Chapter 4.5
Mine wastes management

Mining wastes is generated during the process of extraction, beneficiation and processing of minerals. Extraction is the first phase that consists of the initial removal of ore from the earth. This is normally done by the process of blasting, which results in generation of large volume of waste (soil, debris and other material). This is useless for the industry and is normally just stored in big piles within the mine lease area, and sometimes, on public land. The bigger the scale of the mine, greater is the quantum of waste generated. Open cast mines are therefore more pollution intensive as they generate much higher quantities of waste compared to the underground mines. Open pit mines produce 8 to 10 times as much waste as underground mines.1

Once the ore is brought to the surface, it is processed to extract the mineral, which itself generates immense quantities of waste. That's because the amount of recoverable metal in even high-grade ores is generally just a small fraction of their total mass. Moreover, as the higher grade mineral deposits are getting exhausted, the mineral industry is generating more and more quantity of waste, as they have to now depend on lower grades of reserve. For example, in the United States, the copper ore mined at the beginning of the 20th century consisted of about 2.5 percent usable metal by weight; today that proportion has dropped to 0.51 percent.2

There is no estimation on how much waste is generated by this industry globally. But, everyone agrees that the quantity is so HUGE that is unimaginable. For example, the production of 1 tonne of copper generates 110 tonnes of waste ore and 200 tonnes of overburden.3 Thus, globally the copper industry in 2004 generated 3348 million tonnes of waste material to produce 10.8 million tonnes of copper metal.4 In only 5 years between 2000 to 2004, the global copper industry generated 16709 million tonnes of waste material. It is anybody's guess how much this industry must have generated since it started. And when production of one metal is generating so much of waste, how much the entire industry would be generating.

Every year, mines in the United States generate waste equivalent in weight to nearly nine times the trash produced by all US cities and towns combined.5 The total amount of waste ore (not including overburden) that has been generated to date by the US metals mining industry probably exceeds 90 billion tons.6 In India, a conservative estimate puts generation of overburden (excluding waste produced during processing) at 1861 million tonnes in 2006.7

References:
1 Anon, 2006, Dirty Metal, Mining Communities and Environment, Earthworks, Oxfam America, Washington, pp 4
3 Anon, 2006, Dirty Metal, Mining Communities and Environment, Earthworks, Oxfam America, Washington, pp 4
Though most mining wastes, such as overburden, are inert solid materials, the industry also generates waste that is toxic in nature. Some of these toxic are inherently present in the ore, for example, heavy metals such as mercury, arsenic, lead, zinc, cadmium, etc. These heavy metals leach out of the stored waste piles, contaminating the local environment. However, some toxic chemicals are also found in waste, as they are added intentionally during extraction and processing. For example, gold is extracted through a technique called “heap leaching.” The ore containing the gold is crushed, piled into heaps, and sprayed with cyanide, which trickles down through the ore, bonding with the gold. The resulting gold-cyanide solution is collected at the base of the heap and pumped to a mill, where the gold and cyanide are chemically separated. The cyanide is then stored in artificial ponds for reuse. Each bout of leaching takes a few months, after which the heaps receive a layer of fresh ore. Given the scale and duration of these operations (usually decades), contamination of the surrounding environment with cyanide is almost inevitable. The effort of the industry has been to replace cyanide with mercury, which incidentally is equally toxic.

In 2001, metals mines in United States produced 1,300 tons of toxic waste—46 percent of the total for all US industry combined—including 96 percent of all reported arsenic emissions, and 76 percent of all lead emissions. If these wastes are washed into the soil or rivers, they can contaminate the local environment and have a detrimental effect on plant and animal life.

Almost all types of mineral mining and their processing generate waste material (see table 1: sector specific wastes generated during mining). The quantum of waste generation, however, does depend on the nature of occurrence of the deposit, topography of the area, etc.

