6. SOLID WASTE MANAGEMENT

6.1 PREAMBLE

It is estimated that well over 170 million tonnes of solid wastes related to mining are generated in India every year. This is expected to increase substantially with the increase in the production of various minerals and may exceed 300 million tonnes of waste per year. This figure, of course, relates to the mining of metal and industrial minerals only. Besides this, the mining of coal and certain other decorative rocks like granite, marble, etc. are also expected to produce large amount of solid wastes. A new factor namely, solid waste management has made its presence in the Indian Mineral Industry. Further, change in the National Mineral Policy is expected to bring about large investments in high value minerals like gold, base metals, diamonds, etc. These high value minerals will mostly be mined in large opencast mines producing additionally several million tonnes of mining wastes annually.

Due to shortages of some of the minerals and also depletion of high-grade ores, it is becoming increasingly necessary to mine out leaner grades, which generate large quantities of waste materials. Added to this, the opencast mining, which is being preferred due to its unique high productivity, economic viability and safety aspects, also generates huge volumes of waste rocks in terms of the overburden or the side-burden. Therefore, generation of waste rocks is almost an unavoidable phenomenon whether it is opencast mining or underground mining. Due to the geological constraints and the nature of occurrence of the mineral deposit, it may not be possible to plan for immediate back filling of the waste generated in the worked-out portion of the mine. Therefore, the waste generated during the initial stages of mining has necessarily to be stacked as external waste dumps. Disposal of overburden and waste is done in predetermined location usually within the leaseholds. Proper design, stabilisation and vegetation to contain degradation of land. Besides occupying large areas affecting their important land use like agriculture, forestry etc., the waste dumps also affect the landscape beauty, by standing as isolated barren mounds. Wash-offs from these dumps poses siltation of nearby water bodies and agricultural fields and also prone for wind erosions.

In general, the waste generated from the mines are classified as the mine (overburden/side burden) waste and the ore beneficiation plant waste. The mine wastes are generally in large quantities but mostly inert, whereas the plant waste, though in small quantities are mostly toxic and sometimes hazardous too. The objectives of the solid waste management plan should be:

a. Examine the Possibility for value addition to the wastes generated so that they can be marketed.

b. Neutralisation of the toxic and heavy metals released to the surrounding Environment.

c. Prevention of chemical pollution of underground as well as surface water from the waste by downward percolation and by surface run-offs.

d. To prevent physical and chemical pollution of adjacent land and surface water bodies by water erosions from the unprotected dump surfaces, due to their instability. For dump stability two criteria are to be taken into account. One is the long term stability, which generally caused due to the rise in ground water level, reduction in spoil material strength and weathering, etc. The other is the short-term stability caused due to poor material strength and improper placement.

e. To prevent air pollution by wind erosion of the dust generated from the unprotected waste disposal areas.

f. To restore or improve the aesthetic beauty.

6.2 DUMP MANAGEMENT

External dumps are permanent sources of land pollution through wash off with rains and air blown dust through wind action. They also present an ugly and repulsive look to the viewer, if not duly afforested. The objectives of external waste dump management would be:

(A) The design of the waste dump should accommodate progressive rehabilitation to ensure a minimum area of disturbance at any one time and to establish final rehabilitation at the earliest opportunity. Alternative uses for part of the material, such as a landfill or road/building construction, may also be possible. It is advisable to acquire sufficient additional area, over and above the mining area to cater to a planned external dump.

(B) The following basic objectives for waste dump need be considered in the planning phase, where possible (e.g. if open-pit design permits, or more than one open-pit is proposed) waste rock should be returned to previously excavated areas.

- The height, area and shape of the waste rock dump to be designed having regard to the area of land available, the general topography of the area and the vegetation, in the area.

- All completed surfaces of the waste dump should be stable and able to resist long term erosion.

- Topsoil (20 cm) should be scraped out from the dump site in advance and preserved in low height dumps, duly covered with grass and vegetal cover to increase its life.

- Previously stockpiled subsoil and topsoil should be spread on all completed surfaces where practicable and re-vegetated with suitable vegetation.

- The design and construction of the waste dumps should be such that the completed out-slopes do not exceed 20° from the horizontal.

- Drainage should be constructed to handle heavy rainfall events. Appropriate garland drains and retaining walls should be provided all around and specially to the ultimate boundary of the dump.

In meeting these objectives, it is essential that consideration be given to the aesthetic of the constructed waste dump. The long distance perspective of the shape and colour of the dump in relation to the surrounding landscape needs to be assessed from the main access ways and viewing points of the site. At closer range the view of the dump area should provide the viewer with an impression that the area has been rehabilitated to both blend with the natural land form and that the area supports a stable vegetative cover similar to the surrounding area.

These factors should be established as long-term objectives and planned from the beginning of the operation and provided in the statutory mining plan for approval of IBM.

(C) Since external dumps, which cannot be used for back filling of old pits or otherwise, must be afforested for greenery and stability, their outer slopes must be very gentle, preferably not more than 20°, because steeper the slope more difficult it is for biological rehabilitation. An estimated relationship between the angle of dump slope and efficiency of revegetation, as given in Figure 1 may be kept in view for general guidance in this regard.

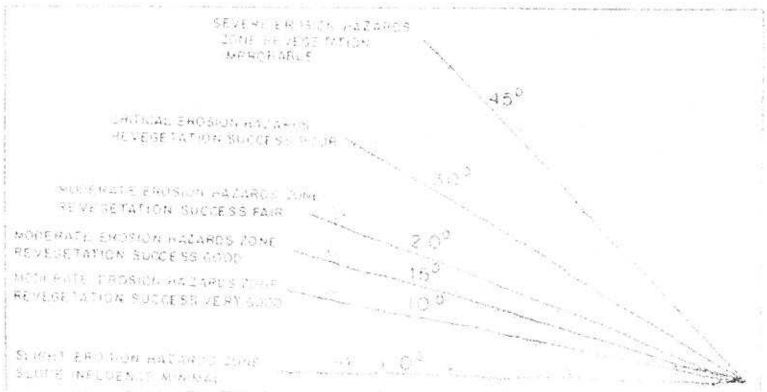


Figure 1

It may be noted that long unbroken slopes allow surface run-off to accelerate and produce rill and gully erosion. Therefore, even a gentle slope of 20° should be of short length so that the vertical height of individual bench is not more than 10 m and to obviate formation of gully along the slopes for 10 m height of the bench a berm of at least 4 m width should be provided, the berm having a gentle slope (say 0.5%) inwards into the dump (Figures 2 and 3). The rainwater from these berms is drained through rock lined vertical drains provided at suitable intervals. The number of vertical drains required is dependent on final slope angles. On steeper slopes, the catchment area for the vertical drains need to become smaller to ensure that runoff water does not exceed the design capacity of the drainage systems. Individual catchment areas should not exceed 2 hectares on fourteen degree slopes, 1.25 hectares on eighteen degree slopes and 1 hectare on twenty degree slopes.

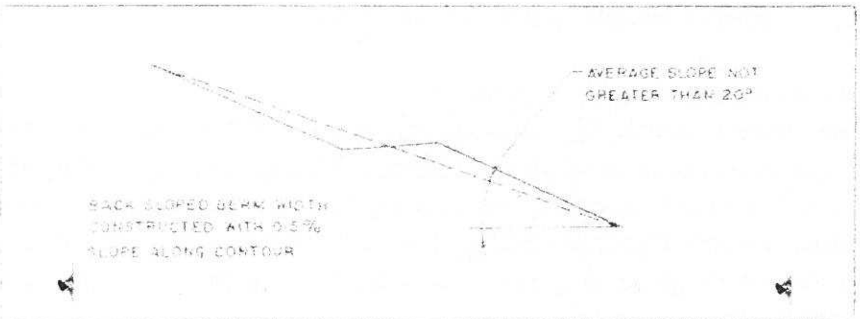


Figure 2 - Basic Slope Profile for most of the Waste

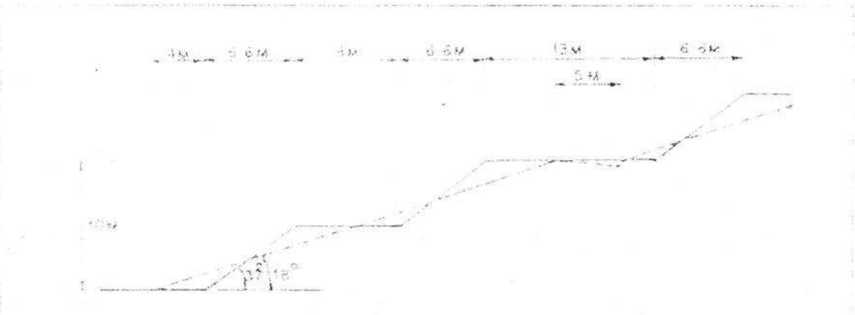


Figure 3 - Example of Waste Dump Re-grading Technique

It needs to be emphasised that these drainage structures should be maintenance free and designed to last for decades to ensure that no failures occur before vege ıtion is well and truly established. Waterways need to be lined with rock and not just hard clay chunks. Alternatives may include meshing secured in place with old conveyor belting or half round pipe.

