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Recovery of values from mining and industrial wastes

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ABSTRACT

Studies were carried out on the recovery of values from wastes from magnesite mines and sponge iron plant. Rougher flotation followed by cleaning of the rougher float resulted in decreasing the silica content to below 1% in the final concentrate from the magnesite mines 'waste dump' sample. The apparent porosity, bulk density and water absorption of the pellets fired at 1750°C were 3.4-4.9%, 3.25 gm/cc and 1-1.5% respectively. Results on the 'altered dunite rock' sample from the magnesite mines was also encouraging. Considering the beneficiation characteristics of coal and the associated impurities in the 'ESP-dust' and 'coal-char' samples from sponge iron plant, a combination of magnetic separation and froth flotation was adopted for their processing. In the final products the ash could be brought down to ~ 33%.

INTRODUCTION

Large amount of visible wastes are generated by mining., mineral and metallurgical industries. These wastes cause severe environmental pollution problems, besides causing losses of values. But owing to the increasing stress on ecological and environmental protection, it has become essential to process these wastes and dispose them in environmentally acceptable form.

In the mining sector, besides the careful dumping of wastes against erosion and spreading, the utilisation of the wastes generated is an important part of the strategy of mines waste management. In a number of cases such as chromite, iron ore, limestone, granite, bauxite, rock phosphate, mica, kaolin, magnesite etc. the problem of waste is quite significant.

During manual as well as semi-mechanised mining of magnesite ore in India, large amount of sub-marginal and high silica magnesite ore wastes are generated. Due to high silica content of 6-8% and above, these do not find acceptance in the industry. Besides this, partially altered mineralised host rock is another waste from the magnesite mines. There are huge accumulated dumps of these wastes in most of the working and abandoned mines.

The sponge iron plant generates huge quantity of wastes in the form of ESP (Electrostatic Precipitator) dust and coal-char. Due to high ash content, these wastes are being dumped near plant sites, posing environmental problems. In the present study, an attempt has been made to process the waste samples from magnesite mines and sponge iron plant to recover values from them or convert them to usable products.

Recovery of magnesite from mine waste samples

The proposed studies were aimed to find the amenability to processing of two waste samples from Talur magnesite mines, Karnataka, namely 'waste dump' and 'altered dunite rock' by physical beneficiation methods for their utilisation. The results on the two samples are discussed below :

Waste Dump sample

About 250 kg of 'waste dump' sample was received from Karnataka. Sample was mostly lumps ranging in size from 100-25mm. Samples looked very weathered, surface being almost covered with black moss. The total quantity of sample was crushed in jaw crusher and roll crusher to -10 mesh size for homogenisation, sampling and subsequent beneficiation studies. The chemical analysis of the sample is recorded in Table-1.

Tanble-1 :Chemical analysis of 'waste dump' sample

Constituents	Wt.%
MgO	41.85
CaO	2.25
SiO_2	6.10
Al_2O_3	0.72
Fe_2O_3	1.20
LOI	45.94

Megascopic, Microscopic and Liberation Characteristics of 'waste dump' sample

The sample mainly comprised of white to greyish white lumps of fine grained magnesite with occasional encrustations and intercalations of brownish matter. Some were brown lumps of altered dunite containing white veins of quartz and carbonate minerals. White lumps of magnesite were found with conchoidal fractures and the weathered surfaces of lumps were marked by micropores and sharp edges. Microchemical tęst indicated minor association of calcite. Specific gravity of rock pieces varies from 2.7 to 3.0.

Microscopic studies showed that the white lumps were compact micro to cryptocrystalline magnesite with pockets of serpentine occasionally associated with different amount of chromite, magnetite, calcite and quartz/chert. Serpentine was also present as disseminated grains in the white mass of magnesite.

Brownish lumps of altered dunite were highly limonitised and contained white veinlets of quartz and carbonate minerals. Quartz was present as mostly crystalline variety with wide variation in size. Presence of chromite and magnetite was more in this type.

Microscopic examination of -10 mesh representative sample showed a fair liberation of quartz in fractions below 60 mesh and serpentine in fractions below 150 mesh. Stains of limonite on grains may interfere in the process of beneficiation and dilute the grade of magnesite concentrate.

Processing of 'waste dump' sample

Considering our past experience on sample from the same source and also the requirement of the final grade of the concentrate, froth flotation was chosen for processing this sample. Sodium oleate was used as collector for magnesite while sodium silicate was used as dispersant/depressant for the siliceous gangues.

The -10 mesh crushed sample was wet ground in laboratory rod mill and floated in the standard laboratory Fagergren Cell. Table-2 shows the flotation results under varying fineness of the feed. The dosage of the reagents were selected from a few bank tests. It is evident from Table-2 that an increase in fineness of the feed increases the yield and leads to progressive enrichment of silica in the tailings. This was attributed to the enhanced liberation of magnesite at finer sizes. The increase in the silica content of the concentrate at finer sizes might be due to increased froth entrainment and carry over in these size ranges. Considering the silica content of the rougher concentrate a feed with 94.7% - 200 mesh was selected for further purification.

