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Environmental Inpact of Open PIT Mining: Case of Bauxite Mining in Guinea

-- A Review --

Mohamed Keita[1] and Oumar Traore[2]

[1]*Mining Department, China University of Mining and Geology, China.*

[2]*Geology Department, Odessa national university Mechnikova, Ukraine.*

Abstract

Bauxite is an important mineral for our society. Bauxite mining is becoming an environmental issue as the demand for aluminum increases in industry. Mining and its associated activities can be responsible for considerable environmental damage. this review discusses the direct and indirect impacts due to bauxite mining to the environment in boke region of GUINEA, Pollution of the water is evident by the colouration of water which in most of the rivers and streams in the mining area varies from brownish to reddish orange, Low pH, high electrical conductivity, high concentration of ions of sulphate and iron and toxic heavy metals, are some of the physicochemical and biological parameters which characterize the degradation of water quality, Contamination of Acid Mine Drainage (AMD) originating from mines and spoils, leaching of heavy metals are major causes of degradation of water quality and some recommendations of dust, water pollution and overburden management and control.

Keywords: Mining, water quality, Acid mine drainage, environmental damage.

1. INTRODUCTION:

Mining is regarded as the world's oldest and the most important activity after agriculture. Mining activities have made tremendous and significant contributions to the world's civilization. Aluminum is the most plentiful metal in earth's crust, representing more than 7% by weight it is the third most abundant element after silicon and oxygen. west Africa basement complex contains large bauxite reserve. GUINEA bauxite reserves are estimated at over 40 billion tons [1]. 23 billion tons of which are located in BOKE region. The reserves are mainly located in following region: boke, kindia, boffa, pita, mali, mamou, dalaba dinguiraye, dabola and siguiri[2].Bauxite and alumina production have been of critical importance to the post-independence Guinean economy. In fact, activities had already begun at several sites during the colonial period and, as is often overlooked, Pechiney's important activities were to continue even after President Sekou Toure's radical break with the French metropolitan power with the referendum of September 28, 1958 [3]. During the first Republic (1958-1984), three main sites were in operation, two of which produced and exported bauxite, and one alumina [4]. Bauxite mining and alumina production provide about 80% of guinea's foreign exchange. Lately, with the increase of alumina demand from the booming economy of china, there is a renew interest in guinea riches. The consortium ALCAN and ALCOA partner with the Guinean government in the CBG (guinea's bauxite company) mining in boke have announced the feasibility study for the construction of 1 million TPa alumina smelter [5]. This comes with a similar project from Canadian start-up global alumina come with a 2-billion-dollar alumina plant in the same region. The Guinean economy is relying on mining (26% of GDP, including the alumina bauxite processing) and agriculture (20%), Mining is the foremost providing 85% of export revenues (ITIE, 2016) and the second at national level. The share of exports in GDP has increased from 34% in 2005 to 41% in 2009, reflecting strong global demand for bauxite, diamonds and gold, and the weakness of the rest of the Guinean economy[Table1] [6]. Guinea bauxite boom has generated thousands of jobs in boke region. SMB employs directly 7663 people and a father 10000 people indirectly. CBG in May 2018 employed 2248 people directly and father 2254 through subcontractors. Despite the creation of job, however, the influx of mining companies into boke region has caused hyper-pollution due to extraction techniques associated with open cast, surface mining, blasting mine, untreated waste water, tailing storage, improper disposal of bauxite residues and toxic wastes that spill directly into the rivers. Boke mining companies still use methods that have been bound such as blasting method used by SMB and CBG. Environmental justice atlas reported 20 houses collapsed in 2015 in the village of Bhoudou waadhe 7km from the sangaredi mine due to the effect of blasting vibration, muddy water has polluted the rivers, the fertility of agricultural fields and vegetable gardens is decreasing, the villager also report respiration problem and coughs [7].

Table 1: Contribution of mining sector in the gross domestic product (GDP) of Guinea 2010-1014.source: MP/DNP, 2014 November.

