbatsar broad gauge line of Western Railway collapsed in the accident resulting in closure of 54 Chuck dungri mines for more than 3 years. Thus looking at the size of operations, conventional open cast mining at 50 m to 100 m depth b.g.l., without any benches and complete ignorance of safety norms, recurrence of such accidents in future cannot be ruled out. Jodhpur-Makrana road, Borawar bye pass, Devi-Gunawati mines, Chousira mines, Rewat dungri mines and pink range mines are other spots vulnerable to such hazards in the area (Fig. 2).

Land Degradation and Loss of Aesthetics

Makrana mining area has witnessed large scale land transformations during last thirty years, leading to land degradation and loss of aesthetics. The quarry area increased from less than 100 ha in 1970 to more than 350 ha during the period 1970-1998. Marble production has also increased from 200 thousand tonnes in 1986 to 581 thousand tonnes in 1999-2000. Comparison of 1967 aerial photographs and IRS 1C Geo-coded data product of 20th February, 1998 for the area reveals large scale land transformation in the area. Quarries and associated dump area has increased from 1.875 km$^2$ in 1967 to 11.21 km$^2$ in 1998, whereas the built-up area around Makrana has increased from 1.10 km$^2$ to 5.00 km$^2$ during the same period. Built up area of Makrana Borawar, Gunawati and Bidriyad towns and surrounding villages and industrial land and waste dumps have increased manifold to accommodate increased mining and related activities in the area. Mine pits, waste dumps and abandoned pits dot the area throughout.

The huge excavation around Makrana has resulted in large anthropogenic mounds and deep trenches. The entire landscape has been degraded and turned into derelict land, as there is no planned reclamation and restoration of quarried landscape. Natural ground slope has been obliterated causing ponding and flooding of water. Unscientific mining, improper waste disposal, high waste generation, lack of vegetation, suspended particulate matter from blasting, dried marble slurry, overburden material and unsegregated waste dumps also cause aesthetic nuisance.

Air and Water Quality

Dried slurry from 317 marble cutting and polishing units, dust from over-burden dumps, blasting in mine pits and marble chip making plants contributes suspended particulate matter (SPM) in and around Makrana mining area. The size analysis indicates that sand size particles constitute about 90% (by weight) of the overburden dumps and about 60-70% of the slurry dumps. Silt and clay size particles are present in substantial amount in slurry dumps (about 30-40%). Large number of trucks, jeeps, water tankers and mining machinery contribute to oxides of nitrogen (NOX), Carbon dioxide (C0$_2$) and Sulphur dioxide (SO$_2$) emissions within the mining area. Other sources of air pollution in the area are lime-kilns and brick kilns. The oxides of nitrogen and sulphur (NOX and SO$_2$) are created by the burning of fossil fuels (mainly coal) being utilised in lime-kilns and brick kilns. Occurrence of these toxic gases and particulate matter together have adverse effects on human health in Makrana as revealed by verbal enquiries from Chief Medical and Health Officer, Makrana Government Hospital, mine labourers, traders and local population. Common complaints are of eye irritation and inflammation and lung infections. The presence of SPM can also be appreciated by seeing the white dust deposition on plant, stems, branches and leaves and on the face and hairs of persons moving in.
Fig. 2. Marble quarries and suggested alignment of railway lines, Nagaur District, Rajasthan.
the area. Surface water bodies in the down wind direction of the mining area show high SiO₂ as compared to the silica content of natural water which is in the range of 1 to 30 ppm Table 1. High silica values in Gangwa Talao (140 ppm) and Manglana Talao (250 ppm), both in the predominant down wind direction (southwest to northeast) are due to contamination of these water bodies from suspended particulate matter. Parbatsar Talao which is 17 km SE of mining area does not fall in the wind direction, has analysed 40 ppm silica. Borawar Talao situated on the western periphery of mining area is in the upwind direction has analysed 5 ppm SiO₂, Gunawati Talao situated in the down wind direction has analysed 5 ppm SiO₂ only as it falls in the shadow zone due to industrial units and buildings around it.

Extension of mining and related activities has resulted in encroachments and indiscriminate dumping of municipal and industrial waste around Kalanada in a small pond northeast of Makrana railway station. The water of Kalanada pond was used as drinking water source till 1967. Kalanada water has analysed, Biological Oxygen Demand (BOD) 70 mg/litre, Chemical Oxygen Demand (COD) 269.6 gm/litre, Total Coliform organisms (TCO) 1100 Most Probable Number (MPN) per 100 ml of sample and E coli 23 MPN per 100 ml of sample, (Table 1). It is severely polluted as per drinking water norms (BIS, 1988, 1991). During rains, Kalanada water starts flooding the slums in the adjoining areas, burial ground east of Kalanada mine and Bhankron-ki-Dhani area. To prevent flooding of these areas excess Kalanada water is released into Kalanada mine through overflow drains. The polluted Kalanada water thus, gets filled up in Kalanada mines and the mines remain closed for 3-4 months. Thus, contamination of groundwater occurs in the area through subsurface flow of contaminated Kalanada water. Bhankron-ki-Dhani well about 400 m northeast of Kalanada mine has analysed BOD (12), COD (25.4) and TCO (23) indicating bacterial and industrial contamination of groundwater in the area due to mining in Kalanada range. Thus, diverting the polluted water of Kalanada into Kalanada mines solves the problem of flooding in the area. This will also help in simultaneous reclamation and restoration. Land reclamation is also easier and cheaper if mining waste is segregated. Value of marble depends on its size, whiteness, fine texture and absence or presence of cracks, fractures, etc. It is, therefore, suggested that as far as possible blasting should be avoided and deployment of wire saw machines be encouraged for mining. Alamagamation of small lease holds and mining on co-operative basis needs to be explored in consultation with mine owners, government representatives and environmentalists for sustainable development of the mining area. This will also help in simultaneous reclamation and restoration of mines. In addition to these remedial measures, vegetation screens all around mining belt, stabilisation of overburden dumps, realignment of Howrah-Jodhpur and Makrana-Parbatsar railway lines are suggested for the environmental management of the area (Fig.2).

