ENVIRONMENTAL IMPACT ASSESSMENT OF BAUXITE MINING SITES IN COASTAL AREAS – CASE STUDY RAIGAD DISTRICT, MAHARASHTRA, INDIA.

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ABSTRACT:
Coastal zone is important for habitats of wildlife, as a safety barrier, food source, mineral resource, recreational area and for industries. Coastal regions are resourceful regions and have the potential for different human activities. Coastal zones are very sensitive and all the human activities are affecting this area and are of important environmental concern. Although human activities like Aquaculture, mining and beach tourism boost the economy and provide employment opportunities to the local people they are also polluting and creating harm to the environment to a great extent.
The paper presents the study of environmental impacts of Bauxite mining in some parts of the Raigad District, Maharashtra, India. This study has taken into consideration physical, geographical, ecological and socio-economic components to study the environmental impacts of different mining processes. To assess the impacts, Rapid Impact Assessment Matrix (RIAM) has been used and the results have clearly shown that there are major negative impacts on the environment like loss of biodiversity, air, water and noise pollution, displacements of settlements. At the mining sites of Harvit, Dandguri –Khujare, Kurwade – Maral and Devkhol are left without backfilling and levelling after extraction of bauxite ore, which lead to the risk of landslides and erosion, Also as per EIA, the mining company has to backfill the area and the has to do plantation It is also observed that, due to blasting, cracks are developed on the walls of structures in Harvit and Kurwade villages. Negative impacts like these can be minimized by adopting sustainable mining methods and also by following Green mining in different countries worldwide. However, mining also has a positive impact on the region like employment opportunities, financial and economic development of any region, and ultimately of any nation.

Keywords: Bauxite mining, Environmental impact analysis, RIAM

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1. Introduction:

Raigad District is one of the coastal districts along the west coast of India. It is an administrative part of the Konkan region of Maharashtra. The geographical position of the district has advantages and has great potential for different residential, recreational, industrial and commercial activities (https://raigad.gov.in/, 2021). Agriculture, fishing, tourism, port construction, sand dredging, poultry, mining, steel industries, fruit processing industries, cottage industries are the activities along the coastal region of the Raigad district. Besides all these activities in the region aquaculture, mining and tourism activities are growing rapidly.

The study area, Raigad District is a part of the western coast of Maharashtra, India. The study area has a reserve forest and dense vegetation (Survey of India toposheet no. 47F/2, 3, 4 and 47G/11 and 47B/16, 1977). The District has a long indented coastline, of 240 km with several creeks and estuaries (Karlekar, 2009). The District has been covered with Deccan basalt, basalt and the laterites are spread in the form of spurs, hills and plateaus (Kale, 2002) and the region is formed with Basalt and Laterite.

The occurrence of laterites as thin surfaces on high plateaus or in low-lying coastal areas. Based on the mode of occurrence, laterite was divided into high-level and low-level by Medlicott and Blanford (1879). Based on the chemical composition mainly SiO2, Al2O3 and Fe2O3 proportions, Martin and Doyne (1927) divided laterite and lateritic soils, While the ratio of Al2O3 and Fe2O3 is used to identify Ferruginous laterite and SiO2, Al2O3 for Aluminous laterite (Sinha Roy, 1967, Karunakaran and Sinha Roy, 1971).

Laterite occurs on the hilltops and at the lower levels in the study area. The laterite deposits are mainly used as bauxite ore. Laterites occur as a capping on the hilltops and also in lower coastal areas (Medlicott and Blanford). The laterite produced in Maharashtra is of two grades alumina grade and cement grade. The alumina-grade production in Maharashtra is limited to very few mines in the study area. Other uses of laterite are cement, abrasive, and chemical. For use in alumina and alumina and aluminium extraction, Al2O3 content of 40 to 45 % was not reported in Maharashtra till 2013 (IBM, 2015). It is also important to note that the production of laterite has increased in recent years (IBM. 2021).

Bauxite is available in many parts of the District. Approximately 12.394 million tonnes of ores are found in the Raigad District (https://www.mahadgm.gov.in/, 2020 (10)). Bauxite is the good source of aluminium. It occurs in the form of capping on the hills in Raigad District and the ore is suitable for the extraction of alumina. Bauxite ore is extracted in the region is utilised to the manufacture aluminium.

