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Dump management in South Kaliapani chromite mines, Jajpur, Odisha, India

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ABSTRACT

The South Kaliapani Chromite Mines of Odisha Mining Corporation (OMC Ltd.) Limited is in ultramafic complex in Sukinda valley of Jajpur District. The mine is connected through the nearest rail head at Jajpur- Keonjhar Road railway station on Howrah Chennai line of South-Eastern Railway. Huge quantity of overburden waste or mine spoil is generated in Chromite mines due to high ore to overbudern ratio having the maximum output of 14.55 Metric Tons of waste generated against 1.0 Metric Tons of ore. The waste having diverse chemical and mineralogical characteristics, is challenged with designing stable waste dumps up to 120 m high dumps with stable configuration. This article elucidates study of slope stability and results of implementation of control measures in designing and maintaining a safe slope of the overburden thereof in South Kaliapani Chromite Mines of OMC Ltd. Authors also recommend the management of active dumps, control measures at active dumps to avoid water accumulation, stabilization of inactive dumps through plantations and overall better dump monitoring.

Key words: Chrome ore, dump, overburden, slope stability

INTRODUCTION

Odisha has a rich source of chromite minerals. Chromite, or iron chromium oxide ($FeCr_2O_4$) is the mineral source of chromium. In its purest form, chromite comprises chromium (Cr_2O_3) at 68% and iron oxide (FeO) at 32%. High purity chromite deposits are rare, due to the natural replacement of chromium and ferrous iron by other elements. After extraction of minerals, the residual remains in dumps are liable to pass on through rainwater to lower lands, if not properly managed may affect human health, plants, and animals. Panda and Patra (2004) studied the chromium phytotoxicity and its bioavailability in rice seedlings in both water and soil culture experiments using chelating agents, organic acids, and some mineral irons. The rapid industrialization in India has currently increased the consumption of natural resources with consequent generation of wastes and pollutants. This has serious consequences on the human health and the environment (Mohanty et al., 2010).

A combination of poor mining methods, waste storage and disposal systems, as well as the day-to-day activities associated with tribute and contract chromite mining are primarily responsible for environmental problems in the mines (Maponga and Ruzive, 2002). Contaminated soil and water pose a major environmental and human health problem. Due to open cast mining process lots of over burden are being generated and leaching from this over burden adds the hexavalent chromium to ground water regime. Ground water in the valley is encountered at a shallow depth in semi-confined aquifer (Mishra and Sahu, 2013). Therefore, it is essential to stabilize the dumps and make necessary surface run-off arrangements to avoid leaching. The surface runoff thus collected is treated in Effluent Treatment Plant before final discharge.

MATERIALS AND METHODS

South Kaliapani Chromite Mine of M/s Odisha Mining Corporation Limited (OMC) is in Jajpur District of Odisha. South Kaliapani Chromite Mine in Sukinda ultramafic complex is in Sukinda Tehsil of Jajpur district in Orissa. The nearest railway station is Baghupal on Padapahar Jn. (on SE-Railway's Rajkharsawan- Barajamda Jn. B.G. Branch Line) – Banspani – Keonjhar – Jakhapura Jn. (on the Howrah - Kharagpur - Cuttack – Visakhapatnam B.G. Main Line) which is at an aerial distance of ~21.5 km east of the mine. The leasehold area is linked with Daitari-Paradeep Express Highway. State Capital at Bhubaneswar and district head quarter at Jajpur are located at road distances of ~150 km (~80 km aerial distance) and ~98 km (~60 km aerial distance), respectively from South Kaliapani leasehold area. It is located between latitudes 21° 00' 49.64076"N and 21° 03' 25.10625" N and longitudes 85° 46' 25.96764" E & 85° 48' 28.53433"E.

The location of the South Kaliapani chromite mine is shown in Fig. 1. The location of the ML area on Google Earth has been shown in Fig. 2. The chromite mining process is largely related to the generation of a huge quantity of wastes and rocks in the form of overburden (OB; Dhakate et al., 2008). The CSIR-Central Institute of Mining and Fuel Research (CIMFR) has rendered its services for assessment of safe slope design. The analysis of strength properties along with engineering judgement was used in the process of analyzing and evaluating the stability of OB Dump with different geometrical configurations.