Purification of Rougher concentrate

The product obtained from the flotation feed at grind size of 94.7% -200 mesh was further purified by refloating the same to bring down silica content in the final concentrate. The results of flotation cleaning experiment are shown in Table-3. As we can see from this table that yields of 32.0%, 42.6% and 58.8% with silica content of 0.90%, 1.28% and 2.03% could be obtained by 3, 2, and 1 cleaning respectively.

Based upon the 1 Kg. batch experiments bulk flotation and cleaning tests were carried out in Denver sub-aeration unit cell (~30 lits.). It was observed that a longer residence is required but the results were reproducible and even better than that obtained in 1 kg. batch operation. The chemical analysis of the final concentrate is shown in Table-4.

Table-2 : Flotation results on waste dump sample

Grind % -200 mesh	Products	Wt.%	Assay % SiO_2	Dist. % SiO_2
47.8	Float	40.0	3.65	23.6
	Tails	60.0	7.89	76.4
	Head (Calc)	100.0	6.19	100.00
76.7	Float	69.2	3.31	37.6
	Tails	30.8	12.36	62.4
	Head (Calc)	100.0	6.10	100.0
94.7	Float	83.2	3.32	45.0
	Tails	16.8	20.12	55.0
	Head (Calc)	100.0	6.14	100.0
98.1	Float	88.8	3.90	56.6
	Tails	11.2	23.71	43.4
	Head (Calc)	100.0	6.14	100.0
99.6	Float	93.2	4.34	67.4
	Tails	6.8	28.79	32.6
	Head (Calc)	100.0	6.00	100.0

Table-3 : Results of cleaning flotation on waste dump sample

Grind %-200 mesh	Products	Wt.%		Assay % SiO_2		Dist. % SiO_2
	Cl.Conc.III	32.0		0.90		4.7
	Cl.Tail.III	10.6	42.6	2.42	1.28	4.2
94.7	Cl.Tail.II	16.2	58.8	4.02	2.03	10.6
	Cl.Tail.I	24.4		6.42		25.5
	P.Tails	16.8		20.12		55.0
Head (Calc)		100.0		6.14		100.0

Table-4 : Chemical analysis of final concentrate from waste dump sample

Constituents	Wt.%
MgO	45.22
SiO_2	1.02
Al_2O_3	0.10
Fe (T)	0.31
CaO	2.26
LOI	50.04

Pelletization of the final concentrate

The concentrate produced from the processing of waste dump sample was subjected to pelletization in laboratory drum pelletizer using starch as binder. The air dried pellets were then fired at 1750°C. Fig.1 shows the pellets made from the flotation concentrate from 'waste dump' sample. Some characteristic of the pellets are shown in Table-5 while Table-6 presents the chemical analysis of the fired pellets.

Table-5 : Characteristics of the pellets

(Green/Fired)	Characteristics	Value
Green	Moisture	17.6%
Green	Size	8-10mm
Green	Drop (45 cm)	12-15
Green	Compressive Str.	1.9-2.25
Air dried	Drop (45 cm)	8-11
Fired	App. porosity	3.4 - 4.9%
Fired	Bulk density	3.25 gm/cc
Fired	Water absorption	1-1.50%