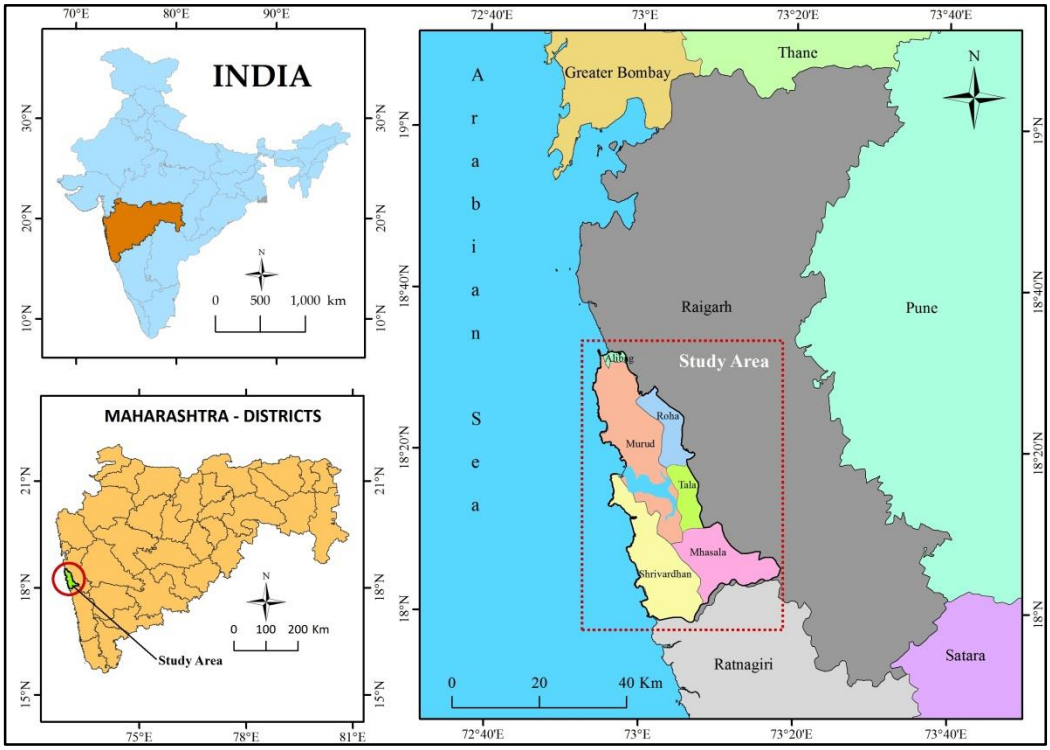

Fig.1. Location map of the study area

Thus, mining activities in any areas are responsible for the various environmental problems. After starting the mines, land degradation starts with the land clearing for the ore extraction which is the foremost process of it. After the clearing process, the mineral extraction process starts and lead to environmental pollution. Once the ore has been extracted, a large amount of waste material has been generated which is then dumped aside in and around the mining area. Also at the time of mine closure, as per the environmental act, the company has to do backfilling and plantation as well. But backfilling and plantation have not been seen in the study area where the mines have been closed. Hence this temporary economic activity leaves long term environmental issues. Therefore it is necessary to follow sustainable and environmental sensitive mining methods.

For the present study mining sites in Raigad District are considered and accordingly the physical setup of this area has been assessed.

