ABSTRACT

The iron ore processing in India produces large amount of tailings as slime during the wet processing and earlier that slime is discarded as waste due to the presence of high percentage of alumina and silica. Research work is going on to recover iron values by reducing alumina and silica levels. This will suppose to improve the productivity of the washing plant. The current review paper is giving case studies about the slime beneficiation work in Bolani and Chitradurga iron ore processing plant for the production of pellet grade iron ore by utilizing slime. The results from the reference research work had showed that the application of beneficiation process for the iron ore slime in India may lead to the sustainable growth of iron ore industries and it has also opened up answers for several questions regarding waste utilization and disposal strategies.

KEYWORDS: Slime, Hydrocyclone, WHIMS (Wet High Intensity Magnetic Separator), R.O.M (Run of Mine)

INTRODUCTION

Iron & steel is the driving force behind industrial development in a country. The vitality of the iron & steel industry largely influences its economic status. The mining of iron ore, an essential raw material for Iron & Steel Industry, is arguably of prime importance among all mining activities undertaken by any country. India is the leading producers as well as exporters of iron ore in the world with the total resources of over 28.52 billion tones of hematite (Fe₂O₃) and magnetite (Fe₃O₄). Hematite and magnetite are the most important iron ores in India.
Diagram 1: The quantity and value of iron ore production in different states of India [1].

Of these, hematite is considered to be superior because of its higher grade. Indian deposits of hematite belong to the Precambrian Iron Ore Series and the ore is within banded iron ore formations occurring as massive laminated, friable and also in powdery form. About 59% hematite ore deposits are found in the Eastern Sector. About 92% magnetite ore deposits occur in Southern Sector, especially in Karnataka. [1]

One of the most immediate technological challenges facing the iron ore mining industry is to deal with the problem of processing alumina rich iron ore fines and slimes. For the sustainable growth of iron ore industry which is beset with serious problems of shortage of land and water, it is absolutely imperative that the art of mineral processing technology is utilized to take the industry closer to a position of zero waste production.

**Need for iron ore Beneficiation:**

Indian hematite ores are typically rich in iron but contain unusually high alumina (as high as seven percent. The current practice of iron ore washing in India results in three products, namely coarse ore lumps directly charged to blast furnace, the classifier fines (3-5% alumina) which with or without beneficiation are fed to sintering plants and the slimes (6-10% alumina) which are currently discarded as waste, the slimes which were discarded as waste are having Fe content.

when the beneficiation process carried out and the reduction of alumina and silica percentage is done in the system with enhancing the Fe content in the slime it can be fed to the blast furnace so that yield of the total process were increased. If the slime or any other iron ore which having the high Alumina percentage is feed into the blast furnace means it will affect total system, the below context gives the effect of alumina presence in the blast furnace feed.

- The alumina content in iron ore fines used in sinter making all over the world is less than 1%. In contrast, iron ore fines in India assay as high as 3.0-5.5%. The sinter
quality produced from such alumina-rich ore fines, is thus much poorer. The adverse effect of alumina on sinter strength productivity and its reduction – degradation characteristics (RDI) are well documented and conclusively established (2-4).

- In the form of alumina-rich lumps or sinter, the blast furnace productivity is significantly affected due to the presence of alumina in the feed. High alumina slag which is highly viscous requires larger quantity of flux (10% MgO) and relatively larger slag volumes resulting in an increase in coke consumption and a decrease in blast furnace productivity. According to one estimate, a decrease in alumina content in the sinter from 3.1 to 2.5% will improve the RDI by at least six points, lower blast furnace coke rate by 14 kg per ton of hot metal and increase its productivity by about 30% under Indian operating conditions (4-7).

The generation of iron ore slimes in India is estimated to be 10-25% by weight of the total iron ore mined – the iron ore values are lost to the tune of 15-20 million tones every year. In addition, these slimes stored in massive water ponds poses enormous environmental hazard. SAIL alone has more than 50 million tons of slimes accumulated over the years. Considering the fact that iron ore production will more than double and rise to at least 300 million tones soon, finding suitable means of safe disposal/utilization of slimes is indeed urgent. But these slimes cannot be reused without beneficiation and reduction of alumina and silica.

**Beneficiation of Indian ore slime:**

This paper has discussed about a review of two plants where beneficiation of iron ore tailings were carried, iron ore mines taken for consideration were Chitradurga plant in Karnataka and Bolani plant in Odisha.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Chitradurga plant(*)</th>
<th>Bolani plant(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(in percentage)</td>
<td>(in percentage)</td>
</tr>
<tr>
<td>Fe</td>
<td>49.86</td>
<td>53.71</td>
</tr>
<tr>
<td>SiO₂</td>
<td>10.19</td>
<td>5.25</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>10.19</td>
<td>6.25</td>
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Table 1:*The chemical composition of the slime sample from the Chitradurga and Bolani mines [8,9].

