EFFECT ON AIR QUALITY AND TREATMENT OF SOLID WASTE GENERATED DURING PROCESSING OF IRON ORES FOR STEEL MAKING

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ABSTRACT

In this investigation an estimate of SPM generated on simulated industrial crushing without proper dust collection system is carried out at laboratory. The SPM level was found to be 1496.09μg/m3 without dust collection system which is much higher than the specified limit. Thus calls for proper measures for collection of dust particles for industrial crushing of iron ores. The solid waste generated during processing of iron ores was treated in a wet high intensity magnetic separator (WHIMS) and flotation. It was possible to produce a concentrate with Fe content of 64.9 % having yield of 48.7 % by WHIMS and 64.5 % having yield of 47 % by flotation. That can be directly used as pellet feed to DRI plants. The remaining waste material may be treated with flocculants such as starch-alum combination followed by solid/liquid separation for safe disposal.

KEYWORDS SPM, Air quality; Classification; WHIMS; Flotation; Solid liquid separation.

INTRODUCTION

Steel production and consumption has grown steadily in developing countries like India, China and Brazil over last several years. The quantum of raw material required for such increased production of steel also increases significantly. Processing of iron ore produces fine dusts(suspended particulate matter) emanating during crushing the ores and causes both air and water pollution. Similarly, the processing of ores produces some usable concentrate as well as substantial amount of rejects in the form of slimes wherein a significant amount of iron values (iron content of 50% or more) are lost. The management of tailings from iron ore mines is an important issue, from the point of view not only of pollution control but also of the conservation of resources[1]. On present day techno-economic considerations, it may not be worthwhile to extract the iron from such a lean source; however, in future, when resources have been reduced by extraction, it may become economically viable to extract iron content by applying new technologies. However, due to the high cost of land and bearing in mind that the deforestation of the forests normally found around iron ore mines for the construction of tailings ponds are protected by statute, it is worthwhile examining the feasibility of minimizing the pond volumes. In terms of tailings management, reduction of tailings volume is feasible, provided the maximum iron content is extracted by a suitable technology by adding additional units to the beneficiation plan[2] .The further recovery of usable ore fines from tailings from conventional iron ore beneficiation plant extends the life of the tailing pond and makes the recovered fines available for use as pellet feed.

The purpose of this study is to investigate the various beneficiation methods viz reverse flotation and wet high intensity magnetic separation for separation of hematite from gangues (alumina and quartz) using a batch, bench-scale, mechanical flotation cell and Humboltz Wedag make WHIMS respectively. The gangue (waste) goes into the froth and the iron oxide is recovered as the sink. As the selectivity of collector ion adsorption is often contributed by regulating agents, so condition are to be controlled to prevent the iron bearing minerals to float. Starch is used as a depressant for iron ore in conjugation with a basic pH. The collector employed for gangue depends upon the gangue mineral, which needs to be characterized.

MATERIALS AND METHODLOGY

Materials

A study was carried out during crushing operation of iron ore in laboratory to quantify its environmental impact on air. The equipment used for this was Respirable Dust Sampler (RDS) model: Envirotech APM 460 NL which uses an improved cyclone (with sharper cut off D-50 at 10 µm) to separate the coarser particle (>10 µm) from the air steam before filtering it on the glass microfiber filter with size < 10 um.

Iron ore slime sample having of size of -150 µm from Eastern India, Jharkhand was taken for the present studies. The deslimed iron ore material obtained from 2” hydrocyclone was used as a feed to WHIMS and flotation.

Reagents

All reagents used are of AR grade. Quaternary ammonium salt i.e. Cetyl trimethyl ammonium bromide (CTAB) or Hexadecyl trimethyl ammonium bromide is used here as collector, Depressant: Starch, Dispersant Sodium metasilicate.

Methods

Prior to flotation desliming of iron ore slime was done using a classifier i.e. 2” hydrocyclone under the following condition; vortex finder 14.3mm, apex 5mm and feed pressure of 10 psi.