Table 1: Sector-specific wastes generated during mining

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>MINING TYPE</th>
<th>BENEFICIATION/PROCESSING</th>
<th>PRIMARY WASTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold-Silver</td>
<td>Surface</td>
<td>Cyanidation</td>
<td>Mine water</td>
</tr>
<tr>
<td></td>
<td>Underground</td>
<td>Elution</td>
<td>Overburden</td>
</tr>
<tr>
<td></td>
<td>In-situ</td>
<td>Zinc precipitation</td>
<td>Spent process solutions</td>
</tr>
<tr>
<td></td>
<td>Experimental</td>
<td>Milling</td>
<td>Tailings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Base metal flotation</td>
<td>Spent ore</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smelting</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amalgamation</td>
<td></td>
</tr>
<tr>
<td>Lead-Zinc</td>
<td>Underground</td>
<td>Milling</td>
<td>Mine water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Floatation</td>
<td>Overburden/ waste rock</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sintering</td>
<td>Tailings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smelting</td>
<td>Slag</td>
</tr>
<tr>
<td>Copper</td>
<td>Surface</td>
<td>Milling</td>
<td>Mine water</td>
</tr>
<tr>
<td></td>
<td>Underground</td>
<td>Floatation</td>
<td>Overburden/ waste rock</td>
</tr>
<tr>
<td></td>
<td>In-situ</td>
<td>Smelting</td>
<td>Tailings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acid-leaching</td>
<td>Slag</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SX/EW recovery</td>
<td>Spent ore</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Iron precipitation</td>
<td>Spent leach solution</td>
</tr>
</tbody>
</table>

7 Calculated on the basis of information in Anon 2001, Overview of mining and mineral industry in India, TERI, New Delhi, pp 70 and data on production of mineral from website of India stat, www.indiastat.com, as viewed on February 10, 2007
Huge amount of land required to dump overburden in Singrauli

Singrauli’s Coalfield is one of the largest coalfields in the country. Presently, the total land involved in 10 mining blocks is 14,873 ha. Of this 44 per cent (6615 ha) is being actually excavated while almost 12 per cent (1820 ha) of land is just being used for storage of overburden dumps. This is significant amount of land which is neither being excavated for minerals nor put to any other useful utilisation. 

Source: Anon, 2000, Reclamation/restoration Technique & Strategy for mined out areas, Indian Bureau of Mines, Nagpur

As mentioned earlier, most inert waste materials are piled up in huge stack while toxic waste are dumped in big ponds. Some of the impacts of the mining waste include:

- Unpleasant visual impact as big piles of waste stand out like sore thumbs.
- Takes up large areas of land for their storage and disposal and also make the land infertile and useless. Waste disposal by in-pit dumping is considered to be the most economical and environment friendly.
- Heavy metal contamination which reduces soil productivity or sterilises the soil altogether.
- Absence of vegetation makes the site more susceptible to runoff, soil erosion, and potentially unstable ground.
- Acid drainage can enter water supplies.
- Blown dust and tailings are a source of air pollution.
- Ruptures of dams, pond and impoundments can flood adjacent lands and discharge pollutants into waterways.

The various type of waste material generated from the mining industry include – wasterock, tailing waste, various

---

With increased dump heights, it is necessary to study and monitor over burden dump stability. A number of cases have been reported when the major Dump Slides and Failures have caused substantial damage and interruption on the production circuit.
salts during the chemical treatment of the ore act as solid wastes in water and other wastes (radioactive wastes, marble slurry, etc.). Some of key wastes generated from the industry are discussed in detail in the following section.

4.5.1. Waste rock

Mining operations generate two types of waste rock - overburden and mine development rock. Overburden results from the development of surface mines, while mine development rock is a by-product of mineral extraction in underground mines. The quantity and composition of waste rock varies greatly from site to site, but these wastes essentially contain the minerals associated with both the ore and host rock.

The ratio of overburden excavated to the amount of mineral removed is called the overburden ratio or stripping ratio. For example a stripping ratio of 4:1 means that 4 tonnes of waste rock are removed to extract one tonne of ore. Lower the ratio, the more productive the mine. Stripping ratio varies with the area under mining. For example, stripping ratio of limestone in Himachal Pradesh is almost zero whereas in Rajasthan it is 0.308 (i.e. 300 kg of waste per tonne of limestone mined). The overburden ratio for surface mining of metal ores generally ranges from 2:1 to 8:1 depending on local conditions. The ratio for solid wastes from underground mining is typically around 0.2:1.