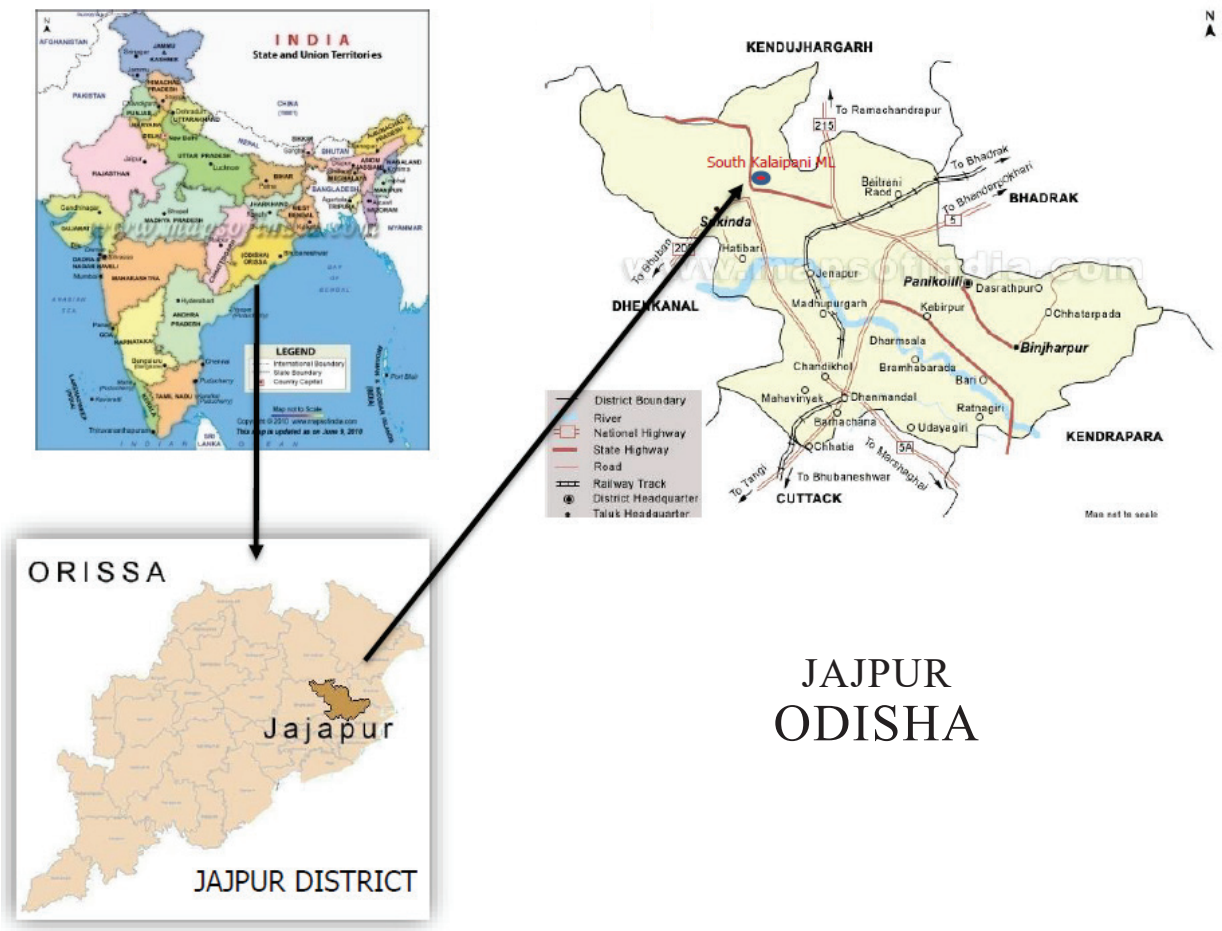

Fig. 1. Location map of south Kalipani chromite mines

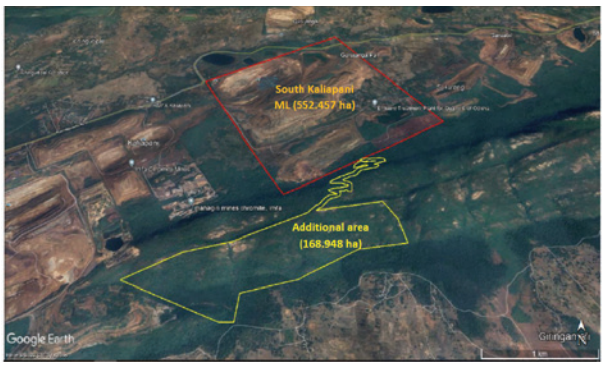

Fig. 2. Location map of south Kalipani chromite mines

The slope stability depends upon the slope geometry and the strength of the properties of slope materials. Engineered properties of materials of OB dump influences the analysis of slope stability. The limit equilibrium analysis using GALENA software was used along with the analysis of the geo-mechanical properties in the dump soil in the rock mechanics laboratory of CIMFR was used for analysis of slope stability (CSIR-CIMFR Report, 2021).

