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Copper Mines in Jhunjhunu and Impact on Copper Mine Workers

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Abstract: The total geographical area of the Jhunjhunu district is 2928 square Kms. This stands at 1.73 percent of the total area of the state from the points of area, Jhunjhunu district stand at 22nd place among the existing 33 districts of the state most of the part of the district is coerce by blow sand and dunes which for part of the great that desert sand shifting and active dunes are main hazards to cultivation. Soil erosion is the Result of constant deforestation and mining activity which have resulted in baring the slopes. The hilly area in south eastern part of district is characterized by hills of Aravalli range, running in north easterly direction. The highest peak, 1051 m high is in the south of Lohagar village bordering Sikar district. Hills are almost barren of vegetation except a few bushes of acacia and cactus. The undulating area with small isolated hills having steep slope lies in the south western part of district.

The major portion of hills is found in Khetri and Udaipurwati tehsils. The general elevation above mean sea level rests between 300 and 450m Quaternary level forms are represented by sand and colluvial deposits of talus and scree at piedment slopes. The desertic plain generally lying at an altitude of about 300m amsl occupies the northern part of the district and is covered with sand dunes. The general slope of the area is from south to north. Sand dunes are drifting in nature. District Jhunjhunu is situated in Arid Rajasthan plain known as Rajasthan. It comprises of Rolling hills, some of the arrival ranges in the southeastern side running in the south eastern Direction and range of the Aravali Hills in extreme southeastern of Udaipurwati existing towards Singhana and Khetri in the east, viz Nawalgarh-Khetri upland its general elevation above means sea level is between 300 to 450 meters. The district of Jhunjhunu is poor in forest resources as the total area under forest including hills is reported to be 39613 hectares which is 6.65 % of total geographical area of the districts. The forest coverage is below the state average of about 9 % under forest. If compared to the 13 % of forest area at national average. The district comes out to be roughly half of the matomn average.The major species available in forest is ‘Jant” tree or Khetri (prosaic specigera) it is found in abundance and is utilized’ for various purpose as providing folder to the animals supplying fuel for domestic purpose and checking sole erosion. For the exploration excavation development of mineral “Govt. of Rajasthan” has stated its mining office in Sikar which is having jurisdiction over both the district Sikar and Jhunjhunu. Jhunjhunu is fairly endowed with various minerals whose industrial use has immensely contributed to the economy of the district. Of these, the most important is the copper belt of Khetri from which mining has been carried out since time immemorial.

Keywords: copper, mining, Jhunjhunu, workers, impact, Rajasthan, diseases, particles, effects, mine.

Introduction

Mining in Jhunjhunu is done by both opencast and underground methods. Copper extraction refers to the methods used to obtain copper from its ores. The conversion of copper consists of a series of physical and electrochemical processes. Methods have evolved and vary with country depending on the ore source, local environmental regulations, and other factors.

As in all mining operations, the ore must usually be beneficiated (concentrated). The processing techniques depend on the nature of the ore.[1,2] If the ore is primarily sulfide copper minerals (such as chalcopyrite), the ore is crushed and ground to liberate the valuable minerals from the waste ('gangue') minerals. It is then concentrated using mineral flotation.

The concentrate is typically sold to distant smelters, although some large mines have smelters located nearby. Such colocation of mines and smelters was more typical in the 19th and early 20th centuries, when smaller smelters could be economic.

The sulfide concentrates are typically smelted in such furnaces as the Outokumpu or Inco flash furnace or the ISASMELT furnace to produce matte, which must be converted and refined to produce anode copper.

Finally, the final refining process in Jhunjhunu is electrolysis. For economic and environmental reasons, many of the byproducts of extraction are reclaimed. Sulfur dioxide gas, for example, is captured and turned into sulfuric acid—which can then be used in the extraction process or sold for such purposes as fertiliser manufacture.[3,4]

Oxidised copper ores can be treated by hydrometallurgical extraction in Jhunjhunu.