According to the data generated by the Indian Bureau of Mines, average stripping ratio for limestone mines in India is 1:1.05. For large-scale cement sector with captive mines, the average stripping ratio is only 1.05. This is quite good, however, the generation of overburden varies from mine to mine. It is as high as 1.363 tonnes per tonne of limestone in case of Madras Cement Limited: KSR Nagar Jayantipuram to 544 kgs per tonne of limestone in case of ACC’s unit at Jamul.

For iron ore mines, the stripping ratio ranges around 2-2.5. This means that for every tonne of iron ore produced, double the quantity of waste is generated. In 2003-04 itself, SAIL generated 4.76 million tonnes of overburden and rejects from its 12 mines in the country.

As demand for coal increases to meet the country’s energy requirement, the coal companies are digging deeper and deeper and even opting for lower grades of coal. The country is even planning for production from 300 m depths at stripping ratio of 1:15 for D and F grade quality of coal. If these mines were operational, it would mean that even if 1 million tonnes of coal were extracted, it would generate 15 million tonnes of waste material. This is huge quantity and in a country like

---

10 Overburden is defined as the material other than the mineral generated during the process of excavation, which is not useful including topsoil.
11 Chandra Bhushan et.al, 2005, Concrete Facts, Green Rating of Indian Cement Industry Centre for Science & Environment, New Delhi
14 Chandra Bhushan et.al, 2005, Concrete Facts, Green Rating of Indian Cement Industry Centre for Science & Environment, New Delhi, pp 35
15 BBY Limited Resources, POSCO, Murchison Metal Limited
17 Waste and Overburden management in Mega opencast project – Problems & technical options, Director General of Mines Safety, Ministry of Labour Government of India
India where land is at premium, it is anybody’s guess whether there would be enough land to store this waste.

There are also operational coalmines in the country, which are already generating large quantities of waste. Opencast mines of North Eastern Coalfields in Assam over the past century have been producing waste rock at a stripping ratio of 1:14. The coal mines of Coal India Limited (CIL) removed about 500 million cubic m (Mcum) of overburden (OB) to produce 260 mt of coal in 2003-04 at an average stripping ratio of 1.92 cu m of OB against per tonne of coal production.

Bauxite ores in India are harder and have a higher stripping ratio when compared to the Australian counterpart. Indian bauxite has a stripping ratio of around 1.2 as compared to only 0.13 in Australia.

Considering all the main minerals produced in the country, a HUGE volume of around 1.86 billion tonnes of overburden and waste material were generated to excavate only 750 million tonnes of minerals. This was the waste generated in only one year i.e. 2005-06. In seven years between 1999-00 and 2005-06, the total quantum of waste generated was 10,767 million tonnes of waste. Among all the key minerals, coal mining generated maximum overburden. And as expected, the amount of overburden generated has increased over the years along with the increase in mineral extraction.

Table 2: The burden of mining wastes in India (in million tones)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Production</td>
<td>300</td>
<td>310</td>
<td>323</td>
<td>337</td>
<td>356</td>
<td>377</td>
<td>407</td>
</tr>
<tr>
<td>- Overburden</td>
<td>1100</td>
<td>1135</td>
<td>1183</td>
<td>1235</td>
<td>1304</td>
<td>1383</td>
<td>1493</td>
</tr>
<tr>
<td>Bauxite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Production</td>
<td>7.1</td>
<td>7.99</td>
<td>8.59</td>
<td>9.87</td>
<td>10.92</td>
<td>11.96</td>
<td>12.34</td>
</tr>
<tr>
<td>- Overburden</td>
<td>4.3</td>
<td>4.84</td>
<td>5.20</td>
<td>6.0</td>
<td>6.6</td>
<td>7.2</td>
<td>7.5</td>
</tr>
<tr>
<td>Limestone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Production</td>
<td>129</td>
<td>123.6</td>
<td>129.3</td>
<td>155.74</td>
<td>153.39</td>
<td>165.75</td>
<td>170.38</td>
</tr>
<tr>
<td>- Overburden</td>
<td>135</td>
<td>129.4</td>
<td>135.3</td>
<td>163.0</td>
<td>160.5</td>
<td>173.5</td>
<td>178.3</td>
</tr>
<tr>
<td>Iron ore</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Production</td>
<td>75</td>
<td>80.7</td>
<td>86.2</td>
<td>99.1</td>
<td>122.8</td>
<td>145.9</td>
<td>154.4</td>
</tr>
<tr>
<td>- Overburden</td>
<td>69.9</td>
<td>75.2</td>
<td>80.3</td>
<td>92.3</td>
<td>114.5</td>
<td>136.0</td>
<td>143.9</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Production</td>
<td>7.5</td>
<td>5.02</td>
<td>4.91</td>
<td>7.82</td>
<td>8.32</td>
<td>9.24</td>
<td>9.44</td>
</tr>
<tr>
<td>- Overburden</td>
<td>14.5</td>
<td>10.60</td>
<td>10.38</td>
<td>15.20</td>
<td>16.26</td>
<td>19.30</td>
<td>18.61</td>
</tr>
</tbody>
</table>