	2010	2011	2012	2013	2014
1-GROWTH					
GDP (in %)	1.9	3.9	3.9	2.3	1.3
GDP per capita (in %)	-1.2	0.6	0.7	-0.9	-1.8
GDP per capita (in USD)	382.5	406.9	508.7	508.7	502.4
GDP per capita (in USD)	412.9	450.7	538.3	538.3	530.6
2-CONSTANT PRICES TO GDP					
Total (in billions FNG)	8022.47	8333.32	8658.80	8856.91	8975.09
Mining sector (in billions FNG)	1166.05	1216.03	1191.08	1110.12	1153.81
Mining sector (in %)	14.5	14.6	13.8	12.5	12.9
3-CURRENT PRICES GDP					
Total (int billions FNG)	27081.62	34320.47	40082.58	44783.05	46180.92
Mining sector (in billions FNG)	6322.87	7761.23	7476.23	7248.27	6876.17
Mining sector (in %)	23.3	22.6	18.7	16.2	14.6

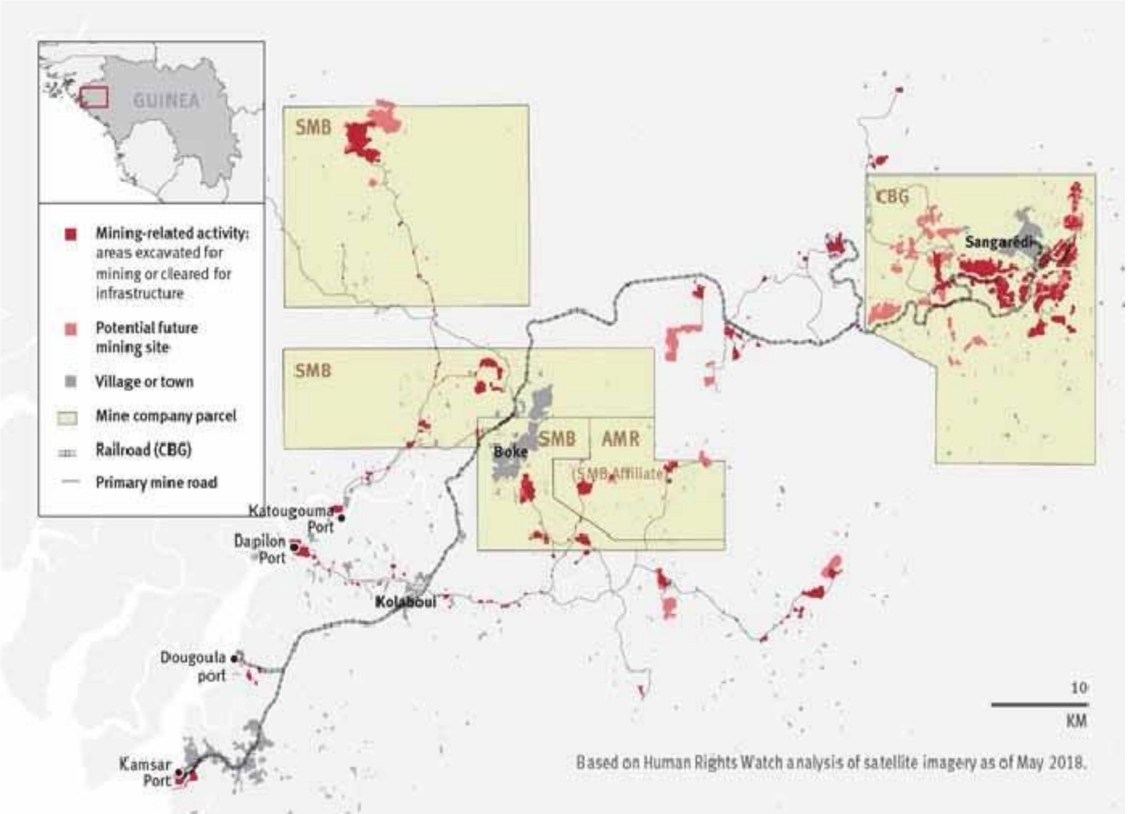

Figure 1: Mining activity areas in the Boké region source: Human Rights Watch.

2. ACIDE MINING DRAINAGE AND WATER QUALITY

Apart from altering the natural landscape, metalliferous mine tailings and stockpiled overburden pose serious pollution hazards to the environment, to human health and to agriculture. Groundwater pollution due to acid mine drainage and seepage from mine waste disposal are the most common environmental concerns [8].