The above table gives the chemical composition of the slime which were collected from both of the mines and the chemical composition shows there is a presence of 49.86 percentage of
Fe in Chitradurga plant slime whereas the alumina percentage was about 10.19 and in the case of Bolani plant the Fe value was 53.71 percentage and the alumina was 6.25 percentage.

Diagram 2 Complete flow sheet for beneficiation of Chitradurga iron ore slime.[8]

The above process sheet describes that beneficiation process carried out in Chitradurga iron ore slime beneficiation plant, the slime was collected and size analysis were done, the size distribution were found to be from 50µm to < 20µm, the most of the particles were under <20µm i.e. the slime were too fine, in the case of ≤ 20µm the percentage of Fe is 49.56% and the more amount of gangue materials were found and in the case of 50µm particles the percentage of Fe is 56.28% and the alumina and silica ranges to 4.43%, 7.26%, the aim of the work is to reduce the value of the silica and alumina in the -20micron particles so that they can be used as pellet for blast furnace feed, when it is processed and the slime is free from gangue material. The slime is treated by hydro cyclone, wilfley table, Wet High Intensity Magnetic Separator (WHIMS) and froth flotation equipment’s, the final product were undergone chemical analysis and the final value of the beneficiated slime was Fe 66.35% and alumina and silica ranges to 1.44% and 1.75%. By considering the flow sheet the slime which having the size range less than 20µm which were processed by certain
mineral processing techniques and the final product is having the ferrite content up to 66.35% where as in the slime it was about 56.28% i.e. rest of the composition is filled with gangue material, when considering the final product the gangue material like silica and alumina were reduced to 1.75% and 1.55% so it is important to analyse the flow sheet in the above process so that it may open a way for green belt production. When considering the beneficiation process two process parameters play a major role one is particle size (dₚ) and the other one is mineralogical characteristics, the other parameters which having the influence in the beneficiation process is specific gravity, surface energy, wetting property of the mineral particles which were finely distributed throughout the slime. In the flow sheet the slime is primarily classified using hydro cyclone. Classification is a method of separating mixtures of minerals into two or more products on the basis of the velocity with which the grains fall through a fluid medium. In mineral processing, this is usually water, and wet classification is generally applied to mineral particles which are considered too fine to be sorted efficiently by screening. Since the velocity of particles in a fluid medium is dependent not only on the size, but also on the specific gravity and shape of the particles. So in this process the maximum denser particles were collected in the under flow and the less dense particles were collected in the upper flow. The next step is feeding the underflow product to wilfley table. The wilfley table is working under the principle of gravity concentration. The separation of mineral particles based upon the gravity to separate minerals of different specific gravity by their relative movement in response to gravity and one or more other forces, the latter often being the resistance to motion offered by a viscous fluid, such as water or air. Mostly the wilfley table used to avoid the usage of froth flotation process to avoid environmental pollution and to have more efficient dewatering, and to have the absence of adhering chemicals which could interfere with further processing. the concentrated product from the wilfley table was allowed for further treatment by WHIMS (wet high intensity magnetic separator) Magnetic separators exploit the difference in magnetic properties between the ore minerals and are used to separate either valuable minerals from non-magnetic gangue, WHIMS is applied for the paramagnetic material which will be attracted along the lines of magnetic force to points of greater field intensity. Whereas the major amount of mineral found in this plant is hematite which can be used in low intensity separator because it is also considered to be ferromagnetic material until or unless the sample is fried to increase the remanence. But to avoid the sub process addition WHIMS is applied to separate the concentrate material from the gangue. Where the middling product was sent to hydro cyclone to undergo a feed back in order to
ensure the concentrate material was not dumped in the tailing. At last the magnetic materials which were separated from the WHIMS were subjected to Froth Floatation. Flotation is a physico-chemical separation process that utilises the difference in surface properties of the valuable minerals and the unwanted gangue minerals. At last the final product were dried and cleaned then subjected to chemical characterisation.