(D) Retreating Pyramidal bench formation with concurrent rehabilitation: With the common practice of short-term dump management in Indian mines where dump faces always advance away from the pit, one rarely gets a dead face for biological rehabilitation. Since, the dumping face is always 'active' under such situation, the dump face can be stabilised land rehabilitated by afforestation only after the end of mine life. Therefore, a radical change in the practice is recommended. This is by adopting retreating pyramidal system with concurrent rehabilitation. The system, in nutshell, provides for building up the outer edge of the planned and ultimate dump first and then retreating backwards while afforesting and rehabilitating the outer 'dead' faces.

6.3 Waste Dumping in Hilly Region

The space available for dumping the waste in hilly regions would be either along the hill slope or in the bottom valley portions. Though the valley fill dump is economic and technically feasible, it may involve damage to the forest growth existing in the valley portion which require necessary permission and compensatory afforestation. Hence, it is mostly preferred to go in for hill slope dumping. Different types of these hill slope dumping are given in Figure-4.

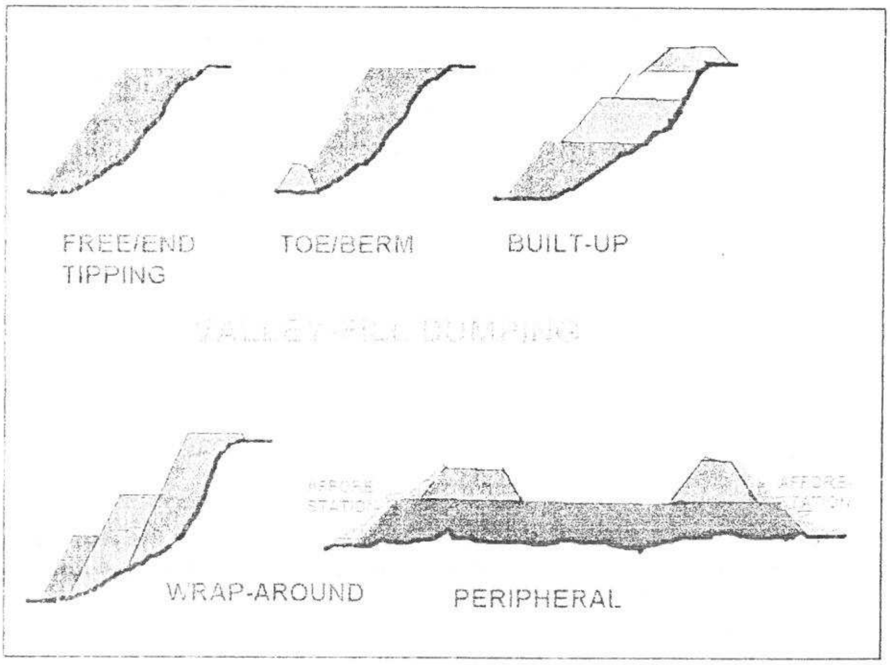


Figure-4

In most of the hilly terrain, the waste dumping procedure in vogue is end-tipping. along the hill slope, in a most economical way without any considerations for it's stability. Thus, most of these dumps occupy the top portions of the hill slope. At places where the hill slopes are steep, i.e. in escapement areas, the dumps may move down, extending into the valley portions and nallah/river bed down below. Irrespective of whether there streams are perennial or seasonal, during the rainy season, the waste material will be washed-off by the precipitated water, contaminating the surface watercourses. Sometimes through percolation, it may even contaminate the ground water system.

The configuration for the waste dump stability is similar to the stability of embankment in civil engineering design, but is not so stringent. For these waste dumps, there are two types of instabilities. One is the long-term instability caused because of the rise in the ground water level and reduction in the strength of material due to water action. The solution for this is growth of a permanent vegetation cover over the dump surface. The other is short-term instability caused due to improper heights and slope angles of the dumps. The stability failures are grouped as circular failures, non-circular failures and foundation failures. The non-circular failures occur in non-homogenous deposition of the waste material with layers of weak materials in and beneath the waste dump. In general, the waste material generated from mining activity is almost homogenous and hence possibilities of non-circular failures are ruled out. Further, because of the end tipping in vogue, large boulders are segregated at bottom and occupy the foundation zone. Hence, the possibility of foundation failures are also ruled out. However, failures due to liquefaction are possible in this area because of the profound seismic activity.