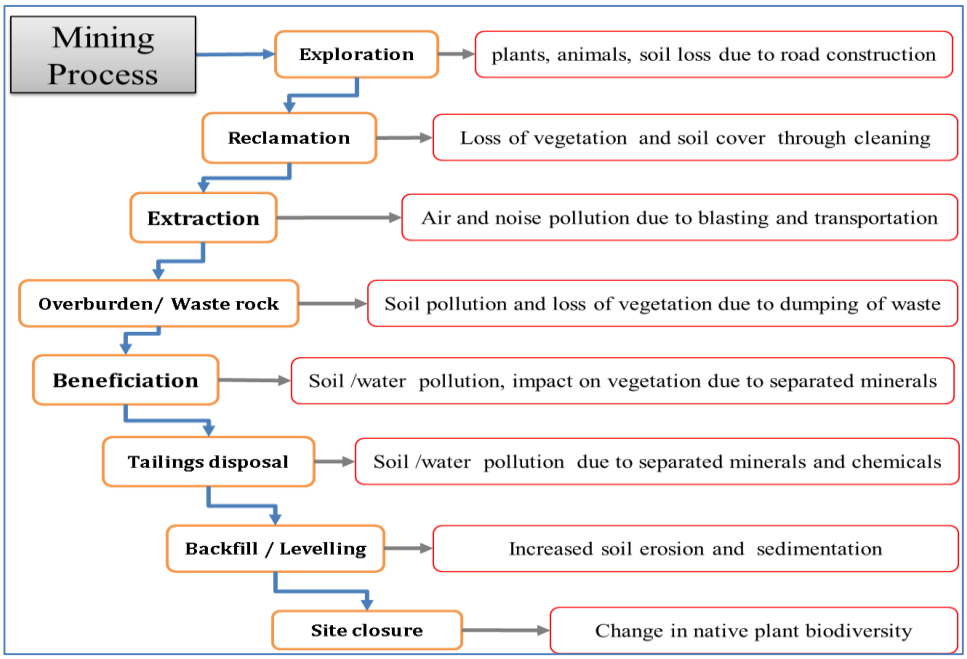

Fig. 2. Generalised mining process at mining areas

Table 1. Mining sites in the study area

Sr. No.	Village	Area (Hectares)	Elevation above MSL	Nearby Settlements
1	Harvit	16.86	121m	Kudgaon, Harvit
2	Kurwade	16.86	139m	Kurawade, Maral
3	Deokhol	44.33	164m	Chikhalap, Hunarveli, Shirvane
4	Dandgauri - Khujare	71.42	128m	Khujare, Asuf, Dandguri
5	DBS – Danda, Bagmandala, Saigaon	148.5	221m	Danda, Bagmandala, Saigaon

Source: Field survey, Author

2. Database and Methodology:

The database used in this study is primary data. The locals are interviewed, they are asked to score the qualitative conditions of the environment, socio-cultural aspects and also economic and operational aspects (Table no. 4) which are affected either positively or negatively by the process of mining in their surroundings. To collect data, people in the form of the focus group were also interviewed to understand their perceptions about the qualitative changes in their immediate surroundings. Based on the responses received from an individual and the members of the focus group, and the scores of the evaluation criterion (Table no.4) final calculation of the environmental score is done. After getting the scores, RIAM environmental scores are calculated. Based on the site-specific RIAM matrix of Physical/geographical, biological/ ecological, social/cultural and economic/ operational matrixes are calculated for all the sites. The representative RIAM matrixes for the Harvit site are given in Tables 6 to 9. Using all the outputs together a final average environmental

score is calculated (Table no, 11). Based on people's perceptions and field observations, the results are finalised.

The environmental impact assessment was focused basically on the following four primary fields:

1. Physical and Geographical aspects
2. Biological and Ecological aspects
3. Sociological and Cultural aspects
4. Economic and operational aspects

In all the above four fields, physical and geographical aspects include land erosion and degradation, and degradation of the physical environment through pollution and mining activities. Biological and ecological aspects include renewable natural resources, conservation of biodiversity and pollution of the biosphere. Sociological and cultural aspects include all the human aspects of the environment that affects the individuals and the communities of that area. Cultural aspects include inheritance conservation and human development projects and programmes. Economical and operational aspects include the positive and negative impacts of the mining operation and also the changes in the environment whether it is permanent or temporary (Sundarakumar, 2010).

The impacts were studied, quantified and assessed based on the field data collected through questionnaire surveys and during field observations. The positive or negative impacts have been compared with the Rapid Impact Assessment Matrix (RIAM) method which provides a transparent analysis of environmental impacts of mining activity. The matrix is based on scoring impact component problems against pre-defined aspects and transferring scores to describe positive and negative impacts (Pastakia 1998).

3. Impact identification and scoping:

For the environmental impact assessment of mining activity, the considered four major fields or components have been decided based on the mining process, which includes exploration, reclamation, extraction, overburden or waste rock, beneficiation, tailings disposal, backfill or levelling and site closure etc. (Fig.2)

The entire mining process (Fig. 2) has affected the important environmental components of the study area that are land use, landscape, air-water quality, flora and fauna, water resources, socio-economic, hazards and risks, public health and safety. Therefore, for the detail impact assessment physical, biological, sociological and economical components for each mining site have been considered. Each component further subdivided into other variables (Table 2 & 3).