Source: 1 Anon 2001, Overview of mining and mineral industry in India, TERI, New Delhi, pp 70
2 Since the data on overburden generation for the year 2000-01 to 2005-06 is not available, it has been calculated based on stripping ratio for the year 1999-00.
3 www.indiastat.com, as viewed on February 10, 2007
5 http://ibm.nic.in/mineralproduction.html, as viewed on February 10, 2007

20 S Khatua et.al, 2006, Ecological debt: A case study from Orissa, India; Ecological Debt: The People of the South are the creditors, pp 145
Overburden dumps kill workers in Goa

Six workers were killed on 9th December 2006 when iron ore mining waste dumps collapsed in the Tollem mines in Goa. The nearly 100-metre high overburden dumps - covering an area in a 200-metre radius - gave way burying the excavating machines as well as the operators beneath them in the interior Sanguem iron-ore mining heartland of the state.

The landslide was so sudden that those trapped were unable to even react. Military personnel were called in to carry out the rescue operations. A case of negligence was filed against the board of directors and managers of the mine.

The low priority given by the mine operators, especially in small-scale and illegal mines, to overburden management culminated into this tragedy. There are several such cases, many of which are not even reported. Source: Six Killed in Goa’s Mining Tragedy, India E News, December 10, 2006, http://www.indiaenews.com/india/20061210/32003.htm

Compared to other minerals, coal mining produces the maximum amount of wastes in India. Limestone and iron ore are the next two biggest contributors to total mining wastes generated in India. According to the data of the IBM, the average stripping ratio for limestone mines in India is 1.05:1\(^2\). For iron ore mines, the stripping ratio varies widely and is about 1-3:1; this does not include the wastes generated during beneficiation and processing, which can be very high. Bauxite ores in India are harder and have a higher stripping ratio of around 1.2:1.

In most cases, overburden and waste rock is just piled up in big heaps on unlined surface without taking proper measures to prevent runoff. Although, the best use for waste rock is to backfill the excavated land, it is rarely done as the companies keep opening different faces of mine without exhausting one area. Alternatively it can be used for road as well as for construction. However, overburden management of most Indian mines is rather poor as they make big piles of waste which is often a hazard for the workers and community.

Overburden is typically not contaminated with toxic components. However, when these are disposed on useful and arable lands for indefinite period, it leads to its degradation. Apart from this, they also degrade adjoining lands sometimes due to leachate, change of local drainage pattern and groundwater conditions, etc.

Take the case of Lamgaon village in Goa 30 kilometres (18.7 miles) east of Panaji, capital of India’s Goa State, which is struggling with problems due to waste from the nearby iron ore mine. The waste from mining, mostly, fine clay, is dumped on hill slopes. From there it is washed down by monsoons rains into lakes, riverbeds and irrigation channels. The villagers complain that so much silt runs into the land that the level of the field has risen by about a third of a meter (3.29 feet). The fertile land which used to once yielded more than two tonnes of paddy is buried under the clay from the mine on the hill. The channel that brings water to the fields in this field is also choked by silt. Its depth has fallen more than a meter (3.29 feet) to 15 centimetres (6 inches) in the last decade. Many villages in the state have been hit by the activities of the 150 mines, which cover about 23,000 in the state.\(^3\)

Villagers and environmentalists have protested against the side effects of mining, but it is only recently that a series of public forums and a long march have drawn media attention and raised awareness of the problem.