Where percentage of fines in the wastes is less, the restriction on height of the dump built-up is not a serious problem. Instead of keeping a single continuous slope, provision of intermittent berms/benches, will reduce the driving forces and are advantages to deep circular failures. They increase the stability than that by adopting further slope flattening. In such cases, the individual slopes of the berms can be increased up to the natural angle of repose of the waste material, provided the embankment is on a firm foundation and will not get submerged. For estimating the safe slope angle for the new dumps, covering the hill slope as well as in the valley fill dumps, prediction on rock mechanics, vibrations due to blasting, intensity of seismic activity in the area and water drainage system are to be considered.

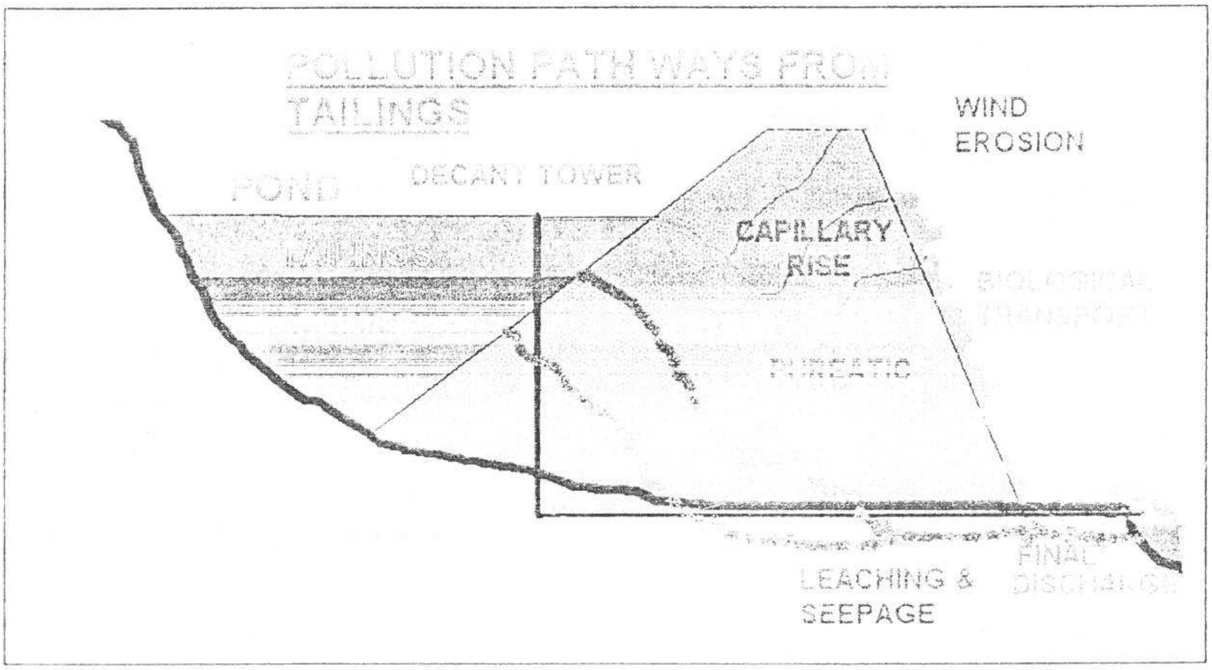
To get the advantage of the simultaneous afforestation, the dumps along the hill slope are to be planned to have peripheral built up dumps, by building up the dumps from the down hill and gradually going up the hill slope. For these dumps, sufficient barrier have to be left between the bottom stream flow and the toe of the dump, so that the waste do not spread into the water courses and also it will not affect the forest growth existing below. To arrest the lateral pressure developed inside these dumps retaining walls with weepers are to be erected at the toe end of the dump profile. To carry the expected storm water discharge, drains are required to be designed below the retaining walls. To remove the solid suspensions in the outgoing water flow, on-stream sedimentation tanks over these nallahs/streams are also sometimes required to be erected. This will also allows recharge of the ground water system and controls the floods.