Most copper ores contain only a small percentage of copper. The remainder of the ore consists of gangue of no commercial value. Gangue from copper mining typically contains silicate minerals and oxides. In some cases these tailings have been retreated as the technology for recovering copper has improved. The average grade of copper ores in the 21st century is below 0.6% copper, with a proportion of economic ore minerals (including copper) being less than 2% of the total volume of the ore rock. A key objective in the metallurgical treatment of any ore is the separation of ore minerals from gangue minerals within the rock.

The first stage of any process within a metallurgical treatment circuit is accurate grinding or comminution, where the rock is crushed to produce small particles (<100 μm) consisting of individual mineral phases. These particles are then separated to remove gangue (rocks residues), thereafter followed by a process of physical liberation of the ore minerals from the rock. The process of liberation of copper ores depends upon whether they are oxide or sulfide ores.

Subsequent steps depend on the nature of the ore containing the copper and what will be extracted. For oxide ores, a hydrometallurgical liberation process is normally undertaken, which uses the soluble nature of the ore minerals to the advantage of the metallurgical treatment plant. For sulfide ores, both secondary (supergene) and primary (hypogene), froth flotation is used to physically separate ore from gangue. For special native copper bearing ore bodies or sections of ore bodies rich in supergene native copper, this mineral can be recovered by a simple gravity circuit.

All primary sulfide ores of copper sulfides, and most concentrates of secondary copper sulfides (being chalcocite), are subjected to smelting. Some vat leach or pressure leach processes exist to solubilise chalcocite concentrates and produce copper cathode from the resulting leachate solution, but this is a minor part of the market.[5,6]

Carbonate concentrates are a relatively minor product produced from copper cementation plants, typically as the end-stage of a heap-leach operation. Such carbonate concentrates can be treated by a solvent extraction and electrowinning (SX-EW) plant or smelted.

The copper ore is crushed and ground to a size such that an acceptably high degree of liberation has occurred between the copper sulfide ore minerals and the gangue minerals. The ore is then wetted, suspended in a slurry, and mixed with xanthates or other reagents, which render the sulfide particles hydrophobic. Typical reagents include potassium ethylxanthate and sodium ethylxanthate, but dithiophosphates and dithiocarbamates are also used.[7,8]

The treated ore is introduced to a water-filled aeration tank containing surfactant such as methylisobutyl carbinol (MIBC). Air is constantly forced through the slurry and the air bubbles attach to the hydrophobic copper sulfide particles, which are conducted to the surface, where they form a froth and are skimmed off. These skimmings are generally subjected to a cleaner-scavenger cell to remove excess silicates and to remove other sulfide minerals that can deleteriously impact the concentrate quality (typically, galena), and the final concentrate sent for smelting. The rock which has not floated off in the flotation cell is either discarded as tailings or further processed to extract other metals such as lead (from galena) and zinc (from sphalerite), should they exist. To improve the process efficiency, lime is used to raise the pH of the water bath, causing the collector to ionize more and to preferentially bond to chalcopyrite (CuFeS2) and avoid the pyrite (FeS2). Iron exists in both primary zone minerals. Copper ores containing chalcopyrite can be concentrated to produce a concentrate with between 20% and 30% copper-in-concentrate (usually 27–29% copper); the remainder of the concentrate is iron and sulfur in the chalcopyrite, and unwanted impurities such as silicate gangue minerals or other sulfide minerals, typically minor amounts of pyrite, sphalerite or galena. Chalcocite concentrates typically grade between 37% and 40% copper-in-concentrate, as chalcocite has no iron within the mineral in Jhunjhunu[9,10].

Jhujhunu in Rajasthan

Discussion

Secondary sulfides—those formed by supergene secondary enrichment—are resistant (refractory) to sulfuric leaching. These ores are a mixture of copper carbonate, sulfate, phosphate, and oxide minerals and secondary sulfide minerals, dominantly chalcocite but other minerals such as digenite can be important in some deposits.