RESULTS AND DISCUSSION

Slope stability analysis

Huge piles of overburden or waste dump are stockpiled near mining sites having high levels of toxic substances which create dust clouds with fumes of many other toxic gases leading to air and water pollution need to be stabilized before monsoon season.

The static external dump has been stabilized through afforested or re-grassed to check wash offs. Waste dump is guarded with retaining walls at their toes along the lower contours. Following the retaining wall, a garland drain is developed for carrying water to the natural drainage system. Settling pits have also been constructed in the drains to arrest solid particles. The retaining walls are of 1.5 m height and 1.5 m thick at the base. The existing waste dumps are stabilized with bio-degradable coir geo-textile. It facilitates new vegetation by absorbing water and preventing topsoil from drying out. Grass-seedling or plantation is done after blanketing the coir matting on the dump slope. This provides support to the dump soil allowing natural vegetation to become established.

Garland drains are dug around 1 m beneath the adjoining contour level at the lower peripheral areas of the dump. The width of the drains is around 1.5 m. A series of settling pits is provided to arrest the wash-off solid particles. The OB dumps areas area compacted, and afforestation is carried out on the terraces as well as along the slopes after spreading a layer of topsoil over it before rehabilitation. Topsoil being generated during mining is used stored in an earmarked area and used for plantation purposes only. Biologically reclaimed part of existing external OB dump along with retaining wall and garland drain in South Kaliapani ML and settling pit at toe of existing external OB dump along with retaining wall in South Kaliapani ML is shown in Fig. 3 and Fig. 4 below (EIA Report, 2021).

Fig. 3. Biologically reclaimed part of existing external OB dump along with retaining wall and garland drain

Fig. 4. Settling pit at toe of existing external OB dump with retaining wall

Management of active dumps

The slopes of dumps are maintained at an overall angle of less than 28 degrees with individual lifts at less than 37 degrees. As the dumps attain final position, the slope is terraced, and proper vegetation is laid which will cause binding of the soil preventing any slope failure. Retaining wall is built across dumps except at few places leaving access to the dumps which will have weep holes for passage of storm water to join garland drains study conducted by CIMFR vide their report dated January 2021, stipulates the following measures:

Dumping of spoil or OB is so done that spoil- banks are benched in accordance with the recommendations of scientific study carried out by an agency having expertise in this regard and in accordance with the stipulations of the permission granted by Directorate General of Mines Safety (DGMS). The width of such benches shall not be less than the height of the bench, and the general slope of the spoil bank shall not exceed one vertical to 1.5 horizontal. The height of spoil bank or OB dump shall also not exceed the height as recommended by the scientific study.

During dumping of OB and maintenance of the dump or its benches, it is ensured that no water is allowed to accumulate at the dump-top or any of the benches already formed. Natural gravitational drainage is provided by sloping the dump-top and the intermediate benches, as well as the haul road leading to dump- top, and collector drains to collect and drain out the rainwater and prevent its seepage into the dump shall further be provided. It is ensured that the collector drains are kept maintained free of debris and loose material that may slide in as shown in Fig. 5(a & b).

Fig. 5(a). GI sheets with drainage arrangements

Fig. 5(b). Pipeline arrangement with vat at the slope of the dump.

Control measures at active dumps to avoid water accumulation

The top as well as benches of all active dumps are regularly inspected at intervals fixed by the Manager, more particularly during rainy season and post-monsoon, by a person not below the rank of Mine Foreman and any deformation or formation of tensile cracks are brought to the notice of the Manager forthwith. If any cracks are observed, they are filled with sandy material immediately to check the entry of water in the dump mass. A record of such inspections is duly maintained in a bound paged book. The dump-design and dump-slope profile parameters of dumps exceeding 60 meters in height are monitored by suitable survey instruments to ensure their accurate and up-to-date geometry. Frequency of such measurement is fixed by the manager and may be increased during monsoon and post-monsoon periods when dump-slopes are more likely to fail because of rain, which may lower cohesion of the dump-material mass.