4.5.2. Tailings

Tailings are the result of mineral beneficiation/milling process. Many minerals cannot be used for metal extraction directly as the concentration of the basic ore is less and has to be concentrated before it can be used. During the process of concentration, which involves grinding and milling,
tailings are generated which is in a form of slurry. The characteristic of tailings depends on the type of ore and hence varies from mineral to mineral. It also depends on the ore physical and chemical processes used to extract the economic product. However, there are certain common contents of tailings such as arsenic, barite, calcite, cyanide, fluorite, mercury, pyrite and quartz.

The slurry or the tailings is stored in a storage area commonly known as a Tailings Dam or a Tailings Management Facility (TMF) or Tailings Storage Facility (TSF). These are generally stored on the surface in retaining structures but can also be stored underground in mined out voids as backfill. Backfilling can provide ground and wall support, improve ventilation, provide an alternative to surface tailings storage and prevent subsidence. However, these are extremely rare. Most common storage facility used today are the dams, embankments and other types of surface impoundments and remain of primary importance in tailings disposal planning (see box: tailing disposal methods)
Tailings disposal method:
i. Pond storage: There are many different subsets of this method. Large earthen dams may be constructed and then filled with the tailings. Tailings may be deposited into natural topographical depressions. Exhausted open pit mines may be refilled with tailings. In all instances, due consideration must be made to contamination of the underlying water table, amongst other issues. Dewatering is an important part of pond storage, as the tailings are added to the storage facility the water is removed - usually by draining into decant tower structures. The water removed can thus be reused in the processing cycle. Once a storage facility is filled and completed, the surface can be covered with topsoil and revegetation commenced. However, unless a non-permeable capping method is used, water that infiltrates into the storage facility will have to be continually pumped out into the future.

ii. Dry sacking: Tailings do not have to be stored in ponds or sent as slurries into oceans, rivers or streams. There is a growing use of the practice of dewatering tailings using vacuum or pressure filters so the tailings can then be stacked. This saves water, reduces the impacts on the environment in terms of space used, leaves the tailings in a dense and stable arrangement and eliminates the long-term liability that ponds leave after mining is finished.

iii: Disposal into underground workings: While disposal into exhausted open pits is generally a straightforward operation, disposal into underground voids is more complex. A common modern approach is to mix a certain quantity of tailings with waste aggregate and cement, creating a product that can be used to backfill underground voids and stopes. A common term for this is HDPF - High Density Paste Fill. HDPF is a more expensive method of tailings disposal than pond storage, however it has many other benefits – not just environmental but it can significantly increase the stability of underground excavations by providing a means for ground stress to be transmitted across voids - rather than having to pass around them – which can cause mining induced seismic.

iv: Disposal into river systems: Usually called RTD – Rivering Tailings Disposal. Not a particularly environmentally sound practise, it has seen significant utilisation in the past, leading to many spectacular environmental damage. It is still practised at some operations in the world, and while experts agree it is a feasible method for locations where the river is rapidly flowing and turbulent and the additional silt loading will not impact on the river quality, it is not generally favored and is seeing a gradual decline in use.

v. Disposal into the oceans: Commonly referred to as STD (Submarine Tailings Disposal) or DSTD (Deep Sea Tailings Disposal). If a mine is located in close proximity to the coast, and the coast itself is not an excessive distance from a continental shelf, STD is conceptually an excellent method for the disposal of tailings. Tailings can be conveyed using a pipeline then discharged so as to eventually descend into the depths. Practically, it is not an ideal method, as the close proximity to off-shelf depths is rare. When STD is used, the depth of discharge is often what would be considered shallow, and extensive damage to the seafloor can result due to covering by the tailings product. It is also critical to control the density and temperature of the tailings product, to prevent it from travelling long distances, or even floating to the surface.

vi. Phytostabilisation: Phytostabilisation is a form of phytoremediation that uses plants for long-term stabilisation and containment of tailings, by sequestering pollutants in soil near the roots. The plant's presence can reduce wind erosion, or the plant's roots can prevent water erosion, immobilize metals by adsorption or accumulation, and provide a zone around the roots where the metals can precipitate and stabilize. Pollutants become less bioavailable and livestock, wildlife, and human exposure is reduced. This approach can be especially useful in dry environments, which are subject to wind and water dispersion.