When a Sulphur-rich rock is exposed as a result of weathering or by the process of mining, the sulphides in the presence of water react to form sulphuric acid. The acid so formed further dissolves and leaches out the metals present in the ore promoting high concentrations [9] .Mining and beneficiation operations greatly increase the rate of these same chemical reactions by removing sulphide rock overburden material and exposing the material to air and water. The dominance of the oxidation reactions become obvious when discharged ground water comes into contact with oxygen, precipitating iron oxihydroxides and decreasing pH[10]. Once acid drainage has occurred, controlling the releases is a difficult and costly problem. Hence prediction is becoming an important tool for regulators and operators. The addition of alkaline substances (crushed limestone to the overburden before dumping can reduce the acid drainage [10].The chemical reactions that cause mine water pollution start when the mine is working. Water in the mine is controlled by pumping, to keep the mine dry. Sulphide minerals, which are found in coal seams and mineral veins, particularly iron pyrites, are exposed to air and release sulphate and soluble metal ions. When the mines close, the pumps are switched off and the groundwater level rises until it reaches the surface or discharges into overlying aquifers. This may take a few months or many years. Flooding of the exposed seams stops the oxidation of the sulphide minerals, but dissolves the metal ions and sulphates to form sulphuric acid. The effect of this depends on the nature of the rocks. If they contain calcite or other carbonate minerals, the acidic mine water can be neutralised and metals may stay immobile. Commonly, however, the water dissolves any metal compounds present resulting in high concentrations of metals, particularly iron, zinc, copper, lead, cadmium, manganese and aluminum. The quality of mine waters varies considerably; they may be alkaline, acidic, ferruginous, highly Saline or clean [11] .Mining had reduced water levels and quality in the local rivers in boke, streams and wells. In several communities adjacent to SMB mines, damage to natural water sources meant villagers were for long periods forced to rely on SMB to bring them water in tankers (Human Rights Watch).

Table 2: Physicochemical and bacteriological analyzes of the Cogon station source: CBG.

PARAMETER	UNIT	WHO STANDARD	SURFACE WATER					
			January			September		
			Raw water	Decanted water	Distilled water	Raw water	Decanted water	Distilled water
P^H	PH	6.5-8.5	7.32	7.05	6.91	6.96	5.86	5.14
Total chlorine	mg/l	0.75-1.40	--	--	3.2	--	--	1.98
Temperature	°C	0-25	22.7	22.6	22.8	26.5	26.1	26.4
Conductivity	MS/cm	0-400	13	35	39	12	28	35
Color	Mg/l Pt/Co	0-15	30	27	19	40	58	14
Turbidity	NTU	0-4	1	2	1	7	11	3
Iron	mg/l	0.3-1.0	0.41	0.37	0.23	0.35	0.38	0.18
Sulfate	mg/l	0-400	1	14	12	4	14	15
Magnesium	mg/l	0-50	0.52	0.76	0.96	0.56	0.52	0.44
Calcium	mg/l	0-100	1.68	4.68	4.4	0.88	2.8	4.44
chlorides	mg/l	0-25	0.3	1.5	1.9	1.5	0.3	1.1
Nitrates	mg/l	0-44	0.44	1.32	1.76	--	--	--
Nitrites	mg/l	0-0.1	0.0066	0.0033	0.0066	--	--	--

Table 3: Physicochemical analysis of the waters of some streams in the study area

Parameter	Laafu	M'Bouroué	Thiapikouré	Pora1	Pora2	Cogon	WHO STANDAD
Temperature °C	28	28	28	26	26	26,7	0-25
P^H at 25 ° C	-	-	6.9	7.10	7.10	7.00	6.5-8.5
Conductivity μs/cm	-	-	23	18	-	14.5	0-400
Calcium (Ca^{2+}) mg/l	6	0.6	0.5	0.5	0.5	1.52	0-100
Magnesium (Mg^{2+}) mg/l	2.7	0.4	0.4	0.3	0.3	0	0-50
Sodium (Na^{+}) mg/l	2.5	0.66	0.66	0.66	1.00	-	-
Total iron (Fe) mg/l	0	0.2	0.06	0.07	0.07	0.35	0.3-1.00
Ammonium (NH_4^{+}) mg/l	0.19	0.33	0.25	0.26	-	-	-
Bicarbonates (HCO_3^{-}) mg/l	34.2	4.9	4.9	3.7	4.00	-	-
chlorides (Cl^{-}) mg/l	1.75	1.38	1.38	1.10	-	-	0-25
Nitrites (NO_2^{-})mg/l	0.006	0.064	0.064	0.012	0.2	0.5	0-1
Nitrates(NO_3^{-}) mg/l	0	0	0	0,44	1,2	0,44	0-0.44
Ortophosphores (PO_4^{3-}) mg/l	0.07	0.08	0.08	0.11	-	-	-
phosphorus (P)	0.02	0.03	0.03	0.04	-	-	-
Potassium (K^{+}) mg/l	0.33	0.33	0.13	0.10	0.10	-	-