Diagram 3: Complete flow sheet for beneficiation of Bolani iron ore slime. [9]

Considering the Bolani plant the run of mines (r.o.m.) ore is crushed in two stages, primary and secondary to reduce the r.o.m 1800 mm to 200 mm by primary crushing and then to 50 mm by secondary crushing. The secondary crushed product —50 mm is screened over 10mm to separate —40+10mm BF lump and —10mm sinter fines for Durgapur Steel Plant, India. The plant has two processing line which can be operated either in dry or wet mode. The low-grade beneficiable ore is treated in wet processing mode whereas high-grade ore is treated in dry processing mode. During wet process operation, the secondary crushed B.O. grade ore of size —50mm is directed to drum scrubber and scrubbed product is wet screened on 10mm screen to separate washed lump — 50+10mm. The wet screened —10mm fines fraction is treated in rake classifier and the classifier underflow washed fines (-10+0.2mm) recovered
over a dewatering screen (0.2mm aperture) and directed to stockpile. The classifier overflow and dewatering screen underflow materials considered as generated slime at 20-25% of r.o.m input to plant. This slime in slurry form (20% solids) is directed to thickener where flocculants are added for settlement of fine iron particles and recovery of recirculating water. The settled slime at thicker bottom having about 40% solid is directed to tailing pond for disposal. The characterization study of the slime showed the presence of iron minerals namely, hematite, martite and goethite and gangue minerals namely, gibbsite, chlorite and kaolinite in Bolani iron ore slime. These slimes are very fine in nature and its average iron content ranges between 52-55% which are Unsuitable for sinter making due to its inferior grade and being discarded as process waste. So the beneficiation process was undergone to produce a pellet grade fines for blast furnace feed. The flow sheet was generated and the beneficiation process was carried as per the flow sheet. Initially the slime was classified by the rake classifier, the rake classifier is working under the principle of classification in this method the denser particles will go for under flow where the less dense particles were moving to over flow. The under flow particles were subjected to dewatering, mostly the dewatering will be carried at the end to separate the final concentrate has to be separated from a pulp in which the water-solids ratio may be high. But it can also use in middle of the treatment in order to make the concentrate for shipment or to prepare the feed for subsequent processes. The underflow product from the rake classifier were provided to the dewatering screen were the over flow were considered to be sinter fines and the under flow is subjected to treatment. The overflow from the rake classifier and the under flow from the dewatering screen were mixed and subjected to hydro cyclone treatment. The flow sheet consist of two stage hydro cyclone were the less denser particles were discarded and high dense particles were collected and subjected to final treatment slow speed spiral classifier(SSSC) and the concentrating material were collected and subjected to cleaning and drying followed with chemical analysis. The beneficiation tests on Bolani iron ore slime by hydro cyclone showed the possibility of upgrading the slime to 63.5%Fe, 1.8 SiO₂ and 2.8%Al₂O₃ with 31.1% product recovery from the slime feed assaying 53.71% Fe, 5.25% SiO₂ and 6.25% Al₂O₃

**Future Use of Slime:**

In order to accomplish the task of developing zero waste technology for Indian iron ores, it is important to find appropriate means of utilizing the ultra-fine iron-rich alumino-silicate residue obtained during the beneficiation of iron ore slimes. Amongst several industrially useful products being explored worldwide and made from waste materials, eco-cements are
perhaps the most promising. Considering the large volumes of cement and concrete products consumed and the rates of growth anticipated in the buildings/construction industry in India, it is only natural that efforts are being made to incorporate industrial and mining wastes as substitutes for raw materials, admixtures, fillers, binders etc. in the construction industry. For example, the use of granulated blast furnace slag, volcanic ash, certain kinds of fly ashes and other materials having adequate lime reactivity in cement and concrete applications is now a standard industrial practice.

Standard specifications are for instance, available in almost all the countries for blended cements. Since there are stringent specifications on the quality of raw materials permitted in the manufacture of Portland cements with respect of composition and the presence of certain impurities such as phosphate, chloride, sulfate, iron oxide, titania, magnesia, etc. the use of waste products is obviously limited. Recent work on special cements, in particular those based on novel alinite and sulpho-aluminate type solid solution cementitious phases, however indicates that good quality cement/concrete products could be manufactured almost exclusively from wastes such as the one produced during the beneficiation of iron ore slimes. These cements are thus called eco-cements [10-15]

Conclusion:

The Review on work done by the researchers based on the processing of iron ore slimes in India indicates the need of the utilization of the alumina rich slimes to increase the overall plant yield and to reduce the land and water scarcity in the iron ore mines. The beneficiated slime may be pelletized and mixed for blast furnace feed. The remaining slime may be used for producing eco cement. The slime beneficiation circuit of Bolani mine is much simple than that of Chitradurga mine. In Chitradurga plant lime is treated with hydro cyclone, wilfley table, WHIMS, and lastly with flotation cells, whereas in Bolani plants, it is treated with two stages of hydro-cyclones with a SSSC(slow speed spiral classifier), so the beneficiation flow sheets totally depends on the percentage of elements present in slimes as well as particle size distribution in the slime

References: