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Marble Waste Management for Protection of Ecology and Environment

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Abstract

Marble mining and processing activities lead to waste generation and pollutant hazards causing the ecological, environmental, and sociological disruption. This study addresses the issue by interacting with some selected mining units engaged in marble production activities in Udaipur- Rajsamand region of Rajasthan, India. The study describes the single and multiple responses of marble mining personnel towards various parameters of the waste generation and highlighted lacking of best mining practices.

Researchers have identified the scale and mode of waste generation through marble units, troubles in addressing waste disposal and finally covered remedial actions to minimize the waste formation to ensure the protection of ecology and environment. The weakness and threats of the marble industry in all respect have been assessed with the objective of adopting high-quality practices of making environment clean and green.

Keywords: *Marble, Mining, Ecological, pollutant..*

1. Introduction

Marble in the ancient era, was within the reach of emperors has been seen from the era of ancient temples and Tajmahal of Agra. But now days it has become the need of the common people. As the marble industry grew up in early eighties, the new industry was welcomed by all sectors of society with the hope that there will be prosperity, employment, market upliftment and industrialization of the region. The expected results were also seen for few years but thinkers and society very soon realized the problems and drawbacks of the much liked industry.

Commercially marble is a crystalline rock composed predominately of calcite, dolomite, or serpentine that hardness of 3 to 4 on Mohs scale and capable of taking good polish. Chemical impurities may be present in marble in the form of Silica (SiO2) as free quartz or silicates, iron oxides as hematite (Fe2O3), Limonite (2Fe2O3.3H2O), Manganese oxide (MnO2), and Alumina (Al2O3) in form of aluminum silicates. Presence of impurities generally imparts decorative patterns and colors to marble. Every industry whether it is a mineral industry i.e. mining, processing or production industry necessarily generate some waste during its production. The big industry sometimes creates a new cottage industry out of its waste.

1.1 Physical and Chemical Properties and Classification of Marble

Marble has following physical and chemical properties which govern the marketability of marble:

1.1.1 Physical properties:

The physical appearance of marble gives glamorous appearance to its viewer, which in turn enhances or reduces its marketability of the marble. Physical properties and texture is of more importance. Physical properties of marble include its colour such as white, green, black, stripped or shaded. Its form, crystallined or non-crystallined, its luster, reflectivity, (80-95%), hardness, (2.8-3.5), specific gravity, (2.7-2.9) and strength which includes measure of its capacity to resist and stress (range is 56-190 MPa) and compressive strength (50-90 M Pa).

1.1.2 Chemical properties:

Chemical properties play a small role in the area of marble utilization and application. Technically different chemical impurities create different colors, shades, figures and appearance of the marble which controls it marketability. But for study purposes the chemical properties of a typical sample of marble is represented in table below:

Table 1: Chemical Analysis of Marble

Chemical Analysis	In Percentage (%)
CaO	30-33
MgO	16-25
SiO_2	0.01-7.6
Fe_2O_3	0.12-0.95
LOI (Loss On Ignition)	36-44

1.2 Classification Of Marble

Marble has been classified into 10 groups by Bureau of Indian Standards (Indian Standard Institute i.e. ISI) (IS 1130-1969) on the basis of colour, shade and pattern. Rajasthan is the most fortunate state where all the 10 groups specified below are occurring:

- Plain White Marble
- White Veined Marble
- Black Zebra Marble
- Pink Adanga Marble
- Grey Marble
- Panther Marble
- Plain Black Marble
- Green Marble
- Pink Marble
- Brown Marble

1.3 Marble Mining

Marble being a dimensional stone is mined out and processed in a completely different manner then any conventional mining and processing activity. The quarrying of marble is different from the mining of other minerals. In marble quarrying, large size of blocks are excavated. Earlier extraction of marble was done manually by using jack hammer and jib crane. But now mechanization has started and one of the Indian mines has achieved the target of highest production in the world. Due to mechanization production as well as recovery of marble has increased. It has reduced the waste generated at the quarry site.

1.4 Processing of Marble

The marble being a dimensional and decorative stone, is to be cut into slabs for its use as floor or wall purposes respectively. The whole process of slabbing is imparted in 'Gangsaw' where a gang of rectangular diamond saws placed side by side at distance (5mm/ 10mm/ 18mm / 20mm) to each other, are given reciprocating motion and vertical thrust on ascending marble block. In result of sawing action with water as coolant, the blocks are divided into slabs of required thickness (8 mm/ 10 mm/ 18 mm/ 20 mm). Slabs are cut into required sizes by diamond wheel cutter. A grove cut in the marble and injection of water cause large amount of marble slurry generation in both operations.