Supergene ores rich in sulfides may be concentrated using froth flotation. A typical concentrate of chalcocite can grade between 37% and 40% copper in sulfide, making them relatively cheap to smelt compared to chalcopyrite concentrates.[11,12]

Some supergene sulfide deposits can be leached using a bacterial oxidation heap leach process to oxidize the sulfides to sulfuric acid, which also allows for simultaneous leaching with sulfuric acid to produce a copper sulfate solution. As with oxide ores, solvent extraction and electro winning technologies are used to recover the copper from the pregnant leach solution.

Supergene sulfide ores rich in native copper minerals are refractory to treatment with sulfuric acid leaching on all practicable time scales, and the dense metal particles do not react with froth flotation media. Typically, if native copper is a minor part of a supergene profile it will not be recovered and will report to the tailings. When rich enough, native copper ore bodies may be treated to recover the contained copper via a gravity separation circuit where the density of the metal is used to liberate it from the lighter silicate minerals. Often, the nature of the gangue is important, as clay-rich native copper ores prove difficult to liberate in Jhunjhunu.

Oxidised copper ore bodies may be treated via several processes, with hydrometallurgical processes used to treat oxide ores dominated by copper carbonate minerals such as azurite and malachite, and other soluble minerals such as silicates like chrysocolla, or sulfates such as atacamite and so on.[13,14]

Such oxide ores are usually leached by sulfuric acid, usually in a heap leaching or dump leaching process to liberate the copper minerals into a solution of sulfuric acid laden with copper sulfate in solution. The copper sulfate solution (the pregnant leach solution) is then stripped of copper via a solvent extraction and electrowinning (SX-EW) plant, with the barred (denuded) sulfuric acid recycled back on to the heaps. Alternatively, the copper can be precipitated out of the pregnant solution by contacting it with scrap iron; a process called cementation. Cement copper is normally less pure than SX-EW copper. Commonly sulfuric acid is used as a leachant for copper oxide, although it is possible to use water, particularly for ores rich in ultra-soluble sulfate minerals.

In general, froth flotation is not used to concentrate copper oxide ores, as oxide minerals are not responsive to the froth flotation chemicals or process (i.e.; they do not bind to the kerosene-based chemicals). Copper oxide ores have occasionally been treated via froth flotation via sulfidation of the oxide minerals with certain chemicals which react with the oxide mineral particles to produce a thin rime of sulfide (usually chalcocite), which can then be activated by the froth flotation plant.

Until the latter half of the 20th century, smelting sulfide ores was almost the sole means of producing copper metal from mined ores (primary copper production). Davenport, et al, noted in 2002 that even then 80% of global primary copper production was from copper–iron–sulfur minerals and that the vast majority of these were treated by smelting.[15,16]

Copper was initially recovered from sulfide ores by directly smelting the ore in a furnace. The smelters were initially located near the mines to minimize the cost of transport. This avoided the prohibitive costs of transporting the waste minerals and the sulfur and iron present in the copper-containing minerals. However, as the concentration of copper in the ore bodies decreased, the energy costs of smelting the whole ore also became prohibitive, and it became necessary to concentrate the ores first.

Initial concentration techniques included hand-sorting and gravity concentration. They resulted in high losses of copper. Consequently, the development of the froth flotation process was a major step forward in mineral processing. In the twentieth century, most ores were concentrated before smelting. Smelting was initially undertaken using sinter plants and blast furnaces, or with roasters and reverberatory furnaces. Roasting and reverberatory furnace smelting dominated primary copper production until the 1960s.

The roasting process is generally undertaken in combination with reverberatory furnaces. In the roaster, the copper concentrate is partially oxidised to produce "calcine" and sulfur dioxide gas.

Roasting generally leaves more sulfur in the calcined product (15% in the case of the roaster) than a sinter plant leaves in the sintered product (about 7% in the case of the Electrolytic Refining and Smelting smelter).As of 2005, roasting is no longer common in copper concentrate treatment, because its combination with reverberatory furnaces is not energy efficient and the SO_2 concentration in the roaster offgas is too dilute for cost-effective capture. Direct smelting is now favored in Jhunjhunu.[17,18]

The initial melting of the material to be smelted is usually referred to as the smelting or matte smelting stage. It can be undertaken in a variety of furnaces, including the largely obsolete blast furnaces and reverberatory furnaces, as well as flash furnaces, Isasmelt furnaces, etc. The product of this smelting stage is a mixture of copper, iron and sulfur that is enriched in copper, and which is called matte or copper matte. The term matte grade is normally used to refer to the copper content of the matte. The purpose of the matte smelting stage is to eliminate as much of the unwanted iron, sulfur and gangue minerals (such as silica, magnesia, alumina and limestone) as possible, while minimizing the loss of copper.This is achieved by reacting iron sulfides with oxygen (in air or oxygen enriched air) to produce iron oxides (mainly as FeO, but with some magnetite (Fe3O4)) and sulfur dioxide.Copper sulfide and iron oxide can mix, but when sufficient silica is added, a separate slag layer is formed.Adding silica also reduces the melting point (or, more properly, the liquidus temperature) of the slag, meaning that the smelting process can be operated at a lower temperature.

Slag is less dense than matte, so it forms a layer that floats on top of the matte.

Copper can be lost from the matte in three ways: as cuprous oxide (Cu_2O) dissolved in the slag as sulfide copper dissolved in the slag or as tiny droplets (or prills) of matte suspended in the slag.

The amount of copper lost as oxide copper increases as the oxygen potential of the slag increases. The oxygen potential generally increases as the copper content of the matte is increased. Thus the loss of copper as oxide increases as the copper content of the matte increases.

On the other hand, the solubility of sulfidic copper in slag decreases as the copper content of the matte increases beyond about 40%.Nagamori calculated that more than half the copper dissolved in slags from mattes containing less than 50% copper is sulfidic copper. Above this figure, oxidic copper begins to dominate.

The loss of copper as prills suspended in the slag depends on the size of the prills, the viscosity of the slag and the settling time available. Rosenqvist suggested that about half the copper losses to slag were due to suspended prills in Jhunjhunu.

The mass of slag generated in the smelting stage depends on the iron content of the material fed into the smelting furnace and the target matte grade. The greater the iron content of the feed, the more iron that will need to be rejected to the slag for a given matte grade. Similarly, increasing the target matte grade requires the rejection of more iron and an increase in the slag volume.

Thus, the two factors that most affect the loss of copper to slag in the smelting stage are:
- matte grade
- mass of slag,

This means that there is a practical limit on how high the matte grade can be if the loss of copper to slag is to be minimized. Therefore, further stages of processing (converting and fire refining) are required.

Reverberatory furnaces are long furnaces that can treat wet, dry or roasted concentrate.[9] Most of the reverberatory furnaces used in the latter years treated roasted concentrate because putting dry feed materials into the reverberatory furnace is more energy efficient, and because the elimination of some of the sulfur in the roaster results in higher matte grades.

The reverberatory furnace feed is added to the furnace through feed holes along the sides of the furnace. Additional silica is normally added to help form the slag. The furnace is fired with burners using pulverized coal, fuel oil or natural gas and the solid charge is melted.

Reverberatory furnaces can additionally be fed with molten slag from the later converting stage to recover the contained copper and other materials with a high copper content.

Because the reverberatory furnace bath is quiescent, very little oxidation of the feed occurs (and thus very little sulfur is eliminated from the concentrate). It is essentially a melting process. Consequently, wet-charged reverberatory furnaces have less copper in their matte product than calcine-charged furnaces, and they also have lower copper losses to slag. Gill quotes a copper in slag value of 0.23% for a wet-charged reverberatory furnace vs 0.37% for a calcine-charged furnace in Jhunjhunu [19,20].