Tailings are of great and growing concern in mining sector, specifically due to presence of heavy metals. The storage of tailings is commonly identified as the one of most important source of environmental impact for many mining operations. This is not surprising considering that the volume of tailings requiring storage can often exceed the in-situ total volume of the ore being mined and processed. In a single year, around 6.5 million tonnes of tailings is generated in the country.  

---

In more than 100 years of operation of Kolar Gold mines, the total quantity of tailings generated was about 35 million tonnes. Some of the tailings were used for filling underground voids and sand stowing. The remaining, 32 million tonnes of this sand, was stored in form of 15 dumps spread out along 8-km long distance in the mine area. These sands have been causing considerable environmental and health hazards for the people in the adjoining areas. During the dry season, the finer particles get air-borne while during monsoon the rainwater carries these sands further down onto tank beds.\(^{25}\)

According to the National Mineral Development Corporation Limited, about 6.0-7.0 million tonnes of Kimberlite tailings have been collected after recovery of diamonds from the mines at Panna, Madhya Pradesh. On an average, 0.9 million tonne of tailing is added to the total accumulated volume every year.\(^{26}\)

The quantity of tailings generated from iron ore mining depends on the quality of the ore. In some areas like Kudremukh, the ore mined is of low grade and contains about 35 to 38 per cent of iron and the balance 62 to 65 per cent, after going through the process plant, becomes tailings. Therefore, the mines of Kudremukh Iron Ore Company Limited (KIOCL) generated substantial quantity of tailings, approximately 14.0 million tonnes per annum. These iron tailings were stored in earthen dam, called Lakya Dam, with a height of 100 mtrs. As in 2005, around 150 million tonnes of tailings are stored in Lakya Dam.\(^{27}\)

Storage of tailings not only requires significant amount of land but also has the potential of causing river and air pollution. Historically, tailings were routinely discharged directly into the nearest surface water course and is still practiced in some parts of the world. This type of tailings disposal creates vast environmental liabilities and costs associated with remediation and reclamation.

Another serious concern of tailing storage is the safety associated with the impoundment structures. Failure of the impoundment can have severe impact on people living in the immediate vicinity as well as the environment. Such accidents related to failure of tailing dams are not uncommon in the country as well as abroad. Some of these case studies are discussed below:

- **Breach of ash pond in NALCO\(^{28}\)**

  On 31 December 2000, NALCO’s 800 acre-ash pond in Damanjodi, Orissa got breached creating an “ash flood” (equivalent to a flow of 5,000 metric tons of ash) that covered the shores of Nandira. Down stream, in the district of Jajpur, five lakh people in 166 villages were affected by ash floods in the Brahmani and Kharasrota Rivers. Ten villages in Angul district were submerged, affecting a total of 773 families in 23 villages. More than 50 cattle were washed away and hundred of acres of crops were destroyed. NALCO provided minimal compensation of: Rs.30,000 per acre for lifting ash from land (a total of around Rs.1 million); Rs.46 lakh to 630 persons towards the destruction of crop and Rs.6.5 lakh towards damaged houses.

---


\(^{27}\) Anon, 2005, Environmental Management at KIOCL, Kudremukh, MINENVIS, a newsletter of the ENVIS Centre on environmental problems of mining areas, Indian School of Mines, pp 1

\(^{28}\) S Khatua et.al, 2006, Ecological debt: A case study from Orissa, India; Ecological Debt: The People of the South are the creditors, pp 149
Merriespruit Tailings Dam Failure in South Africa\textsuperscript{29}

On the 22nd February 1994, the Merriespruit tailings dam failed by overtopping due to heavy rains that caused a flowslide of part of the embankment. 6,00,000 m\textsuperscript{3} of tailings flowed out of the impoundment to eventually stop 2 km away in the town. Seventeen people were killed and scores of houses were demolished. The 31 m high embankments had problems prior to the major failure. Small slips had caused the impoundment to close temporarily, and only mine water with small amounts of tailings were deposited. The deposition of these tailings caused the supernatant pond to move to the opposite side of the impoundment which rendered the decant system useless. Heavy rains that fell on the day of the failure (30 – 55 mm in 30 minutes) caused the overtopping. The failure could have been prevented if a suitable operating manual and emergency plan had existed.