Table 2. Physical and Biological components used for impact assessment

Physical /Geographical		Biological /Ecological	
PG1	Landscape	**BE1**	Deforestation
PG2	Land/ Soil erosion	**BE2**	Flora and Fauna
PG3	Air Pollution	**BE3**	Natural Habitats
PG4	Water Pollution	**BE4**	Wildlife and Birds
PG5	Noise Pollution	**BE5**	Ecological balance
PG6	Landslides	**BE6**	Solid wastes and disposal
PG7	Vibrations	**BE7**	Sewage disposal
PG8	Geological changes	**BE8**	Natural resources

Source: Field survey & Pastakia 1998 & K. Sundara Kumar, 2010

Table 3. Sociological and Economical components used for impact assessment

Sociological / Cultural		Economical / Operational	
SC1	Resettlement	**EO1**	Loss of nearby land value
SC2	Loss of Livelihood	**EO2**	Loss of resources
SC3	Loss of lives or Accidents	**EO3**	Productivity of land
SC4	Damage to property	**EO4**	Financial development
SC5	Education / Training	**EO5**	Commercial establishments
SC6	Health aspects	**EO6**	Employment opportunities
SC7	Power / Water supply	**EO7**	No Green belt development
SC8	Recreation facilities		
SC9	Aesthetics		

Source: Field survey & Pastakia 1998 & K. Sundara Kumar, 2010

Table 4. Description of the evaluation criteria

Evaluation Criteria	Description	Scores	Description
A1	Importance of the impact and effect	4	Important for the national interest
		3	Important for the regional interest
		2	Important for the areas out of the project
		1	Important for the local condition
		0	No geographical or other importance
A2	The magnitude of the change, damage and effect	+3	Major positive benefit
		+2	Significant improvement in the present condition
		+1	Improvement in the present condition
		0	No change/impact
		-1	A negative change in the present condition
		-2	A significant negative change in the present condition
		-3	A major negative change in the present condition
B1	The permanence of the impact-causing activity	3	Permanent: The project activity causing impact is meant to be a permanent. Example: loss of livelihoods, loss of bio-diversity, no green belt development.
		2	Temporary: The project activity causing impact is temporal. Example: Vibrations, resettlement.
		1	No change
B2	Reversibility of impact	3	Irreversible impact: The impact is irreversible if the original condition is not restored after the activity is finished. Such activity has changed the environment permanently for a long period. Example: loss of biodiversity, deforestation.
		2	Reversible impact: The impact is reversible if the original state will be restored after the activity is finished. Example: Air pollution, Noise pollution.
		1	Not applicable: Targeting the impact is impossible
B3	Accumulation of impact	3	The impact is cumulative. The project activity probable has a combined impact with other activities in the same area. Example: Noise pollution, air pollution and wastewater emissions, impact, in general, is often cumulative.
		2	Impact is non-cumulative
		1	No change/not applicable

(Source: Pastakia 1998 & K. Sundara Kumar, 2010)

The final assessment of Environmental Score (ES) is calculated as:

$AT = A1 \times A2$

$BT = B1 + B2 + B3$

$ES = AT \times BT$

Where,

A1 = Importance of the impact and effect; A2 = Magnitude of the change, damage and effect,

AT = Total of A1 & A2

B1 = Permanence of the impact-causing activity

B2 = Reversibility of impact

B3 = Accumulation of impact

BT = Total of B1, B2 & B3

ES = Environmental score

IC = Impact class

The evaluation criterions are of two types:

(A) Criteria that can change individual environmental score obtained;

(B) Criteria that individually cannot change the environmental assessment score (Table 4)

The mining project includes multiple activities and all these activities make an impact on the environment. Therefore, based on the above-identified components and their potential impact, scores have been assigned. For example, in the mineral extraction process mud is produced in a huge amount and it is considered a solid waste. This solid waste is dumped in the surrounding area of the mining site, so it has a negative impact on the vicinity areas and causes landslides. Hence, the score of A1 will be assigned as 2 as it causes an impact outside the mining project. As the magnitude of the effect is negative, the score for A2 will be -2. Lastly, the impact of solid waste is permanent, irreversible and cumulative. Hence, the scores of B1, B2 and B3 will be 3, 3, and 3 respectively. In this way, scores for all the components are assigned to each mining site in the study area.