Beneficial Impact

The only beneficial impact of Makrana marble mining is on the socio-economics of the region. Makrana marble mines contributed Rs.9.64 crores to the state exchequer in the form of royalty, Rs. 15.27 crores in the form of sales tax and Rs. 4.60 crores as excise duty during the year (1997-98) DMG (2000). The mines provide job opportunities to more than 50,000 persons who are entrepreneurs engaged in the mining and related works or skilled, semi-skilled and un-skilled labourers or traders.

Suggested Remedial Measures

Use of natural resources and their transformation into economically valuable commodities has to be sustainable (WCED, 1987). Otherwise, the very base of development is eroded. Marble mining at Makrana is a classic example of unscientific mining and improper waste disposal in total disregard to aesthetics, proper land use practices etc. Mining and waste disposal practices prevalent in the area need to be reviewed. Processing waste can be disposed of in abandoned pits and gully erosion areas northeast of Jusri and east of Bidiyad railway station. Segregation of overburden, mine muck, marble slurry and municipal waste dumps is suggested to prevent contamination of groundwater and land reclamation and restoration. Land reclamation is also easier and cheaper if mining waste is segregated. Value of marble depends on its size, whiteness, fine texture and absence or presence of cracks, fractures, etc. It is, therefore, suggested that as far as possible blasting should be avoided and deployment of wire saw machines be encouraged for mining. Alamagamation of small lease holds and mining on co-operative basis needs to be explored in consultation with mine owners, government representatives and environmentalists for sustainable development of the mining area. This will also help in simultaneous reclamation and restoration of mines. In addition to these remedial measures, vegetation screens all around mining belt, stabilisation of overburden dumps, realignment of Howrah-Jodhpur and Makrana-Parbatsar railway lines are suggested for the environmental management of the area (Fig.2).
Table 1. Water Quality Data — Mokrana Marble Mining Area, Nagaur District, Rajasthan

<table>
<thead>
<tr>
<th>S.No</th>
<th>Location</th>
<th>Type of Sample</th>
<th>Remarks</th>
<th>pH</th>
<th>TH</th>
<th>TDS</th>
<th>Cl</th>
<th>Ca</th>
<th>Mg*</th>
<th>Na</th>
<th>K</th>
<th>SO₄</th>
<th>NO₃</th>
<th>F</th>
<th>B</th>
<th>SiO₂</th>
<th>CO₃</th>
<th>HCO₃</th>
<th>BOD</th>
<th>COD</th>
<th>TCO</th>
<th>Ecoli</th>
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<tbody>
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<td>1.</td>
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<td>Sewage and industrial contamination</td>
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<td>505</td>
<td>145</td>
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<td>500</td>
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<td>50</td>
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<td>1</td>
<td>75</td>
<td>ND</td>
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<td>50</td>
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<td>219</td>
<td>300</td>
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<td>70</td>
<td>1.00</td>
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<td>≤5</td>
<td>26</td>
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<td>6.</td>
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<td>4</td>
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<td>8.</td>
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<td>180</td>
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<td>350</td>
<td>7.85</td>
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<td>380</td>
<td>20</td>
<td>67</td>
<td>28</td>
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<td>15</td>
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<td>Chlorinated composite water of municipal supply tube wells.</td>
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<td>170</td>
<td>455</td>
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<td>11.</td>
<td>Bile</td>
<td>Ground water</td>
<td>Alkaline water with low TDS</td>
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<td>395</td>
<td>1020</td>
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<td>12</td>
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Desirable limits (BIS (1991))

- pH: 6.5 - 8.5
- TDS: 300 - 2000 mg/L
- Cl: 50 - 600 mg/L
- Ca: 250 - 1000 mg/L
- Mg*: 75 - 450 mg/L
- Na: 30 - 300 mg/L
- K: 1.00 - 200 mg/L
- SO₄: 1.50 - 400 mg/L
- NO₃: ≤5 mg/L
- F: 1 - 2 mg/L
- B: ≤1 mg/L
- SiO₂: ≤10 mg/L
- CO₃: ≤1 mg/L
- HCO₃: ≤1 mg/L
- BOD: ≤20 mg/L
- COD: ≤60 mg/L
- TCO: ≤25 mg/L
- Ecoli: ≤1000 cell/mL
<table>
<thead>
<tr>
<th>S. No</th>
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<td>856</td>
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<td>Tube well</td>
<td>High TDS, Na, NO, and Silica</td>
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<td>3400</td>
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<td>Unsafe for drinking excessive TDS, Cl, Na, K, NO₃, and F</td>
<td>8.55</td>
<td>730</td>
<td>7000</td>
<td>1534</td>
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<td>278</td>
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<td>High B, COD</td>
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<td>250</td>
<td>1730</td>
<td>310</td>
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<td>90</td>
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<td>8.16</td>
<td>330</td>
<td>1400</td>
<td>105</td>
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<td>930</td>
<td>268</td>
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Note: All values are in ppm except pH. Total Coliform Organisms (TCO) and E Coli are in terms of most probable number MPN/100 ml of sample. ND - Analysis not done. *As per BIS (1998); ! As per BIS 1988; # No relaxation below 6.5 and above 8.5
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