A record of such measurement is maintained in the bound paged book kept for the purpose, which is signed by the surveyor entrusted with such responsibility and is counter-signed by the Manager. Persons engaged in inspection of the dumps and their benches, and those engaged in monitoring of dump-geometry are imparted job-specific training before being deployed for the purpose. OB or spoil removal from the mine and its dumping in OB dump-yards is placed under overall charge of an Assistant Manager, who shall ensure during dumping of spoil or OB that dump-design and dump-slope parameters are kept maintained in accordance with this SOP.

Dumping of OB or spoil in OB dumps and regulation of movement of tipper-trucks on dumping platform in each of the working shifts is carried out under personal supervision of a competent person (Mine Foreman or Mining Mate). Before commencement of dumping operations and at regular intervals during his shift, the competent person shall inspect the dumping platforms or dump-tops, where from dumping of OB or spoil is carried on, for any signs of sinking and or formation of tensile cracks. If signs of any formation of tensile cracks or sinking of dumping surface are observed, dumping operations in the said area is stopped immediately and brought to the notice of the Assistant Manager or Manager forthwith. Dumping in the said area shall resume only after the matter has been investigated, corrective actions have been taken and formal approval has been accorded by the Manager. The competent person shall regulate the movement of dumpers or tipper-trucks in an orderly manner so that there is no crowding at the dumping platform and shall also ensure that dumpers or tipper-trucks dump OB or spoil at the designated places and in the manner prescribed. Only top dumping of OB or spoil is done to prevent dumpers or tipper-trucks rolling back and down the dump-slope. Dumped OB or spoil material is regularly pushed down the dump slope by dozer.

Where edge dumping of spoil or OB becomes unavoidable, a berm or embankment is provided at the edge of the dumping platform whose width at top shall not be less than 1 meter and its height is not less than the diameter of the tyres of the largest dumper or tipper-truck engaged in dumping or stacking. Movement of the dumpers or tipper-trucks is regulated by the competent person standing on an elevated traffic island to prevent the risk of him being run-over by the tipper-trucks. He shall not stand near the dump-edge or in the operational area of dumpers or tipper-trucks engaged in dumping of OB or spoil. Suitable code of signals by means of coloured flags or batons are framed and implemented for the purpose as shown in Fig. 6.

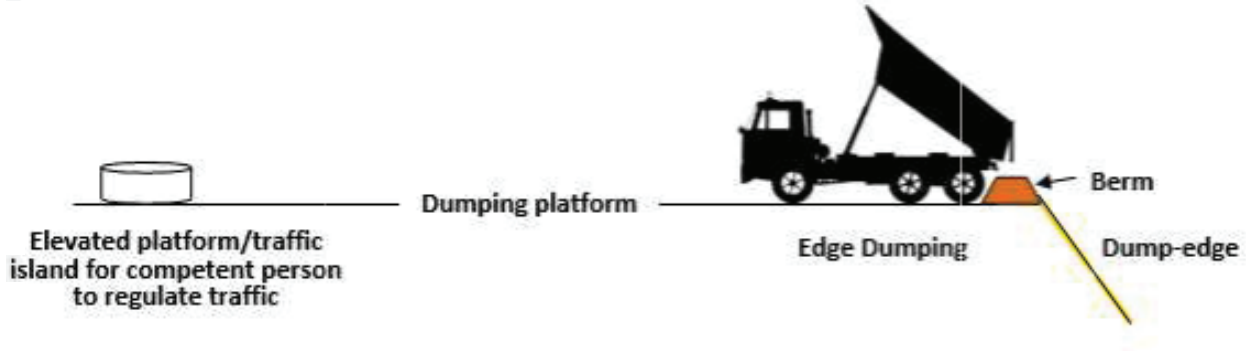

Fig. 6. Safe dumper movement schematics

All ore, including low-grade ore, is stacked at places belonging to the mine and duly approved by the manager in writing. The sites chosen for stacking of different categories of ore, including low-grade ore is such that ore is not stacked beneath or close to power, transmission, or telephone lines, also ensuring that the toe of the ore- stock piles do not get extended within 100 m of any public works, public road, power or transmission or telephone lines and permanent structures not belonging to Mine. A suitable fence is erected between such public works or road or building or structure not belonging to Mine and the toe of the stockpiles to prevent unauthorized persons from approaching it. The slope of stockpiles is the natural angle of repose of the ore being stacked and should not exceed 37 degrees from horizontal. The toe of the stockpiles shall not be retained by artificial means as to increase their slope more than natural angle of