In the case of calcine-charged furnaces, a significant portion of the sulfur has been eliminated during the roasting stage, and the calcine consists of a mixture of copper and iron oxides and sulfides. The reverberatory furnace acts to allow these species to approach chemical equilibrium at the furnace operating temperature (approximately 1600 °C at the burner end of the furnace and about 1200 °C at the flue end, the matte is about 1100 °C and the slag is about 1195 °C). In this equilibration process, oxygen associated with copper compounds exchanges with sulfur associated with iron compounds, increasing the iron oxide content of the furnace, and the iron oxides interact with silica and other oxide materials to form the slag.

The slag and the matte form distinct layers that can be removed from the furnace as separate streams. The slag layer is periodically allowed to flow through a hole in the wall of the furnace above the height of the matte layer. The matte is removed by draining it through a hole into ladles for it to be carried by crane to the converters. This draining process is known as tapping the furnace. The matte taphole is normally a hole through a water-cooled copper block that prevents erosion of the refractory bricks lining the furnace. When the removal of the matte or slag is complete, the hole is normally plugged with clay, which is removed when the furnace is ready to be tapped again.

Reverberatory furnaces were often used to treat molten converter slag to recover contained copper. This would be poured into the furnaces from ladles carried by cranes. However, the converter slag is high in magnetite and some of this magnetite would precipitate from the converter slag (due to its higher melting point), forming an accretion on the hearth of the reverberatory furnace and necessitating shut downs of the furnace to remove the accretion. This accretion formation limits the quantity of converter slag that can be treated in a reverberatory furnace.

While reverberatory furnaces have very low copper losses to slag, they are not very energy-efficient and the low concentrations of sulfur dioxide in their offgases make its capture uneconomic.Consequently, smelter operators devoted a lot of money in the 1970s and 1980s to developing new, more efficient copper smelting processes. In addition, flash smelting technologies had been developed in earlier years and began to replace reverberatory furnaces. By 2002, 20 of the 30 reverberatory furnaces still operating in 1994 had been shut down.

In flash smelting, the concentrate is dispersed in an air or oxygen stream and the smelting reactions are largely completed while the mineral particles are still in flight. The reacted particles then settle in a bath at the bottom of the furnace, where they behave as does calcine in a reverberatory furnace. A slag layer forms on top of the matte layer, and they can separately be tapped from the furnace. The matte, which is produced in the smelter, contains 30–70% copper (depending on the process used and the operating philosophy of the smelter), primarily as copper sulfide, as well as iron sulfide. The sulfur is removed at high temperature as sulfur dioxide by blowing air through molten matte.[21] The purity of this product is 98%, it is known as blister because of the broken surface created by the escape of sulfur dioxide gas as blister copper pigs or ingots are cooled. By-products generated in the process are sulfur dioxide and slag. The sulfur dioxide is captured and converted to sulfuric acid and either sold on the open market or used in copper leaching processes. The blister copper is put into an anode furnace, a furnace that refines the blister copper to anode-grade copper in two stages by removing most of the remaining sulfur and iron, and then removing oxygen introduced during the first stage. This second stage, often referred to as poling is done by blowing natural gas, or some other reducing agent, through the molten copper oxide. When this flame burns green, indicating the copper oxidation spectrum, the oxygen has mostly been burned off. This creates copper at about 99% pure. The copper is refined by electrolysis. The anodes cast from processed blister copper are placedinto an aqueous solution of 3–4% copper sulfate and 10–16% sulfuric acid. Cathodes are thin rolled sheets of highly pure copper or, more commonly these days, reusable stainless steel starting sheets (as in the IsaKidd process). A potential of only 0.2–0.4 volts is required for the process to commence. In industrial plants current densities up to 420 A/m2 are possible. At the anode, copper and less noble metals dissolve. More noble metals such as silver, gold, selenium, and tellurium settle to the bottom of the cell as anode slime, which forms a salable byproduct. Copper (II) ions migrate through the electrolyte to the cathode. At the cathode, copper metal plates out, but less noble constituents such as arsenic and zinc remain in solution unless a higher voltage is used in Jhunjhunu.