Table5. Environmental Score range bands of RIAM

RIAM Environmental score ES	Range Value (RV) Alphabetic	Range Value (RV) Numeric	Description of Range bands
+108 to +72	E	5	Major positive impact
+71 to +36	D	4	Significant positive impact
+35 to +19	C	3	Moderate positive impact
+10 to +18	B	2	Positive impact
+1 to +9	A	1	Slight positive impact

0	N	0	No change
-1 to -9	-A	-1	Slight negative impact
-10 to -18	-B	-2	Negative impact
-19 to -35	-C	-3	Moderate negative impact
-36 to -71	-D	-4	Significant negative impact
-72 to -108	-E	-5	Major negative impact

Source: Pastakia and Jensen, 1998

4. Results:

Based on the observation of old, historical satellite images, mining activity in the study area is going on since the year 2001 and is altering the landscape with major changes. To study the environmental impacts of mining, Rapid Impact Assessment Matrix is used and studied all the mining sites in the study area. The input components and their assigned weights and classification are being explained in detail below:

1) RIAM for Harvit Bauxite mining site:

Table 6. Physical / Geographical components (PG)

Physical /Geographical		A1	A2	B1	B2	B3	ES	IC
PG1	Landscape	2	-3	3	3	3	-54	-D
PG2	Land/ Soil erosion	2	-3	3	3	3	-54	-D
PG3	Air Pollution	2	-3	2	2	3	-42	-D
PG4	Water Pollution	2	-2	2	2	2	-24	-C
PG5	Noise Pollution	2	-2	2	2	3	-28	-C
PG6	Landslides	2	-3	2	2	3	-42	-D
PG7	Vibrations	2	-3	2	2	3	-42	-D
PG8	Geological changes	3	-3	3	3	3	-81	-E
	Average ES						**-45.88**	**-D**

Table 7. Biological /Ecological components (BE)

Biological /Ecological		A1	A2	B1	B2	B3	ES	IC
BE1	Deforestation	3	-3	3	3	3	-81	-E
BE2	Flora and Fauna	3	-3	3	3	3	-81	-E
BE3	Natural Habitats	3	-3	3	3	3	-81	-E
BE4	Wildlife and Birds	3	-3	3	3	3	-81	-E
BE5	Ecological balance	3	-3	3	3	3	-81	-E
BE6	Solid wastes and disposal	2	-2	2	2	3	-28	-C
BE7	Sewage disposal	2	-2	2	2	3	-28	-C
BE8	Natural resources	3	-3	3	3	3	-81	-E
	Average ES						**-67.75**	**-D**

Table 8. Sociological / Cultural components (SC)

Sociological / Cultural		A1	A2	B1	B2	B3	ES	IC
SC1	Resettlement	3	-3	2	2	3	-63	-D
SC2	Loss of Livelihood	3	-3	3	3	3	-81	-E
SC3	Loss of lives or Accidents	3	-3	3	3	3	-81	-E
SC4	Damage to property	2	-2	2	3	3	-32	-C
SC5	Education / Training	2	2	3	3	3	36	+D
SC6	Health aspects	2	-3	3	3	3	-54	-D
SC7	Power / Water supply	2	-2	2	2	2	-24	-C
SC8	Recreation facilities	2	-3	3	3	2	-48	-D
SC9	Aesthetics	3	-3	3	3	3	-81	-E
	Average ES						**-45.63**	**-D**

Table 9. Economical / Operational components (EO)

Economical / Operational		A1	A2	B1	B2	B3	ES	IC
EO1	Loss nearby land value	2	-3	3	3	3	-54	-D
EO2	Loss of resources	2	-3	2	2	3	-42	-D
EO3	Productivity of land	2	-3	3	3	3	-54	-B
EO4	Financial development	3	3	2	2	3	63	+D

EO5	Commercial establishments	2	2	2	2	2	24	+D
EO6	Employment opportunities	2	3	2	2	2	36	+D
EO7	No Green belt development	3	-3	3	3	3	-81	-E
	Average ES						**-15.43**	**-C**

Table 10. Summary of components

Range	**-72 to-108**	**-36to-71**	**-19to -35**	**-10to -18**	**-1 to -9**	**0to 0**	**+1 to +9**	**+10 to +18**	**+19 to +35**	**+36 to +71**	**+72 to +108**
Class	**-E**	**-D**	**-C**	**-B**	**-A**	**N**	**+A**	**+B**	**+C**	**+D**	**+E**
PG	1	5	2	0	0	0	0	0	0	0	0
BE	6	0	2	0	0	0	0	0	0	0	0
SC	3	3	2	0	0	0	0	0	0	1	0
EO	1	2	0	1	0	0	0	0	0	3	0
Total	**11**	**10**	**6**	**1**	**0**	**0**	**0**	**0**	**0**	**4**	**0**