repose of the ore being stacked. Stacking of ore including low-grade ore is done in a manner that stockpile slopes are benched in accordance with the stipulations, if any, of permission granted by DGMS or at intervals not exceeding 20 m in height. The width of such benches shall not be less than the height of the bench. Stockpiles slopes may as well be benched at lesser intervals in the interest of safety if space requirements so permit. The height of stockpiles shall not exceed 40 meters.

Stabilization through plantation

The species for plantation is selected based on soil quality, place of plantation, chances of survival, commercial value (timber value, ornamental value, etc.), etc. It is to be noted that only indigenous species is planted. Exotic species like Subabool (*Leucaena leucocephala*), Eucalyptus and Australian Acacia (*Acacia auriculiformis*) will not be planted. Also, Teak (*Tectona grandis*) will not be planted as it is not native to the region. The species for green belt or vegetation covered development is selected in consultation with the State Forest Department. Mixed plantations are done keeping optimum spacing between the saplings. However, the species suitable for planting in the area as recommended by Central Pollution Control Board (CPCB) in their publication "Guidelines for Developing Green belts" (CPCB, 2000).

Once dumping or back filling has been completed, a path is cleared to the designated area so that the basic inputs (water, manure, and seedlings) can be carried up to the site. Next, a layer of topsoil must be spread over the area and roughly leveled. Grass seeds or seedlings are planted on the soil layer to stabilize the soil. Plants selected for plantation in and around the waste dumps should have pollution hardy nature, fast growth rate, glabrous or pendulous leaves, and large crown volume to surface area of fluttering leaves.

Trenches of 45 cm × 45 cm are dug on the flat top of the dumps and the excavated material is used to form a bund on the dip side of the trenches to retain maximum water in the trenches during rains. Suitable benches are made on the waste dumps and a size of 60 cm × 60 cm pits are dug on the benches at 23 m intervals. The pits are filled with a mixture of topsoil, organic manure, and phosphoric fertilizers. Saplings are planted in these pits once monsoon has commenced to ensure the maximum survival of the saplings. Initially hardy pioneers' species, *Ficus benghalensis, Ficus religiosa* and *Acacia auriculiformis* are planted to help build up the soil. Subsequently, *Acacia auriculiformis* is cut down (as this species is an invasive species) replaced by species such as *Azadirachta indica*, *Annona squamosa*, *Pongamia pinnata*, *Ziziphus mauritiana*, *Ficus* spp. etc.

Plantation on the slope of the dumps will commence as soon as the first bench is ready. The terrace on the slopes is sloped in ward. 60 cm × 60 cm pits are dug at 1.5 m intervals and filled with a mixture of topsoil and organic manure. There are open masonry drains on the terraces. These will receive water from the higher terraces and convey it to the next lower terrace. Before the commencement of the monsoon the slopes and terraces are covered with a layer of soil (held with suitable mechanical soil binder) and sprinkled with water. Just before the commencement of the monsoon seeds of grasses and small shrubs are sprinkled on the soil covering of the dump slopes or seedlings of such plants are planted on the slopes.

Besides, it is also proposed to stabilize the existing dead waste dump with bio-degradable coir geo-textile. It facilitates new vegetation by absorbing water and preventing topsoil from drying out. Grass-seeding or plantation is done after blanketing the coir matting on the dump slope. This will provide support to the dump soil allowing natural vegetation to become established (Singh, 2010).