Failure of the Omai Tailings Dam\textsuperscript{30}

The Omai gold mine is in the humid tropics of Guyana. The open-pit mining operations started in 1993. Both the tailings dam to contain the wastes and the mine itself lie on the banks of the river. On Aug 19, 1995, a major breach of the tailings pond dam occurred and an estimated 3.2 million cubic meters of tailing pond water (which contained high concentrations of cyanide) spilled into the Omai River. Production was suspended at the mine. The spill was contained on August 24. The Omai case demonstrated that no dam without adequate seepage protection around conduits or without adequate filters can be expected to survive for long.

Tailings Dam Failure in Brazil\textsuperscript{31}

Brazil's state government of Minas Gerais had to shut down the Mineracao Rio Pomba bauxite mine after the failure of a tailings dam on January 22, 2007. Streets and houses in the towns of Mirai and Muriae - in the south-western Brazilian state of Minas Gerais bordering the state of Rio de Janeiro - were partially buried several metres deep in mud. Plants and animals in the area also suffered serious damage. Furthermore, the water supply of several towns was interrupted as the mudslide affected the rivers. Heavy rains caused the dam to break, releasing 2 million m\textsuperscript{3} of mud into the Muriae river. However, state environmental regulators said the mud did not contain any toxic waste.

The San Marcelino (Philippines) Tailings Dam Spill\textsuperscript{32}

Mine wastes from two damaged tailings dams and spillways of the Dizon Copper Silver Mines Inc. (DCSMI) in San Marcelino, Zambales, in Philippines spilled into the Mapanuepe Lake and eventually into the Sto. Tomas River on Friday Aug. 30, 2002. The inspection by the environment protection authority revealed that heavy rains impounded water on the Bayarong and Camalca dams and spillways, eroding these and eventually causing the mine wastes to leak to the lake below. Each dam's catchment area spans 50 hectares. About 2,000 families live near the mine site, located in an upland area some 30 kilometers east of the San Marcelino town proper, according to the Zambales Disaster Response Network. The lake and the river remained as fishing grounds and irrigation sources for five Zambales towns.

Inez Coal Tailings Dam Failure (USA)\textsuperscript{33}

\textsuperscript{29} Source: http://www.tailings.info/merriespruit.htm as viewed on 22\textsuperscript{nd} January 2007.
\textsuperscript{31} Source: http://www.corpwatch.org/article.php?id=14312 as viewed on 1st February 2007.
\textsuperscript{32} Source: http://www.wise-uranium.org/mdafsm.html as viewed on February 01 2007.
\textsuperscript{33} Source: http://www.wise-uranium.org/mdafin.html as viewed on February 01 2007.
On Oct 11, 2000, a coal tailings dam of Martin County Coal Corporation's preparation plant near Inez, Kentucky, USA, failed, releasing a slurry consisting of an estimated 250 million gallons (950,000 m$^3$) of water and 155,000 cubic yards (118,500 m$^3$) of coal waste into local streams. About 75 miles (120 km) of rivers and streams turned an iridescent black, causing a fish kill along the Tug Fork of the Big Sandy River and some of its tributaries. Towns along the Tug were forced to turn off their drinking water intakes. The spill contained measurable amounts of metals, including arsenic, mercury, lead, copper and chromium, but not enough to pose health problems in treated water, according to a federal official. The full extent of the environmental damage isn't yet known, and estimates of the cleanup costs go as high as US $60 million. The investigation of the spill shows that the protective barrier between an underground mine and the Martin County coal-waste impoundment was far thinner than regulators thought.

While rocks and soil constitute most mining wastes, the industry also generates waste that is toxic in nature. Some of these toxins — mercury, arsenic, lead, zinc, chromium and cadmium—are inherently present in the ore. They leach out of stored waste piles and contaminate the land and water resources. Some toxic chemicals are also found in the wastes as they are added intentionally during extraction and processing. For example, gold is extracted through a technique called 'heap leaching' which uses cyanide. After use, the cyanide is stored in artificial ponds for reuse. Mine wastes also contain salts and radioactive wastes.