Results

The main physical conditions of copper mine workers in Jhunjhunu were found to be problems related to high-altitude work, the inhalation of copper dust, and noise exposure; eating and musculoskeletal disorders, cardiovascular and respiratory disorders, accidents, and low back pain. Regarding mental health conditions, the following were highlighted: psychological demands, the impact on the sleep quality due to shift work, fatigue, anxiety, depression, violence on subcontractors, and worsening of life standards after relocation, due to copper inhalation. Working in copper mine impacts the health of workers, increasing the exposure to health conditions that increases the sense of suffering and worsens their quality of life. The evidence indicates that they expose themselves to risks and hazards to their physical health, such as, temperature variations, cardiovascular disturbances because of work in high-altitude, fractures, injuries, falls, lacerations, and musculoskeletal disorders, respiratory diseases, like tuberculosis, exposure to polluters and toxic chemical agents, among others. Mental conditions include stress at work, caused by a shifts work system, tasks, and extensive commuting that lessens social relations and limits the emotional bond with family and friends; even so, it can affect relatives, as they witness the depressive symptoms of their partners. At the same time, shift work can affect the sleep-wake cycle; which increases the sense of distress that turns into anxiety and depression symptoms. Due to the aforementioned, one action that can help to lessen occupational health risks and ensure more healthy surroundings in the Jhunjhunu copper mining industry is the increase of knowledge about the group of diseases ailing the workers of this market. The main diseases in surface and underground mines were sensory overload (prolonged interaction with computational or radio systems), risks of cervical sprain injuries on truck and machinery operators, the exposure to radiant temperature, which increases the cardiovascular load, and, finally, unsafe actions caused by poorly designed and distributed spaces. Workers with chronic copper exposure increase lymphocyte damage and decrease control of antioxidant mechanisms, increasing the risk of cancer [22]. The miners face extreme temperatures, high workload, risks of injuries, and the development of musculoskeletal disorders. All these complications, are because mining work implies the performance of heavy activities, such as the handling of machinery, extensive shifts, vibrations, and demanding postural loads. The exposure to suspended dust and annoying noises; those from a copper cathode plant, to hazardous chemicals (sulfuric acid, solvents); those in the flotation area, to working outdoors; those in a process plant, to falls and electrical risks; those in underground mines, to the risk of being caught by landslides; and those in administration, at ergonomic risks. Working in high altitude implies the exposure to hypobaric hypoxia, which is chronified by variations on altitude caused by the shift systems, producing physical alterations, jeopardizing the ventilatory response, pulmonary-circulatory adjustments, and the cardiovascular response. The greater the feeling of physical fatigue, the greater the feeling of cognitive fatigue; with Acute Hill Sickness having an important weight on it. The conditions associated to these sensations were the level of job satisfaction, workload, and the shift system. Negative variations in them led to an increase in the sensation of both fatigues. During the research work, it was observed that the risks and diseases hurt and degrades body attributes, leading miners to suffer effects on their health. The injuries, musculoskeletal disorders, alterations on the respiratory system impact their quality of life since they create disability and limit their possibilities for the development of new tasks and specialties. This urges us to assume that the repercussions not only refer to physical alterations; but also involve their mental health, as a physical health condition implies an increase in suffering. This is further reinforced because copper mining work implies a negative impact for the workers mental health; where the work risks and hazards end up harming them, increasing pathogenic suffering at work.

Conclusions

Based on the above, it is possible to conclude that copper mining work affects the health of workers in Jhunjhunu in different days. During the research work, it was observed that the risks and diseases hurt and degrades body attributes, leading miners to suffer effects on their health. The injuries, musculoskeletal disorders, alterations on the respiratory system impact their quality of life since they create disability and limit their possibilities for the development of new tasks and specialties. This urges us to assume that the repercussions not only refer to physical alterations; but also involve their mental health, as a physical health condition implies an increase in suffering. This is further reinforced because copper mining work implies a negative impact for the workers mental health; where the work risks and hazards end up harming them, increasing pathogenic suffering at work in Jhunjhunu [22].

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