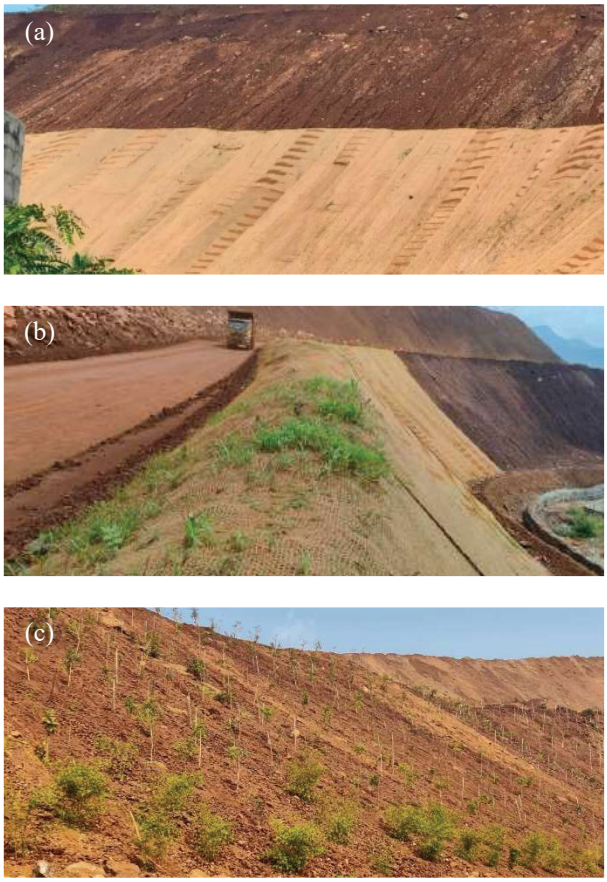

Fig. 7 (a,b,c). Photos of plantation with coir matting under taken at stabilized parts in the active dumps

Dump monitoring

The following dump monitoring practices are followed: The operations connected with stacking of ore in each stockpile are placed under the charge of a competent person in each of the working shifts who shall personally supervise such operations. Re-handling operation for dispatch of ore from the mine (if carried out simultaneously along with stacking of ore) shall also be placed under the charge of a separate competent person. Operations connected with stacking of ore received from mine and re-handling of ore from stockpile for dispatch are kept segregated, above or below each other and shall not be done simultaneously from the same place or vertically.

Before commencement of dumping of ore in stockpiles or re-handling of ore there-from, and at regular intervals during the shift, the dumping and loading platforms or surfaces is inspected by the competent person for signs of sinking and or formation of tensile cracks. If signs of any formation of tensile cracks are observed, dumping of ore or re-handling operations is stopped immediately and the same is brought to the notice of the manager forth with. Dumping of ore or re-handling shall resume only after the matter has been investigated, corrective actions have been taken and formal approval is accorded by the Manager. The competent person (s) shall regulate movement of dumpers or tipper-trucks engaged in stacking of ore or of buyers' trucks engaged in dispatch or ore from the mine in an orderly manner so that there is no crowding during stacking of ore or re-handling of stockpile.

Movement of the dumpers or tipper-trucks or buyers' trucks is regulated by the competent person standing on an elevated traffic island to prevent risk of him being run- over by the tipper-trucks or buyers' trucks. Suitable code of signals by means of coloured flags or batons are framed and implemented for the purpose. Only top-dumping of ore is done to prevent dumpers or tipper-trucks rolling back and down the stock-pile slope. Dumped ore shall either be levelled or pushed down the stock-pile slope by dozer at regular intervals. Stockpiles exceeding digging height of the loading equipment deployed for re-handling is re-handled top-down wards by forming artificial benches on the stack-slopes. The width of such benches is adequate as to permit safe operation of the equipment deployed for loading and transport of ore.

CONCLUSION

In chrome ore mines, dumping of spoil or OB shall be so done that spoil-banks are benched in accordance with the recommendations of scientific study carried out by an agency having expertise in this regard and in accordance with the stipulations of the permission granted by DGMS. The mining process creates over burden and waste rock while extraction of mineral content from the excavated reserve (typically the strip ratio of over burden to actual mineral reserve is very high in chrome mining).

As a result, huge piles of over burden or waste dump is collected near mining sites and contains significant levels of toxic substances and creates dust clouds with fumes of other toxic gases there by leading to air pollution and water pollution as a result of run off during monsoon season. Hence, the waste dump needs to be stabilized with procedures as described above. The slope monitoring allows failures to be predicted and safe working conditions. The review of monitoring results, visual inspection and regular briefing of field people help to detect the onset of failure. The slope monitoring of dumps is being done by the mine management with the help of total station surveying equipment. To date no large-scale failure is reported.

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