During the dry season all parameters meet WHO standards. This shows that surface water is not polluted by the operations of the blasting process. Unlike the dry season, during the winter season, temperature, turbidity, color do not meet WHO standards. This indicates that the surface water is really polluted during this period. In the alluvial zone mainly, the degradations are important by modification of the piezometric regime, by the vulnerability to the pollution of the updated aquifers, by the contamination of the brooks and rivers. *Table 1-2.*

3. AIR QUALITY

There are various dust generating activities and processes in the mining industry. Sources such as material storage silos, process boilers and heaters, onsite power generators etc. are the major point sources in the mining industry. The exhaust gases emanating from the mining equipment and other vehicles operated within the mine site are mobile sources of particulate matters. But the most predominant sources of particulates in the mining industry are the fugitive dust sources. Fugitive sources comprise earth moving and material handling operations, crushing, screening, milling, blasting and drilling, haul roads, and wind erosion of exposed surfaces. Fugitive sources are more difficult to control as compared to point sources. Mine dust can cause serious nuisance and aesthetic. Deterioration in the surrounding environment and communities. Fortunately, due to relatively large particulate matter sizes associated with the mining emissions and the relatively short release height of the pollutants, such negative impacts are usually confined in relatively small areas. Within these areas of impact, fugitive dust may result in damage to the vegetation, agriculture and human [12] .

Calculation of the quantity of rocks hole blasted case of CGB:

$$Qtr = a.\ b.\ hg,\ [m3] \qquad \text{Equation1}$$

a - distance between two consecutive holes (a = 6m)

b - Distances between two successive rows (b = 5m)

hg - Height of the step, varies currently 3 to 13 m is an average of 8m.

$$V = Qtr.\quad Ntr \qquad \text{Equation2}$$

Ntr- Numbers of drilled hole

Numbers of drilled hole (Ntr) in CBG mine is (80÷120) the average is 150 so the volume of blasted rocks is determined is 36000 m3. Considering that each blasting, the 2% of the volume of blasted rocks is transformed into dust, the volume of these will be: 720 m^3. With an annual production about of 15000.000 T / year a volume of 7653061m^3/year a probable emission of 153061 m^3 / year of dust into the atmosphere can be expected.

4. NOISE AND VIBRATION

Noise pollution associated with mining may include noise from vehicle engines, loading and unloading of rock into steel dumpers, chutes, power generation, and other sources. Cumulative impacts of shoveling, ripping, drilling, blasting, transport, crushing, grinding, and stock-piling can significantly affect wildlife and nearby residents. Vibrations are associated with many types of equipment used in mining operations, but blasting is considered the major source. Vibration has affected the stability of infrastructures, buildings, and homes of people living near large-scale open-pit mining operations[13] .Shocks and vibrations as a result of blasting in connection with mining can lead to noise, dust and collapse of structures in surrounding inhabited areas. The animal life, on which the local population may depend, might also be disturbed (European Union in 2000) .20 houses collapsed in 2015 in the village of Bhoudoun Waadhe 7km from the SANGAREDI mine due to the effect of blasting vibration (Environmental justice atlas).

Table 4: DIN-4150 standards on vibration frequencies related to building.

N°	TYPES OF BUILDINGS	Value of reference speed [mm/s]
1	- Residential, commercial and other similar buildings whose construction is in a state of conservation corresponding to the rules generally recognized by the construction technique.	8
2	- Buildings made very rigid with heavy parts and elements of rigid frames in a state of conservation corresponding tthe rules generally recognized by the construction technique.	30
3	- Buildings which are not in a conservation corresponding to the rules generally recognized by the technique of construction and the houses placed under the protection of the historical monuments.	4

Table 5: Comparison of Romanian and International Noise Standards.

Country/Region	Acceptable Noise Level, dB(A)		
	Industrial Areas, Day/Night	Commercial Areas, Day/Night	Residential Areas, Day/Night
Romania	65	65	50/40
EU(UN WHO)	65	55	55/45
Australia	65/55	55/45	45/35
Japan	60/50	60/50	45/35
USA	70	60	45

5. Loss of Land

The creation of landscape blots like open pits and piles of waste rocks due to mining operations can lead to the physical destruction of the land at the mining site. Such disruptions can contribute to the deterioration of the area's flora and fauna. There is also a huge possibility that many of the surface features that were present before mining activities cannot be replaced after the process has ended. The removal of soil layers and deep underground digging can destabilize the ground which threatens the future of roads and buildings in the area [3].Mining operations routinely modify the surrounding landscape by exposing previously undisturbed earthen materials. Erosion of exposed soils, extracted mineral ores, tailings, and fine material in waste rock piles can result in substantial sediment loading to surface waters and drainage ways. In addition, spills and leaks of hazardous materials and the deposition of contaminated windblown dust can lead to soil contamination (European Union).

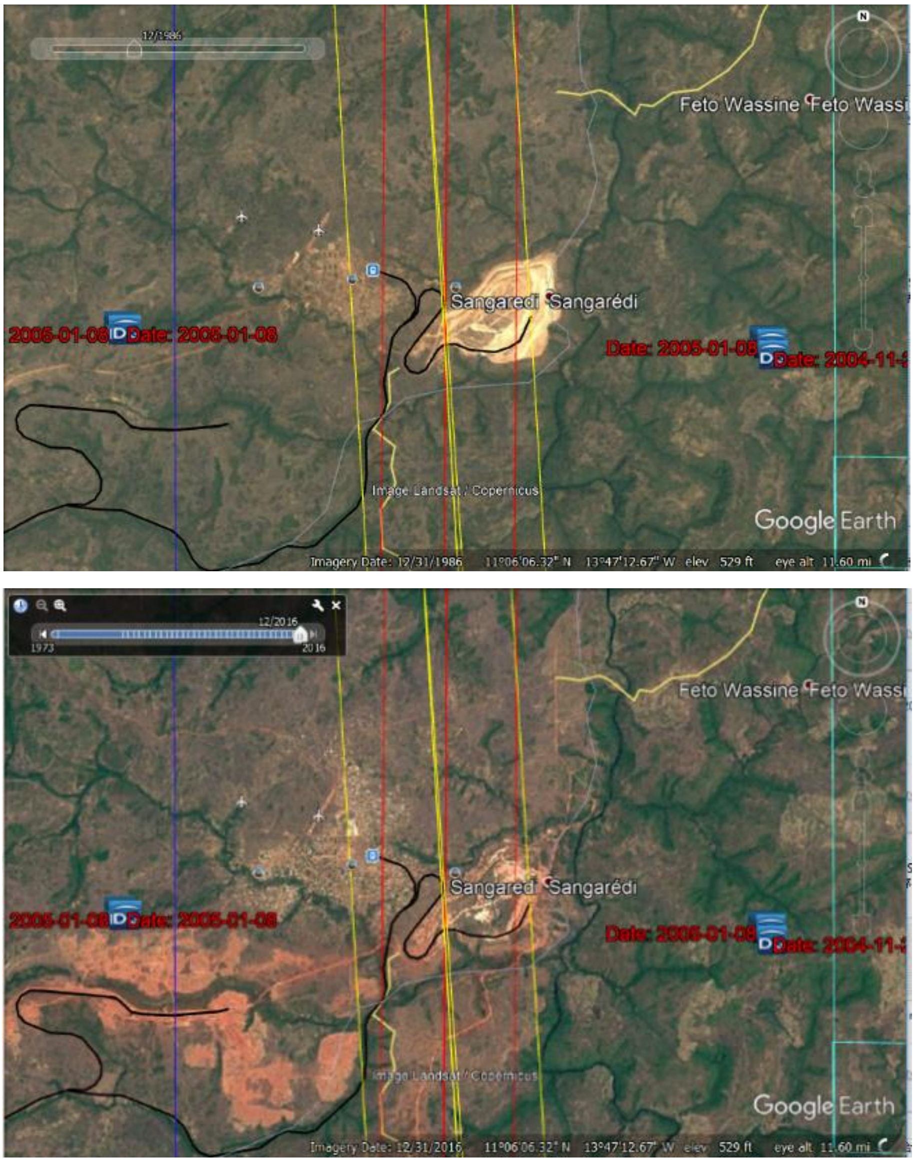

Figure 2: Satellite picture 1986 and 2016.