4.5.3 Waste Management

Overburden management of Indian mines is extremely poor; in most cases, the waste is just piled up in huge heaps, and mining companies do not bother themselves with measures to prevent run-off or fugitive dust from waste piles. The best use for overburden waste is to backfill the excavated land, but it is rarely done in practice as companies keep opening different faces of the mines without completely exhausting any one of them. The result is that Indian mines are characterised by large numbers of pits surrounded by big dumps all around. Fines from these dumps are carried by rainwater into nearby watercourses or lands and pollutes both. During dry summers, these dumps become a key source of air pollution for the surrounding areas.

Overburden management

The overburden management and stabilisation is important from the environmental and aesthetic point of view. The most common method of stabilisation is by plantation. Overburden dumps are generally reclaimed by tree species as plantation improves the moisture contents, bulk density, pH and overall nutrient contents of soils. Tree species like Dalbergia sissoo, Eucalyptus, Cassia seamea, Acaccia mangium and Peltaphorum are found to be ideal for bioreclamation of overburden dumps. In addition, there are other preventive measure to arrest erosion particularly at the initial stage of overburden management:

- Excavation from a new pit should begin only after an existing pit has been exhausted. This would ensure that the overburden and interburden generated is used for backfilling the exhausted pit, instead of being dumped elsewhere.
- Till a pit is exhausted, the overburden should be properly compacted and stacked in specified locations in low-lying non-mineralised zones within the lease area.
- The height and slope of the overburden dumps should be maintained to prevent accidents.
- Drainage should be considered to handle heavy rainfall.
- Sedimentation tanks should be constructed to treat run-offs
A good mining practice is to store the **topsoil** for reuse, but this is largely ignored in India. In many cases, the topsoil becomes a part of the waste pool and is disposed off with the overburden. The topsoil is the most valuable resource for re-vegetation after mining, as it contains the majority of the seeds, roots and microorganisms. Simultaneously replanting (which begins during mining operations) is very important because if topsoil is stockpiled for a long period of time, its quality deteriorates. Therefore, conservation and protection of topsoil is crucial. The best practices involved in the topsoil management are as follows:

- Scrap the topsoil prior to drilling and blasting.
- Scraped topsoil should be used immediately for the plantation work.
- If topsoil is not used immediately then it should be staked at designated area.
  - Stacked topsoil area should be surrounded by embankment to prevent erosion and height should not exceed more than six meter.
- Stacked topsoil should be stabilized further by grasses and bush to protect from the wind.

Handling and management of tailings becomes particularly critical when it contains radioactive material. Uranium mining, for instance, generates large volumes of tailings wastes, that contains a number of radioactive materials, which are extremely harmful to human beings and animals. The ways of disposal of radioactive wastes include retention in repositories (concentrate and retain) or release into the environment (dilute and disperse). Due to delays in developing radioactive waste disposals facilities, the waste has to be stored for increasingly longer periods. Some countries are also considering extended storage as an alternative to disposal.

Some other practises for tailing management are as follows:

- Tailings must be managed to optimise human safety and environmental protection.
- On-land tailings impoundment systems must be designed and constructed by taking into account the soil characteristics, hydrology, and seismic and precipitation conditions (to accommodate surface run-on). The designs should address the structural integrity of the tailings dams or deposits even post-closure.
- On-land disposal systems should be designed to isolate acid leachate-generating material from oxidation and percolating water. Marine and riverine discharges are not acceptable.
- The design of the tailings management system must address post-closure issues such as the long-term geotechnical stability of the impoundment, the chemical stability of the tailings, long-term surface and groundwater management, including pollution control, and restoration.

Absence of topsoil is the most common feature of the mine spoils or dumps. If present, it is very poor in nitrogen, which is essential for plant growth. This is due to the absence of soil organic matter. Moreover, shortage of soil micro flora restricts the decay of plant material. In addition, the stony nature of mine wastes makes it very unsuitable for the growth of the vegetation. Since the progress of natural vegetation process is very slow on mine spoils, selective plantation of...
suitable native species is desired in most cases. In the initial stages of revegetation, quick growing grasses with short life cycle, legumes and forage crops are recommended. It will improve the nutrient and organic matter content in soil. Plantation of mixed species of economic importance should be done after 2-3 years of growing grasses.

The timing of seeding is important for successful re-vegetation. Usually, seeding should take place immediately before rains begin or early on in the rainy season. In tropical areas, seeding should take place during wet season. Fertilizer is commonly used to speed up natural processes by increasing species number, plant cover and density, and growth rates.