For transport of waste to these dump sites, two alternate systems can be considered (i) by conventional road transport through tippers and (ii) through gravity haulage or by gravity chute system. Though the gravity system is comparatively Eco-friendly and economical, but because of their rigidity and of the other reasons, their application is limited.

6.4 TAILINGS

Tailing is the residue of ore processing and represents a significant component of mineral waste. Though tailing is chemically similar to its parent ore but the presence of milling reagents, evaporation of free water, etc. can change the properties. Tailings include a variety of heavy metals, radioisotopes, cyanide, hydrocarbons, salts, etc. Such constituents can leach from the tailings and enter surface and ground water. They can be disseminated through wind and water erosions. They can even migrate upward via capillary action and diffusion, to contaminate the soil placed over the tailing surface to support vegetation. They can even be absorbed by the vegetation and enter into food chain. The details of pollution pathways expected in a tailing dam is given in Figure-5.

Some of these mining and milling wastes especially the pyretic, when exposed to the atmosphere have capability to become acid producing, attributed by the microorganisms and is often recognised as an environmental hazard. Though the mining industry is fully aware of the environmental problems, pollution hazards and attempts are being made to manage them, there is scope for improvements particularly in respect of treatment of toxic effluents and recovery of useful minerals/metals.



Apart from the sediment deposition, environmental hazards noticed in the effluent discharge of some of the major metalliferous mines, due to the presence of toxic and other micro elements are as given below:

1.	Iron & Manganese mines	Fe, P, Mn, S, Ni, Mg
2.	Chromite mines	Cr, Cr^{+6},Co, Ti, Fe, Mn, Ni, Mg
3.	Lead & Zinc mines	Pb, Zn, Cu, Fe, S, Cd, As
4.	Copper mines	Cu, Mo, S, Fe, Ni, Ti, P, Mn, Sr, Ba
5.	Asbestos mines	Asbestos fiber, Serpentine
6.	Limestone & Dolomite mines	Ca, Mg, Sulphate ions, Electrical conductivity
7.	Phosphate mines	P, S
8.	Gold mines	As, S, Cn
9.	Bauxite mines	Al, Ti , F

Amongst the toxic elements present in the tailings, lead is generally known to affect the blood system, cadmium causes kidney damage and hypertension, Arsenic is toxic and carcinogenic, sulphur affects respiratory system and damage plants. Hexavalent chromium is a very toxic element known to be carcinogenic and other microelements present like nickel, cobalt, manganese and titanium are also equally harmful. Aluminum acting on the nervous system. Thus, the effluent released from the tailings are having high degree of metallic concentration. The rain water entering into mines having pyrite deposition is prone to be acidic because of the contact with sulphide mineralisation and likely to pollute the surface as well as ground water resources. This problem of acid mine drainage is being faced in some of the base metal as well as the coal mines. Bio-accumulation and concentration of toxic elements from the waste and tailing dumps, resulting in their entry into the natural food chain is another serious environmental problem.

6.5 DUMP REHABILITATION

Establishing a vegetative cover is the best long term strategy for stabilization and erosion control. To begin this process the top soil should be replaced to a similar depth as that removed from the site originally (i.e. 200-300 mm). If topsoil is in short supply it may be necessary to place the topsoil in strips. This at least provides areas of improved surfaces for regeneration.

To increase the success of vegetation establishment, rehabilitation techniques should aim to increase rainfall infiltration. The term used for this approach is "water harvesting" and many specific techniques have been developed for various applications. The most basic of these techniques is to leave the surface of the dump as rough as possible by deep ripping along the contour after the top soil has been spread. The roughness and ripping allows for water penetration and provides places for seeds to lodge. Replacing pre-stripped vegetation also helps this process and reduces wind erosion. Creating a surface which enhances water harvesting will also help to leach soil salts out of the surface profile and aid the revegetation programme.

In areas where salt content of the overburden is high, it is recommended that the dumps be screened with overburden of the lowest possible salt content. This is usually from material closer to the surface. This selective handling of overburden may be considered expensive. However, such treatments will be required to provide a suitable environment for plant growth, as it will take many years for the salts to leach out of the surface layers. The screening material needs to be covered by topsoil.

In all cases the surface and faces of waste dumps will need to be ripped to break compaction and to allow water penetration. This ripping will usually be carried out by a dozer after the topsoil and old vegetation material is spread. It is stressed that water harvesting and erosion control are the key issues in establishing the final surface for the rehabilitation programme.

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