As per the above-mentioned calculations, weightage has been assigned as per description evaluation criteria (Table 4) to all other mining sites that are Kurwade-Maral, Devkhol, Dandguri-Khujare and Danda-Baghmandala-Saigaon. All the weights have been categorized as per Environmental Score range bands (Table 5) and the final average environmental score is calculated and categorized in specific impact classes as below:

Table 11. Average Environmental Score of all mining sites

Sr. No	**Site Name**	**Avg. PG.**	**Avg. BE.**	**Avg. SC.**	**Avg. EO.**	**Total Avg.**	**IC**	**IC Description**
1	Harvit	-45.88	-67.75	-45.63	-15.43	-43.67	-D	Significant negative impact
2	Kurwade	-44.63	-67.75	-47.11	-10.86	-42.59	-D	Significant negative impact
3	Deokhol	-42.88	-67.75	-38.38	-12.57	-40.40	-D	Significant negative impact
4	Dandguri – Khujare	-42.00	-69.50	-41.75	-12.86	-41.53	-D	Significant negative impact
5	DBS	-47.63	-72.00	-40.25	-17.14	-44.26	-D	Significant negative impact

5. Discussion and Conclusion:

Environmental impact assessment of Bauxite mining activity in the Raigad District has been carried out through Rapid Impact Assessment Matrix method. This method is useful to analyse environmental impacts easily and transparently. Based on the average table (Table 11), negative impacts of the mining activity are more than positive impacts in the study area.

At Harvit site, the mining company has reclaimed the land for the extraction of Bauxite which was rich in flora and fauna. Many herbs were also present there. Also, many villagers have reported that there are cracks on the walls of their houses due to blasting activity. These incidences were reported time to time to the company officials but neither the company has repaired the houses nor stopped the activity. Currently, the company has extracted all the Bauxite and left the depression as it is. The company has not done the backfilling and the plantation. Due to which landslides occurred and farmers faced heavy losses in farming. But the company has given training to the villagers about the mining processes to get employment opportunities. But later on, they only gave transportation jobs to local people.

Kurwade and Devkhol sites also have more negative impacts than positive impacts. The only positive impact is that there is a regional commercial development and the company has given employment opportunities as a driver to some villagers. Also, they have provided some funds for the educational activities in the village. The company has committed to provide educational and recreational facilities like school and garden to the villagers but failed to do it. The negative impacts of mining in these villages are loss of biodiversity, pollution, loss of habitats of wild animals, loss of aesthetic value of a place and loss of natural resources.

The Dandguri – Khujare and DBS (Danda – Bagmandala – Saigaon) sites have a large area than the other mining sites in the study area. Due to larger area and large scale blasting activity has created greater impact on the movement of wild animals and due to which wild animals scared and used to run away into the villages. In addition to this, blasting activity is also responsible for the damages to the residential structures of villagers. Many villagers have complained that transportation of extracted ore has generated the air and noise pollution in the study area. These sites provided security and driver jobs to the

villagers and also provided financial assistance in the form of funds for educational activities in the village.

In the field, it was reported by local people that the site was rich in flora and fauna. Before mining, many important herbs were also present there. Initially, the locals were trained to work on mining sites but they had meagre opportunities. Many villagers reported that due to blasting at the mining site, cracks are developed in the walls of the houses. Now, at the mining site of Harvit, the ore has been completely extracted and the site is abandoned. It was observed and confirmed through site visits that, no backfill or afforestation is done after the ore extraction. Due to the downslope movement of the dumped material, the farming around the site has been badly affected.

Hence, it can be concluded that most of the negative impacts are in Physical-geographical and biological, ecological components at all the sites but positive impacts are only related to economical components that are for employment opportunities and financial – commercial development. But these opportunities are temporary as with the mine closure there are no opportunities for developments in the areas.

The RIAM carried out for the mining sites in the coastal areas of Raigad District indicated that all the mining sites are found to be under the 'Significant moderate impact' category. Therefore, it can be concluded that mining activity carried out in the study area has resulted in temporary economic development but lead to environmental degradation which is the permanent impact. All the negative impacts of mining can be minimized by the 'Environmental Management Plan' which includes measures to save environmental degradation and improvement of eco-profile of the project as well as the surrounding area. The outcome of the study will be of great help to planners and decision-makers to prepare strategies for 'Green Mining' which ultimately help to sustain the coastal environment.

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