6. RECOMMENDATIONS

Redo impact assessments that did not involve effective consultation with local communities or which did not adequately assess or propose mitigation for the environmental and social consequences of mining. Improve internal monitoring of social and environmental impacts: Ensure that existing community relations teams and health, safety and environment staff are adequately staffed, resourced and trained to effectively monitor the environmental, social and human rights impacts of mining[14]. Conduct independent monitoring: Commission independent monitors, paid for by the company but operating as a separate entity, to periodically (every six months) evaluate the environmental and social impact of mining operations and publish periodic reports by those monitors. Improve transparency: Publish environmental and social impact assessments, environmental and social management plans and periodic environment monitoring reports. Summaries and full reports should be translated into local languages, made available online, and posted in public buildings, including at prefectures and sub prefectures in directly affected communities[14].

- **Dust control**

Operation of heavy earth moving machinery in the overburden dumps generate huge amount of dust and the high wind velocity moves the dust particle to the nearby residential areas which creates a lot of problems. The generation of dust particles can be controlled with the help of following methods [15]:

i. Water sprays can be used for control.

ii. The slope of the haul road in the dump should be optimized for the smooth movement of the dumper and that reduces the dust generation.

iii. Height of the waste rock dumping should be minimized to reduce the dust generation by wind erosion.

iv. The dumps should be wherever feasible, made in such a manner that the impact of predominant wind direction is minimum.

v. Wind also entrains dust from overburden dumps and spoil piles (either dry as disposed or the dry portions of impoundments), and other disturbed areas.

vi. Sprays from water trucks are often used when the mine is operating.

vii. During temporary closures, particularly after the active life, stabilization and reclamation should be aimed in part at reducing fugitive dust emissions.

viii. Rock and/or topsoil covers, possibly with vegetative covers, can be effective controls.

- **Noise pollution**

During the operation stage the noise level in the overburden dump sites can be minimized by the following methods: 1. Minimize the haul road gradient in the dump as far as possible. Since the noise level of the dumper depends upon the power required by the engine. Lower the gradient of the haul road, lower the power needed and hence the noise level can be minimized to some extent. 2. Reduce the overburden material falling during the dumping operation[16][14].

- **Economic valuation of environmental impacts of overburden**

Economic valuation of environmental impacts of overburden The costs of externalities like soil erosion, fertility loss, water and air pollution safety risk & health etc. should be envisaged and commensurate with the production cost so as to highlight the economic valuation of environmental costs associated with handling of overburden. These costs of externalities should be internalized in the cost of production. Overburden dumps should be both physically and biologically stabilized and the cost of such reclamation considered as cost of replacement should be included in the cost of production [16].

- **Overburden management**

Overburden management The following factors are of crucial importance in selecting a site for disposal of overburden including mines wastes: Proper area for disposal should be identified at the planning stage. The sites should always be located on a secure and impervious base (solid rock if possible). Their location and building up should ensure minimum leaching effects due to natural precipitation The sites should be as far away as possible from natural water courses, shallow aquifers etc. Where this is not feasible uncontaminated fresh water streams etc. should be diverted from such waste storage areas. Overburden wastes with abnormally high concentrations of iron sulphides or other undesirable reactive elements should be disposed off in sanitary landfills. Such dumps and piles must not be permitted to become a major visual feature of the local landscape [16][17]. The height of the dump should preferably to exceed the mature tree top level in the area. The type and characteristics of the overburden waste rock is also important in determining the height of the dump. Low height dumping of piratical material minimizes oxidation and leaching, while low height coal dumps reduce the risk of spontaneous combustion.

- **Techniques for overburden waste disposal**

  i. Utilization of the overburden and mine waste by backfilling to help in reclamation, restoration and rehabilitation of the terrain, without affecting the drainage and water regimes.
  ii. Dumping the over-burden and wastes in available low lying areas accompanied by leveling and providing soil cover to utilize the land profitably.
  iii. If considered suitable, the wastes may be used as road metal or construction aggregates, after crushing to proper size.
  iv. The overburden dump must be properly graded and terraced with contour drainage as necessary.
  v. Terracing of overburden dumps must be accompanied by stabilization of the slopes and terraces using proper vegetation. [17]

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