For flotation test, the pulp was kept agitated for 2 min for clear dispersion of the solid particles in the flotation cell. pH of the solution was adjusted to the required value by adding NaOH or H2SO4, depressant solution (starch) was added according to the required dosage and conditioned for at least 10 min. Then the pulp was conditioned with a dispersant (sodium metasilicate) and collector. Later frother was added and then air is allowed to pass into the cell. Forth was collected for a given length of time. Both froth and the sink products were treated for solid/liquid separation, dried and chemically analyzed for their Fe content.

For wet high intensity magnetic separation study(Humboltz Wedag make model Jones P40), deslimed iron ore slime of 2” classifier having dry weight 500gm was feed as slurry with solid concentration 10 % from top with required current flow and sieve size for the desired result. The magnetic, the nonmagnetic and the middling fractions were collected at the bottom during running operation of machine. The solid weights of the products were measured after drying and these products were analysed for Fe %.

RESULT AND DISCUSSION

Environmental impact on air during crushing operation of iron ore in laboratory

Crushing operation of iron ore generated preferential of suspended particulate matter (SPM) and respirable particulate matter (RPM) to air which causes a lots of pollution to atmosphere. In this concern, a study was undertaken in laboratory to know the extent of pollution generated during operation and also during un-operational time of crusher unit without proper dust collection system and the results are presented in Table 1.

Table 1:- Air quality measurement done for a period of 8 hours at 20-metre distance from crushing units in the laboratory.

Parameter	Dust emitted (μg/m^3)	Iron content
SPM	1496.09	Fe % 6.72
RPM	393.61	15.42 ppm

The result shown in Table 1 depict that crushing of iron ore by jaw crusher for a period of 8 hours in laboratory produces SPM (Suspended Particulate Matter) and RPM as 1496.09 μg/m3 and 393.61 μg/m3 respectively. The SPM concentration is higher than the Fugitive dust standard (1200 μg/m3); however, the RPM concentration is below than the recommended Fugitive dust standard (500 μg/m3).

While the data got after analysis of Fe content (glass filter paper) through AAS (Atomic Absorption Spectrometer) shows 15.42 ppm (RPM) and chemical analysis of sample collected in dust cup (SPM) shows Fe content of 6.72%. The data reveals that Fe % in SPM (Suspended Particulate Matter) is higher than the Fugitive dust standard (4.4 %) and the Fe content in RPM (Respirable Particulate Matter) is also higher than the USEPA (United States Environmental Protection Agency Standard):- 5ppm. As SPM has the tendency to settled down due to its heaviness, it causes less pollution to environment while the RPM due its small size (-10 μm) causes various respirable diseases to human being.

CHEMICAL ANALYSIS & PARTICLE SIZE DISTRIBUTION OF SLIME SAMPLE

Iron ore slime as received was analyzed for iron content by wet chemical methods and Fe content was found to be 51.16%. The slime sample was subjected to wet screen analysis and the results are given in Fig.-1

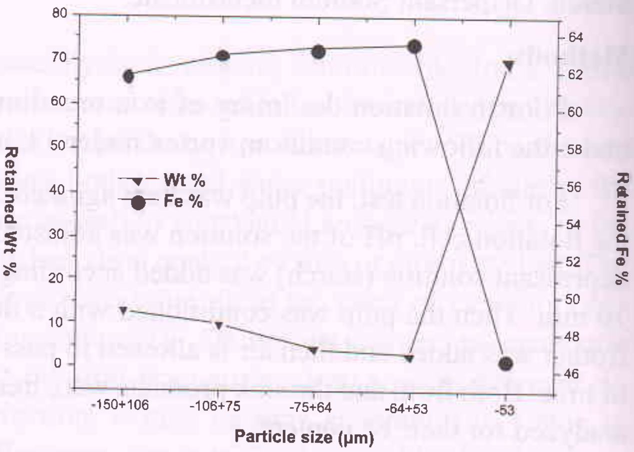

Fig. 1: Screen analysis of the iron ore slime sample.

Thus, Fig. 1 shows that the sample is extremely fine in nature and 69.7% of the material is passing below 53 μm. Classification is expected to enrich the coarser fraction with valuable iron content and remove ultrafine gangue materials which can interfere with the flotation of coarse / medium sized particles.

MINERALOGICAL CHARACTERISTICS

Mineralogical studies indicated that the sample contains mainly hematite and geothite, which are the major iron-bearing mineral phases. Quartz and kaolinite occur as the major gangue phases.

XRD study of the as received slime sample revealed that the major iron bearing minerals are hematite followed by goethite. Magnetite is present in little amount. The gangue mineral was identified as quartz. The liberation was found to be more than 90 % for the -150+106 µm size fraction.

BENEFICIATION

As indicated in the Fig.1, the slime sample contains a large proportion of very fine particles, which may interfere in the flotation process and hence a desliming operation was conducted on the iron ore slime sample using a 2" Mozley's Hydrocyclone unit.

Desliming

The as received slime sample was subjected to hydrocycloning under best operating condition as shown in Table-2. Based on the above studies, it is possible to obtain a deslimed product with a yield of 67.3% containing 60.6% Fe.

Table-2: Results of desliming using laboratory 2" hydrocyclone

Product	Yield (%)	Fe Assay (%)	Operating condition
Cyclone underflow	67.3	60.6	Pressure: 10 psi; Vortex Finder Dia:14.3 mm
Cyclone overflow	32.7	31.4	Apex Dia : 5 mm; Solids: 10 %

REVERSE FLOTATION

Reverse cationic flotation of deslimed iron ore slime was carried out using cationic collector CTAB for removing silica and alumina impurities. The effect of solid concentration on the performance of the flotation were studied by keeping other parameters constant and the results are discussed below:-

Effect of solid concentration on flotation of iron ore

The effect of solid concentration on reverse flotation of iron ore slime was studied and the results are given in Fig.2. The detailed experimental condition is as follows: Collector concentration:1.5 kg/t; pH:7.7, Depressant (Starch):1kg/t; Dispersant (Sodium silicate):100 ppm; Frother (MIBC):0.058 kg/ton and Impeller rotation:1100 rpm.

It is evident from Fig.2, an increase in the solid concentration from 10 to 45 % increases the % yield of concentrate from 24.59 to 90.7. On the other hand, the % Fe of concentrate first increases from 57.34 to 64.51 with increase in the solid concentration from 10 to 20 % and then decreases to 61.04 with increase in solid concentration from 20 to 45 %. So, 20 % solid concentration enables optimise action of reagent on the mineral resulting good separation thus making the concentrate rich in iron with an increase in yield. Hence, 20 % solid concentration was maintained as it gives reasonable result in terms of % yield (69.76) and % Fe (64.5).

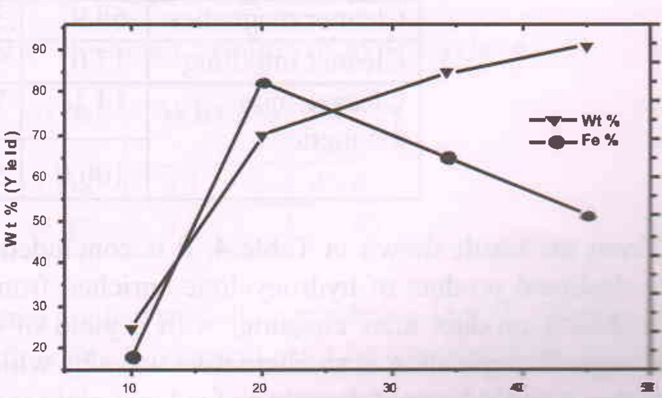

Fig. 2: Effect of solid concentration on flotation of iron ore.

Based on the above studies, it is possible to obtain the required valuable from iron ore slime using froth flotation with a yield of 69.76 % (46.94% with respect to original sample) containing 64.5 % Fe. These valuable obtained could be used directly as feed material for pellet to DRI plants. The best condition for froth flotation is given in Table-3.

Table-3: Operating condition for froth flotation of iron ore.

Product	Yield (%)	WRO(%)	Assay (%)	Optimised test condition
Sink conc.	69.8	47.0	64.5	Collectors: 1.5 kg/t; Depressant: 1 kg/t Dispersant: 100 ppm; pH: Natural; impeller rotation:1100 Hz and solid concentration:20%
Float	30.2	20.3	51.94	

MAGNETIC SEPARATION (JONES P40 WHIMS)

The concept of magnetic separation is based on the ability to magnetise a particular mineral by applying certain current and then physically collect it. In WHIMS (Wet High Intensity Magnetic Separation), electromagnets generate high magnetic intensity up to 20,000 gauss in the separation chamber with the application of desired current.

The deslimed iron ore sample obtained at best condition of hydrocyclone was subjected to Wet High Intensity Magnetic Separation for their enrichment. The effects of current (magnetic field) on the performance of the WHIMS was studied and the result is shown in Table 4.

Table 4. Magnetic separation of deslimed iron ore slime at current 0.6 ampere

	Condition: 10% solid concentration ; Grid dia.: - 8 mm		
Process product	**wt%**	**WRO,%**	**Fe%**
Magnetics*	81.8	55.1	63.1
Middling	11.7	7.9	51.74
Non-magnetics	6.5	4.3	42.4
	100.0	67.3	60.43
Cleaning of above *magnetic fraction by WHIMS			
Process product	**wt%**	**WRO,%**	**Fe%**
Cleaner magnetics	68.9	38.0	67.2
Cleaner middling	17.0	9.4	57.56
Cleaner non-magnetics	14.1	7.7	50.2
	100.0	55.1	63.09

From the result shown in Table 4, it is concluded that at a current of 0.6 ampere, Fe content of the deslimed product of hydrocyclone enriched from 60.6 % to 65.3% on mixing the magnetic and middling product after cleaning, with a yield of 46.85 % (with respect to original sample). Thus magnetic separation is an alternative ways by which the iron ore slime get enriched to such an extent that it could be used directly as feed material for pellet to DRI (Direct-Reduction Iron) plants.

Advantages in using iron ore pellets instead of iron ore lumps are many – conservation of resources such as iron ore and keeping better environment are the most important among others.

Hydrocyclone (Classifier)

Further, the product obtained as overflow of 2" classifier after desliming having Fe content 31.39 % was subjected to 1" classifier under given condition for enrichment as shown in Table 5.

Condition-: apex- 2.2 mm, vortex finder- 7, pressure- 20 psi ; solid concentration: 10 %

Table 5: Product of 1" hydrocyclone

Cyclone output	wt%	WRO,%	Fe%
U/F	37.9	12.4	40.28
O/F	62.1	20.3	27.21

As evident from Table 5, the deslimed product obtained increases its Fe % from 31.39 to 40.28 with a yield of 37.9 %. So considerable amount of particle are recovered but with low Fe grade. Hence this deslimed product is subjected to WHIMS and flotation for further enrichment.

The particle size distribution of both 1"hydrocyclone underflow and overflow products were carried out using Beckman Coulter make DelsaNano C Zeta Sizer and the results are presented in Table 6.

Table 6: Particle size analysis of 1" hydrocyclone product

Product	d_{10}, %	d_{50}, %	d_{90}, %
Under flow	0.207 μm	2.992 μm	25.724 μm
Over flow	0.177 μm	0.507 μm	5.546 μm

The particle size analysis reveals that most of the coarser particles in range of 30 μm go to underflow while the ultrafine remains in overflow with size range <5 μm.

Froth flotation

The deslimed product obtained from 1" hydrocyclone was subjected to reverse flotation at the optimised result as given in Table 3. The result of flotation is given in Table 7.

Table 7: Froth flotation of 1" deslimed product of hydrocyclone

product	wt %	WRO,%	Fe %
sink	50.58	6.3	45.69
float	49.42	6.1	17.65

As shown in Table 7, Fe % of the deslimed product partially upgraded to 45.69 % which could not be used as feed directly for pellet making, thus this experiment can't be considered for up gradation for recovering valuable mineral.

MAGNETIC SEPARATION (WHIMS)

The underflow flow material obtained after treatment with 1" hydrocyclone is further treated with magnetic separator for recovering valuables and the results are given in Fig. 3.

From the result shown in Figure 3, it is concluded that at a current of 0.5 ampere, Fe content of the deslimed product of Hydrocyclone enriched from 32.39 % to 51% with a yield of 10.1 % (1.3 % with respect to original sample). This magnetic material obtained here, mixed to magnetic product obtained after treating deslimed product of 2" hydrocyclone having Fe % 65.3 with yield 47.4 %. Thus the final products obtained have Fe content of 64.9 % with yield 48.7 %. This can be directly used as pellet feed to DRI plants.

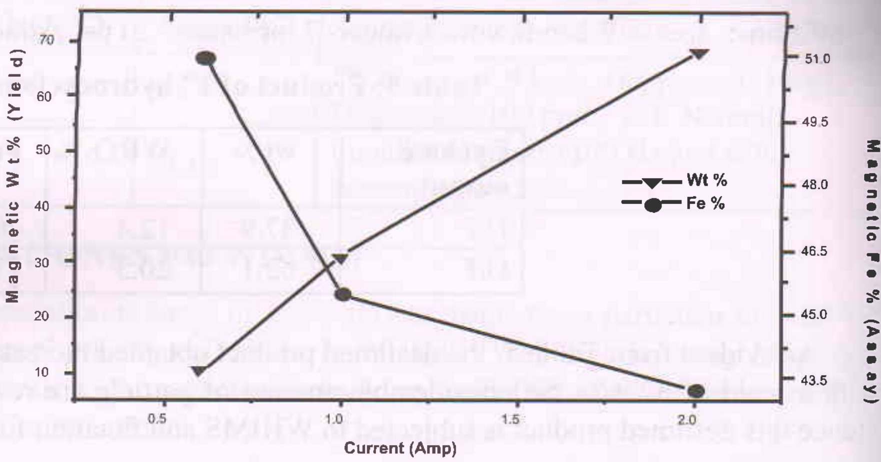

Fig. 3: Effect of current on the performance of WHIMS

After removal of valuable materials as concentrate (to be used in DRI), remaining materials can be aggregated by flocculating the fine solids using starch- 20 ppm + Alum- 80 ppm combination at a natural pH giving 94.8 settled wt % for time period 30 minutes. Alum ($K_2SO_4\ Al_2(SO_4)_3\ 24\ H_2O$) with its hydrophilic group get attached to the silica causing settling of gangue (mainly silica). As Fe content in the gangue is very low (38.38 %) so scarce dose of starch (20 ppm) act as a flocculant (depressant) for hematite causing its settling. The cake was formed by filtering the settled gangue mixture after settling process under the above optimised condition. The filter residue in the form of cake can be safely disposed or used as a buliding material.

CONCLUSIONS

- The SPM level was found to be 1496.09µg/m3 without dust collection system which is much higher than the specified limit. However, SPM has the tendency to settled down due to its heaviness, it causes less pollution to environment while the RPM due its small size (-10 µm) causes various respirable diseases to human.
- Desliming of the slime sample gave a product with a yield of 67.3% contains 60.6% Fe under best condition.
- It is shown that deslimed product on reverse flotation and WHIMS gave yield 47 % containing 64.5 % Fe and yield 47.4% containing 65.3 % Fe respectively which can be directly used as pellet feed.
- To maximise the yield 2"hydrocyclone overflow was treated in 1" hydrocyclone and the underflow product was subsequently treated in flotation and WHIMS producing 1.3 % by weight with 51% Fe.

- The final product obtained have Fe content of 64.9 % with yield 48.7 % from WHIMS circuit. This can be directly used as pellet feed to DRI plants.
- The remaining waste materials can be disposed safely by flocculating the fine solids using starch- 20 ppm + Alum- 80 ppm combination at a natural pH giving 94.8 settled wt % for time period 30 minutes.
- In addition to the economic benefit from the utilization of the slime as a resource, it also minimizes the land requirement, surface degradation, groundwater pollution, and destruction of forests, impact on society, and human health and safety.

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