2. Waste and It's Types

Waste is defined in simple words as "The end material that is non-usable in any form, obtained after all the 'primary' and 'secondary' application." In other words from a systems' view point, waste is any unnecessary input to or any undesirable output from any system encompassing all types of resources. Waste management is a multi-disciplinary activity involving engineering principles, economic, urban and regional planning, management techniques and social sciences, to minimize the

overall activity of the system under consideration. A systematic approach to waste management encompassing the waste of all kinds of resources at all stages should be adopted. The definition is true for many of the industrial activities including marble mining and processing. According to above definition, the waste should be only non-usable after even secondary application but in case of marble mining and processing waste, even the reduction in primary usage causes heavy reduction in financial returns since the large size blocks / tiles fetching returns reduced as compared to smaller blocks / tiles or any secondary product

The marble waste generation during extraction of marble blocks can be estimated at 30 % to 40 % of the production (in mechanized mines using methods such as wire saws) and at 60 % to 70 % in mines using conventional techniques of blasting. This waste includes odd blocks of various sizes and shapes, unwanted blocks and rock fragments produced during trimming and shaping of mined out blocks before dispatch to processing units. This leads to uncontrolled stripping of vegetation cover and subsequent soil erosion. Dust generated during quarrying can also blanket surrounding areas leading to vegetation die-off and adversely affecting the fertility and quality of top soil. While marble waste may be useful in many industries, but is needs economic considerations. Unlike any other industry / mining, any dimensional stone industry produces large amount of waste, in terms of small blocks, small tiles, or broken tiles etc., (Indirect waste) along with the normal processing waste (Direct waste). These indirect wastes are from total reserves itself which were designated to produce much higher revenue but only giving small due to small sizes of product.

As far as marble waste is concerned many scientist and researcher have classified the waste generated in mining and processing into following categories. For the purpose of understanding and differentiate the generated waste we can further divide the waste into two broad classes;

2.1 Mining/Quarry Waste

The main stages of quarry waste include;

(i) Before exposure of hard Rock; since it is an initial work of mine development is necessary to remove the top soil to expose the rock of marble or another rock of overburden. Generally it removed at initial stage and stacked at the nearest place to mine re-handled at later stage for proper dumping. The methods employed for topsoil removal varies widely, depending on the size of the quarry and the capability and inclination of management for reclaiming the land. But in the process of top soil removal a certain quantity of marble is wasted in blasting operations

(ii) Removal of overburden; the next step in open cast mining is to expose the rock or marble by removing the overburden. The thickness of overburden may be any from zero to several meters. This thickness decides the method of its removal and also decides the profitability of the business and initial investment in the project. Overburden usually comprises of weathered rock, embedded or scattered boulders of various sizes, rubble etc. Drilling and blasting is frequently needed to blast the rock portion. The good quality boulders could be utilized for producing blocks. Other weathered portions of rock rubbles etc are stacked in relevant place. This work is the main potion of the waste generation.

(iii) Production of marble; in the production of marble, benches reformed and a considerable amount of waste is generated during this stage. Moreover waste is also generated in formation of roads, ramps and other development works in benches. Extraction of blocks also generates waste in sizing blocks and resizing of big blocks, if necessary.

2.2 Processing Waste

The processing waste is the result of slabbing, sizing and polishing operations. During these operations, a groove, of the width of cutting tool and length of block / slab is converted into the waste (slurry.) In the gang sawing, after each slab thickness (8/18 /20 mm) there is a groove of 5 mm thickness (sawing thickness) i.e. in one block 62 (in 62 blade gang saw) grooves are cut for entire length and breadth.

Various types of waste generated during processing of marble are:

(a) Cutting waste

(b) Polishing waste and

(c) Handling waste.

In addition to this the forms processing waste may include Slurry (due to dust from cutting, carving and polishing operations), Rejected pieces /chips resulting from final cutting of usable tiles or slabs of desirable dimension (commonly termed as crazy) and Chips and small pieces, resulting from carving etc. Dressing waste is also a form of waste in processing in which waste is generated in dressing of the irregular slab or tile dressed to regular size before initial process of tiling. The slurry generated during processing is estimated to be about 10% of the total stone quarried (20% to 25% of the block as received from the quarries) and during polishing as 5% to 7%.

3. Waste Management

Waste management includes minimization, disposal and reutilization of the waste generated in mining and processing of marble. Waste management is a multi-disciplinary activity involving engineering principles, economic, urban and regional planning, management techniques and social sciences, to minimize the overall activity of the system under consideration. A systematic approach to waste management encompassing the waste of all kinds of resources at all stages should be adopted. The definition is true for many of the industrial activities including marble mining and processing. According to above definition, the waste should be only non-usable after even secondary application but in case of marble mining and processing waste, even the reduction in primary usage causes heavy reduction in financial returns since the large size blocks / tiles fetching returns reduced as compared to smaller blocks / tiles or any secondary product.

3.1 Mining waste minimization

The method of mining should be adopted in such a way the mining waste in zero mining waste is generated or at minimal quantity. At present the mining waste is approximately 50% of the handled rock mass of marble. The main cause of waste generated in mining is use of explosive in blocks separation. The blasting should completely be avoided in dimensional stone mining including marble. This generates cracks in the blasted rock itself as well as in the remaining rock. This practice generates most of the waste in mining. Instead of this bench height should be kept as per maximum size feed to gang saws (i.e. 10 ft. High), this will reduce direct waste. Deployment of modern wire saw, derrick crane and block handlers will reduce the waste at respective stages in mining. Minimization and even using non blasting techniques is the best way to minimize waste in mining.

3.2 Mining waste disposal

As the waste disposal in mining is a very tedious, energy and money consuming operation. The natural cracks present in the strata also generate the major part of the mining waste. The waste so minimize should be disposed at the place nearest to the mining area to minimize the transportation cost. But care should be taken that the disposal site should not degrade the ecological and environmental condition of the vicinity. The waste should be disposed off very scientifically to minimize the impacts at the demarked site for the disposal by government. The site may be at an average distance of a particular cluster of mines, maintained on NGO, Governmental or Mines Association Level. The top soil of the dumping yard be protected and be used after the dump for plantation to get re- vegetating of pre- dump condition. A perfect method cannot be devised for proper disposal but some of the suggestions as the mining sites vary from place to place but disposal can be improved with better infrastructure facility like roads. In case of mine dumps, the height, area and shape of the dump should be designed as per the land available. The completed surfaces of dump should be stable and able to resist long-term erosion. The designed land construction of the waste dumps should be such that the completed out slopes do not exceed 200 from the horizontal. Drainage should be constructed to handle heavy rainfall events. Handling and disposal of the quarry waste in an environmental friendly manner is the primary concern of the quarry owners. Realizing the urgent need for conservation of land and an environmental friendly system of disposal of quarry waste and enhance return of the reserves.

3.3 Mining Waste Reutilization

It is necessary to minimize the mining waste as it true that we cannot zero the waste in mining. So we can utilize the generated waste by its value addition by transforming the shape and size of the waste to some marketable products e.g. small idols, tableware, flower pots etc. Mining waste generally comprises of overburden, small pieces of marble and top soil. The overburden can be utilized in building construction or may be dumped to the nearest place to mines for its use in future for back filling or reclamation (Filling of mined out area). Far away dumping may be uneconomical and may not be adopted by private small scale mine owners. The small pieces may be used for filling the voids in mining operations. Use in quarry boundary and other walls. Small pieces can be used for construction of houses, offices etc nearby, use in construction of waste/reject dams, use in construction of retaining walls and embankments etc. The mining waste may be reutilized with implementation of rules and on cluster basis the initiating may be taken by social working societies for awareness to reutilize the waste.

3.4 Processing Waste Minimization

The researchers so far have concluded that processing of marble at block dressers, gang saws and tiling plants is in order of about 20%, gang sawing waste and further 10 to 20% of handling and other wastes depending upon the output block geometry and total production. The 20% of gang sawing waste is in forms of slurry, which is absolutely dependent upon the size of groove. For the minimization of these waste, experiments for reduction of groove size is required and beyond the scope of the study. Minimization of this 20% can only achieved by this option only, but overall minimal waste can be achieved by performance enhancement of the operations. Also the additional waste of 10 to 20% is solely dependent upon the output quality of mining, transporting and processing. Well maintained alignment of the machine as well decreases the generated waste with better cutting of the stone.

3.5 Processing waste disposal

The processing waste is generally slurry, which is a by-product of sawing of marble on gangsaws, wiresaws, and block dressing machine and wheel cutters. The marble powder mixed with water in cutting makes the slurry. The slurry disposal sites should be far from human settlements. Proper care to be given to it as compared to mine waste, since its ingredients are fine, which after air borne create lots of problems of environment and human health. Water should complete be taken out from slurry and thus only cake should be disposed off. The slurry may be used to level up the undulating farming land after conserving the top soil and later on top layering on the levelled ground to improve efficiency of farming. The slurry should be used in low profile surface for filling and prior to that top soil be preserved for top laying after levelling the ground and converting the land cultivable to protect ecology and environment.

3.6 Processing Waste Reutilization

The processing operation of marble industry produces approximately 20% of the input in terms of marble powder. This is resulting in huge quantity. It consumes lots of energy and money to properly dispose off. But the environmental people have objected it strongly and the industry has been forced to think of its proper disposal and reutilization of this menace. So many organizations, NGO, association and government bodies have worked for its gainful reutilization. The common line of research was to prepare bricks from the slurry in light of huge quantity to be reutilized. They have prepared and tested a lot of combinations of cement, sand and marble slurry dust (MSD) mixtures and inferred very positive results; that they are better than conventional, in terms of look, strength and glaze and above all, consumes waste. Many experiments have been published and efforts have been made to utilize the marble slurry dust in various industrial products.

4. Research Study

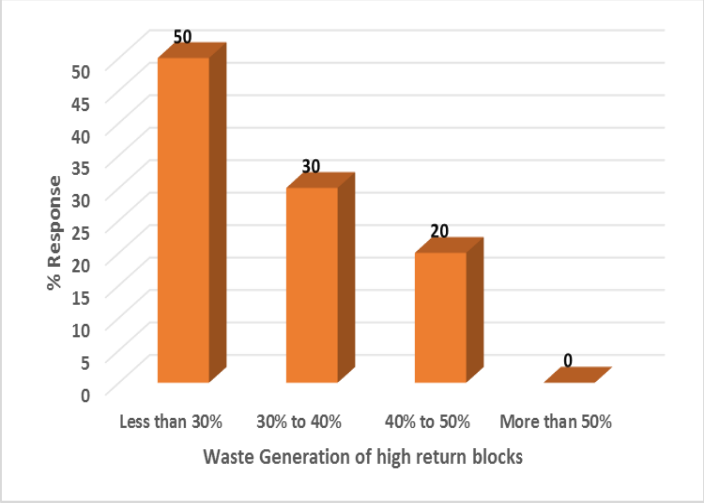
A research study was done on ten popular mines which are extensively engaged in marble mining to identify adoption of general practices in marble waste management. The study comprises questionnaire encapsulating the responses from industries.

Conclusions of all responses have been shown in tabular form in this segment. Table 1 and Graph 1 show the response of industries towards the production of high return blocks of marbles.

Table 1: Approximately Percentage of - Fresh / Large (High Return Blocks)

Response	N	%
Less than 30%	5	50
30% to 40%	3	30
40% to 50%	2	20
More than 50%	0	0
Total	**10**	**100.00**

Graph 1: Approximately Percentage of - Fresh / Large (High Return Blocks)



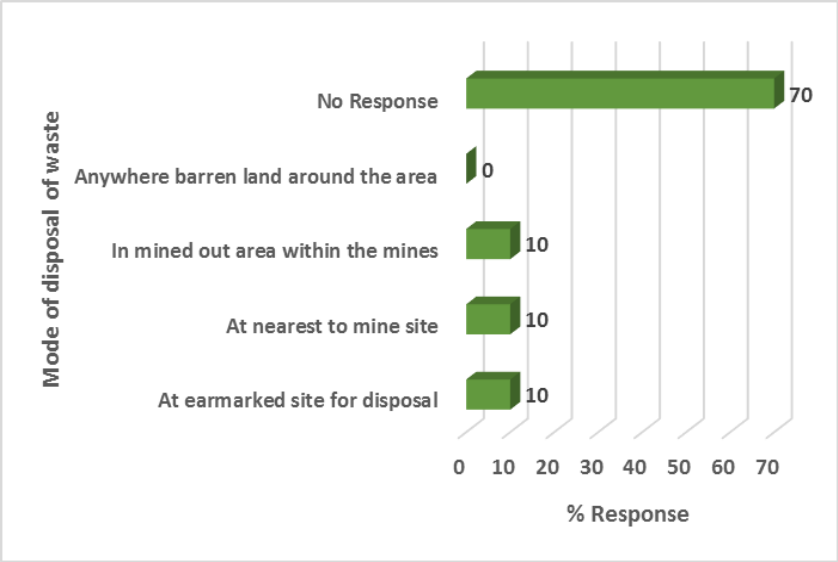
It has been observed that 50 % of industries are producing less than 30% fresh and high value blocks. About 30% mines are producing 30% to-40% high value blocks. Only few mines produce more fresh and high value blocks and no mining area produces more than 50% fresh blocks in my survey. This indicates that the level of waste generation is very high in marble industries as majority is towards less than 30% high value products and more than 70% is towards waste generation.

Now, Table 2 and Graph 2 represents the response on waste disposal mode adopted by industries.

Table 2: Mode of Disposal of waste

Response	N	%
At earmarked site for disposal	1	10
At nearest to mine site	1	10
In mined out area within the mines	1	10
Anywhere barren land around the area	0	00
No Response	7	70
Total	**10**	**100.00**

Graph 2: Mode of Disposal of waste



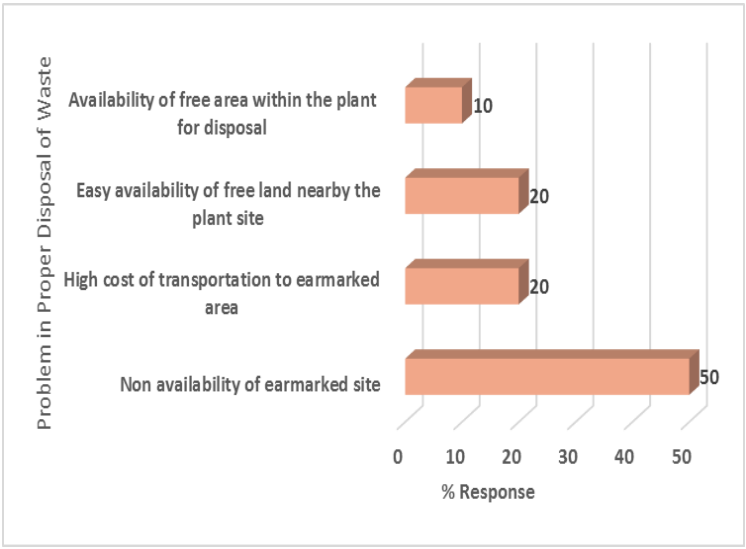
70% of the respondent kept silent on this important question regarding mode of disposal of the waste and 10% accepted to dispose it on earmarked site which clears that waste is not disposed off in productive ways which hampers the environment. Hence, waste generation is high but waste management issues have not been sincerely addressed by industries.

Further, problems faced by industries in waste disposal have been assessed by researchers and indicated in Table 3 and Graph 3.

Table 3: Problem in proper Disposal of waste

Response	N	%
Non availability of earmarked site	5	50
High cost of transportation to earmarked area	2	20
Easy availability of free land nearby the plant site	2	20
Availability of free area within the plant for disposal	1	10
Total	**10**	**100.00**

Graph 3: Problem in proper Disposal of waste



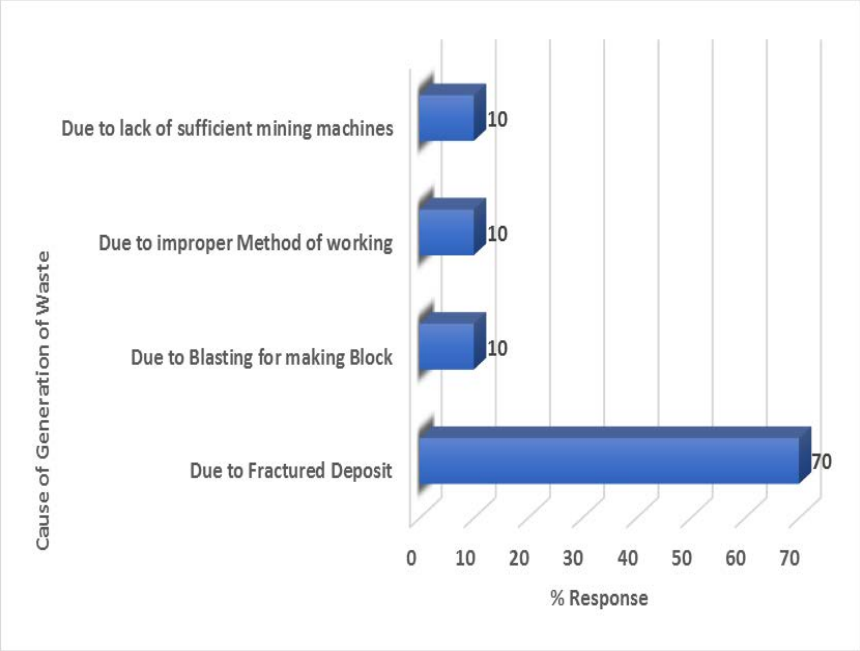
50 % of the respondent realized the most important problem is non availability of the earmarked site near their mines, more than 20 % accepted that free dumping land is available near their site. 20% found high cost of transportation of waste to earmarked site. Due to these problems of waste disposal, environment problems are arising.

By reducing the marble waste generation problems like waste disposal and its impact on environment may be reduced. Therefore, root causes of marble waste generation have been analyzed and represented in Table 4 and Graph 4.

Table 4: Cause of generation of waste

Causes	N	%
Due to Fractured Deposit	7	70
Due to Blasting for making Block	1	10
Due to improper Method of working	1	10
Due to lack of sufficient mining machines	1	10
Total	**10**	**100.00**

Graph 4: Cause of generation of waste



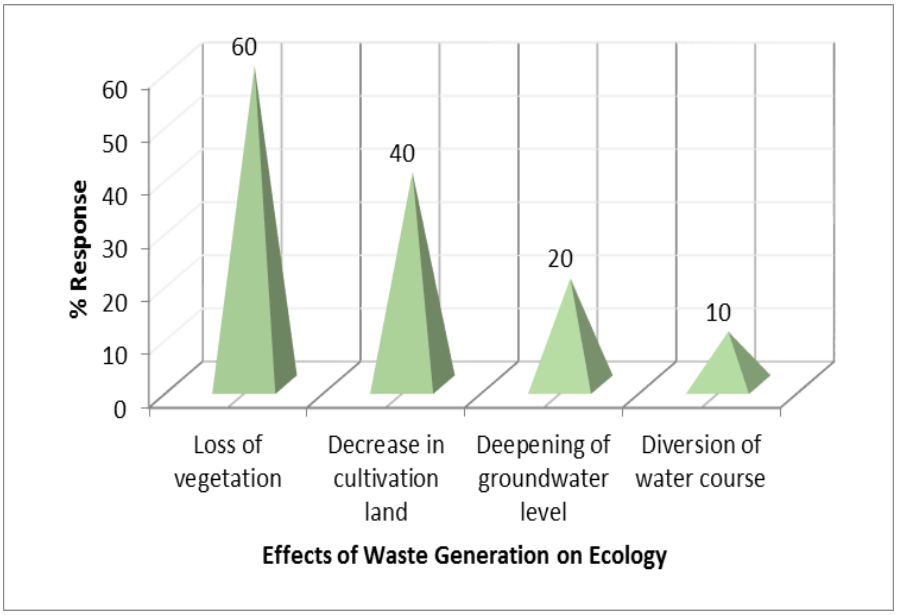
It has been identified that the main cause of waste generation is fractured deposit; nearly 70% mines owners realized that this is the major cause of waste generation in marble mining. Remaining respondents replies with unremarkable answers.

Researchers on other side have also recognized the scale of ecology damage in various sectors shown in Table 5 and Graph 5.

Table 5: Effects of waste generation on ecology

Response	N	%
Loss of vegetation	6	60
Decrease in cultivation land	4	40
Deepening of groundwater level	2	20
Diversion of water course	1	10

Graph5: Effects of waste generation on ecology



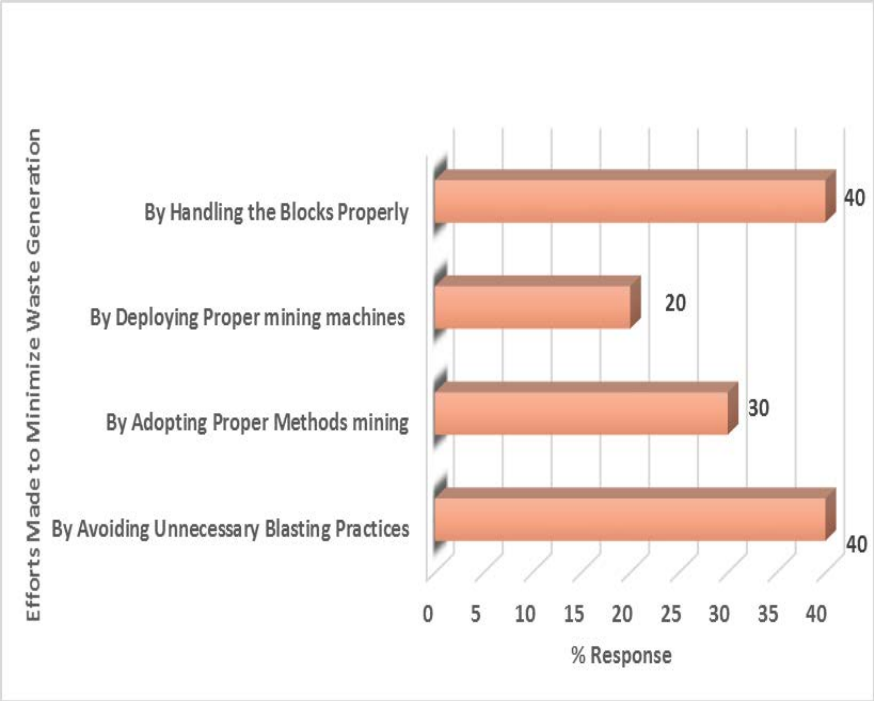
The main effect of waste generation on ecology as responded by 60% respondents is loss of vegetation and 40% say that it decreases the cultivating land.20% of the respondents of the mines under research study reported it as deepening of ground water as an effect of waste generation. However 10% are in opinion of diversion of water course as an effect of waste generation.

Poor waste management of marble waste has been majorly damaging vegetation and cultivating land. So it is important to alter on current practices to ensure minimum waste. Opinion on minimizing marble waste have been taken from industries again and get multiple responses and are encapsulated in Table 6 and Graph 6.

Table 6: Efforts made to minimize waste generation

Response	N	%
By Avoiding Unnecessary Blasting Practices	4	40
By Adopting Proper Methods mining	3	30
By Deploying Proper mining machines	2	20
By Handling the Blocks Properly	4	40

Graph 6: Efforts made to minimize waste generation



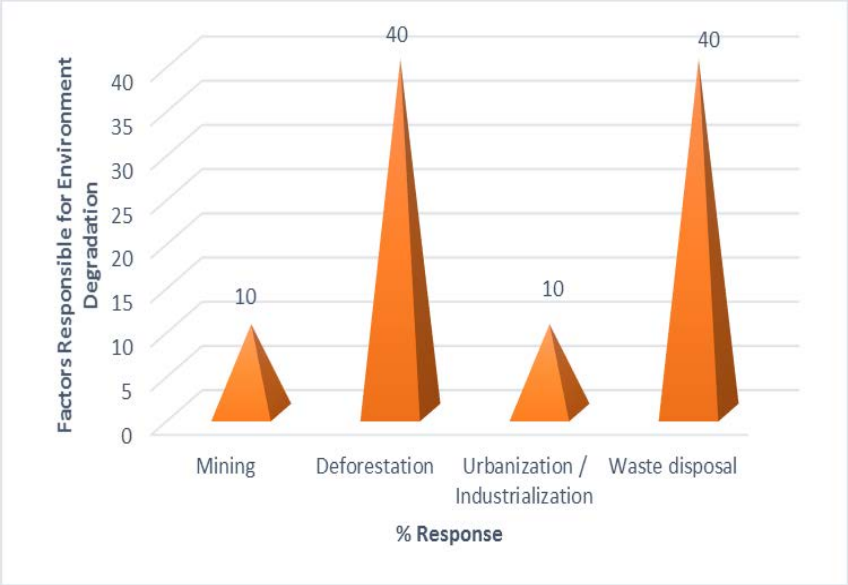
Proper care taken in handling the blocks can reduce the waste to great extent as reported by 40% respondents. 40 % say that waste can be minimized by avoiding blasting practices in marble mining, 30 % are in the opinion that waste can be minimized by adopting proper mining methods. 20% relieved that proper use of mining machines can also reduce generation of waste to a great tent.

A general observation on environment degradation was also taken from the industry personnel to enhance awareness concerns among them. The responses have been shown in Table 7 and Graph 7.

Table 7: Factors responsible for environment degradation

Response	N	%
Mining	1	10
Deforestation	4	40
Urbanization / Industrialization	1	10
Waste disposal	4	40
Total	**10**	**100**

Graph 7: Factors responsible for environment degradation

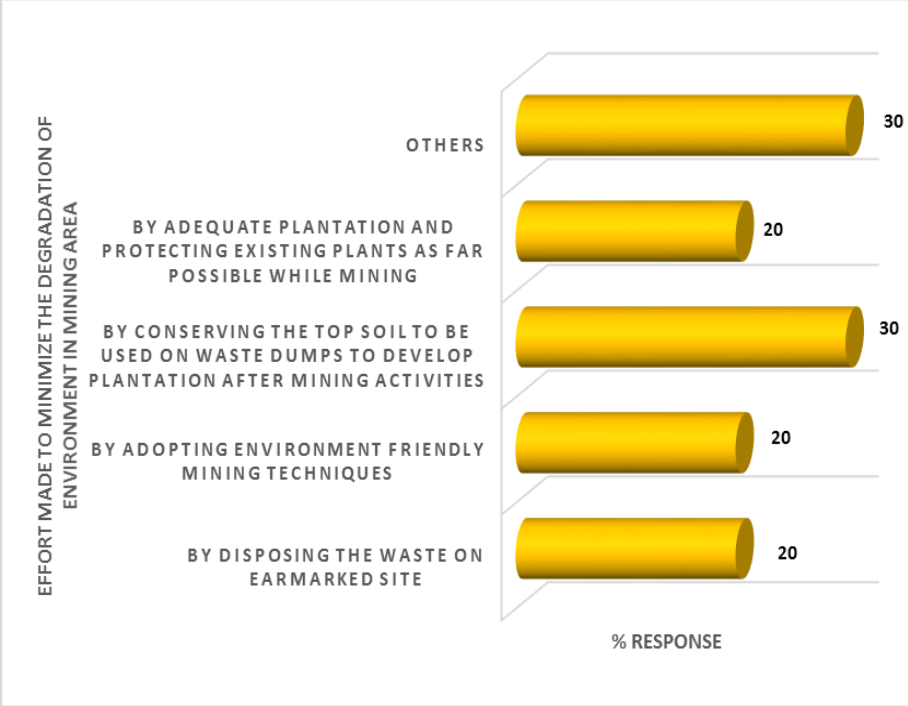


10% mine operators are in the opinion as mining to be responsible for environmental degradation.40% Mining people claimed deforestation to main cause of this degradation. However 40% of the respondents were in the view that waste disposal was also a cause of environmental degradation. Hence, it has been pointed out that both poor waste disposal methodology and deforestation activities are contributing majorly towards environment degradation. Further, various options have been identified by researcher to save environment via improved marble mining activities and shared with marble mining personnel. Multiple responses on these options are recorded in Table 8, 9,10 and Graph 8, 9,10.

Table 8: Effort made to minimize the degradation of environment in mining area

Response	N	%
By Disposing the Waste on Earmarked site	2	20
By Adopting Environment friendly mining techniques	2	20
By Conserving the top soil to be used on waste dumps to develop Plantation after mining activities	3	30
By Adequate Plantation and Protecting existing Plants as far Possible while mining	2	20
Others	3	30

Graph 8: Effort made to minimize the degradation of environment in mining area



There was quite mixed opinion of the representative at the mine regarding efforts made by them to minimize the degradation of environment in vicinity of their mines. 30 % relieved that they conserve top soil to be used on waste dumps to develop plantation after mining is over, about 20 % told that they minimize the degradation by disposing the waste at earmarked site for this, 20 % do this by adopting environmental friendly mining techniques. Lager portion about 30 % were making other efforts to minimize the degradation of the environment. It is observed that sincere efforts are missing towards technological advancement which can lead to marble waste reduction during processing.

Table 9: Efforts made to upgrade / protect ecology and environment by utilizing the waste at mining site

Response	N	%
Sufficient Trees / Plants have been developed with mining on non-mining area	3	30
The top soil of all mining area has been preserved to be used after mining activities to recover the vegetation as initial condition	2	20
The waste generated has been dumped on earmarked area	1	10
Optimum Plantation has been done on dumping site	4	40
Others	1	10

Graph 9: Efforts made to upgrade / protect ecology and environment by utilizing the waste at mining site

Various efforts have been made by the mines owners of the research area.30% mine owner have done optimum plantation on dumping site to enhance vegetation in area. 30% have planted sufficient trees in mining and non-mining area.20% of the respondents have preserved the top soil to be used afterwards the mining activity is over to grow vegetation in mined out area.

Table 10: Various methods of waste utilization

Response	N	%
Road / building construction	5	50
Filling of mined out area	2	20
Preparation of marble chips and powder for industrial use	1	10
Other	3	30

Graph 10: Various methods of waste utilization

50% mine owners of the research area utilize the waste in road and building construction.20% use the waste in filling the mined out areas. Whereas 30% adopted other methods to utilize the waste generated in mining.

5. Conclusions

Necessary measures to reduce the damage to environment and ecology of the mining area for waste disposal and vicinity need to be taken to go a long way to better the quality and management of the environment in marble mining sector. By adopting proper mines waste disposal methods this can be checked. Better technique of mining with least blasting and deployment of mining machineries is adopted so as least waste is generated in mining operations. Proper land area be identified and allotted closer to the marble processing centers, for disposal of the pressed marble slurry cake. This land should be developed as a proper landfill site for which competent consultants should be engaged. It should be ensured that the marble slurry is disposed off only at the above earmarked site. To manage this site, a Trust be formed comprising of the representatives of Administration as well as the Industry. Sufficient land is earmarked around this landfill site for allotment to entrepreneurs for Producing Building / Construction material based on marble slurry and these units may be developed in a cluster. The mine owners and processors must be bound to dispose the waste at such site that can be reused by various users of the waste in form of building material, filling material or ornamental by products out of the waste irrespective of the dumping cost or disposal cost with implementation of rules under environmental protection rules. Regular maintenance of mine-machinery etc. stress on systematic development of mining pit for block mining. Introduction of pollution control measure at various levels (especially for dust and noise). Environmental control through regular monitoring and assessment with respect to changes was seen in surrounding land quality, workers health, surface and underground water, flora and fauna etc. Waste disposal and reclamation of waste land by afforestation. Roads of better quality for safe transportation of heavy marble blocks to reduce transportation waste.

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