Table-6 : Chemical analysis of fired pellets

Constituents	Wt.%
MgO	90.50
SiO_2	4.50
Al_2O_3	2.20
Fe(T)	0.30
CaO	2.40
LOI	0.10

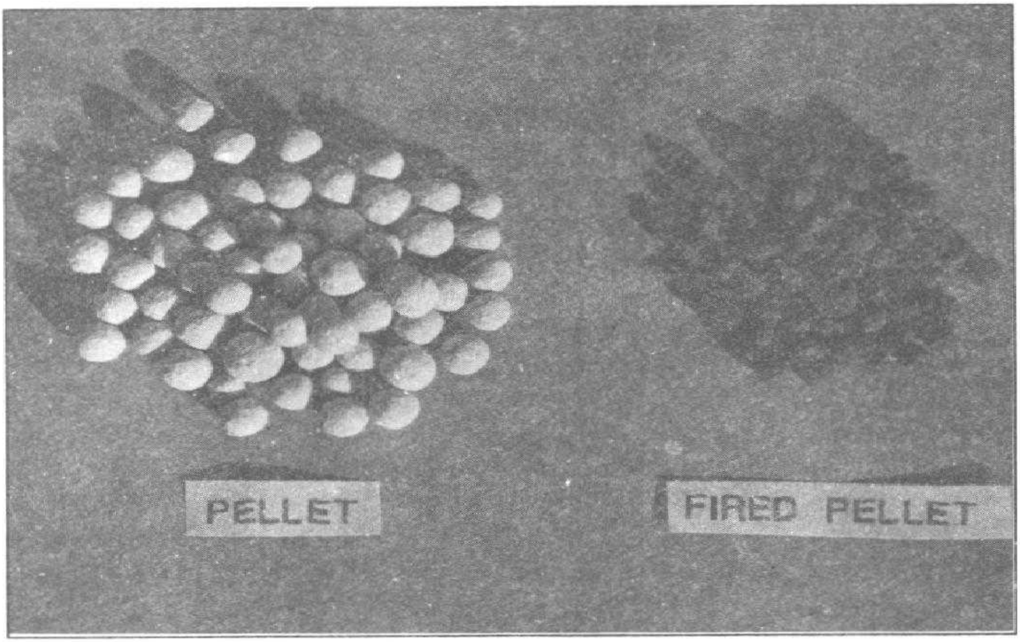

Fig. 1: Air dried and fired pellets made from flotation concentrate from 'waste dump' sample

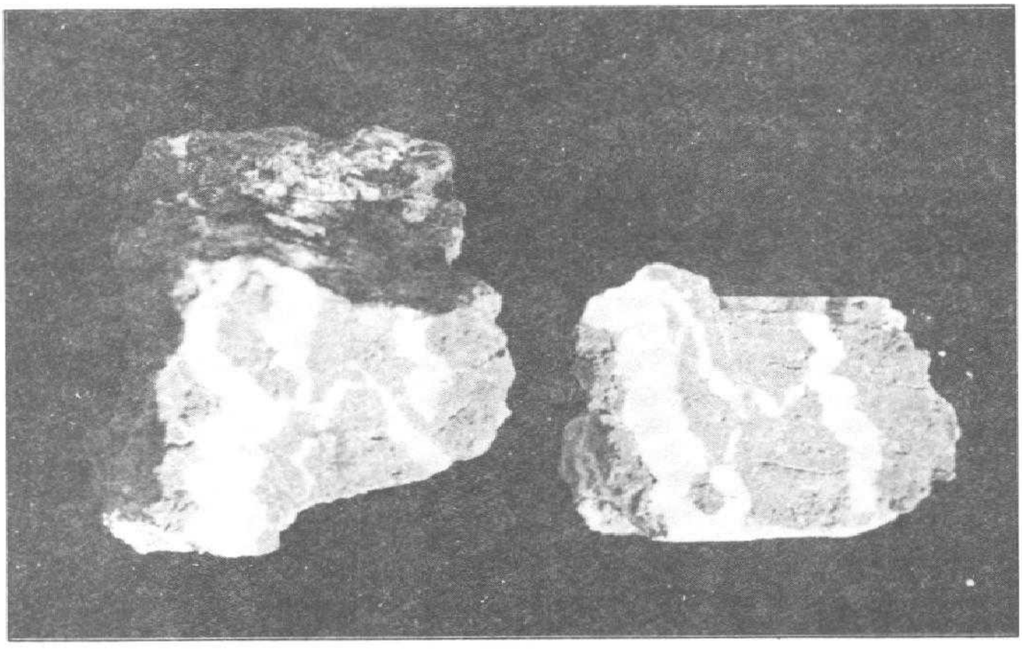

Fig. 2: Close-up view of lumps containing veins of magnesite (Mg) in dunite (Ad)

Characterization and processing of 'altered dunite rock' sample

During the visit to the magnesite mines of Karnataka suggestions were made by NML team to find the amenability of separation of iron rich dunite from fine magnesite veins and bands from samples dumped in the mine heads as sub-grade and unusable for refractory making. The dunite fraction separated by a bulk preconcentration step, if viable could possibly be used as a substitute for dolomite in iron ore sintering and the magnesite fraction too become a feed stock for further beneficiation to a usable concentrate. By this a larger utilisation f this waste material would be possible. With the above idea the 'altered dunite rock' was studied for concentration.

The 'altered dunite rock' sample assayed 36.2% MgO with 19.82% SiO_2 and 1.93% Fe_2O_3. It comprised mainly of lumps of buff to brown colour altered dunite with veins and stringers of carbonate, quartz and chalcedony. Other lumps were greyish white to milky white with brownish intercalations. Fig.2 shows close-up view of the typical lump containing veins of magnesite in altered dunite sample.

Microscopic studies of the brownish lumps showed that these contained veins and stringers of quartz, chalcedony and magnesite with minor association of calcite. The magnesite is encircled by aggregates of quartz while serpentine is present as disseminated grains.

Microscopic examination of -10 mesh representative sample showed a fair liberation of magnesite from quartz and other silicates in fractions below 150 mesh but grains with limonitic strains were present in all the fractions below and above 150 mesh. Clusters of elongated quartz/chalcedony were found in the form of wavy bands. In the magnesite veins of altered dunite the silicates were present as segregated grains coated with limonitic matter. Presence of disseminated chromite and magnetite was more in altered dunite than their occurrences in white lumps of magnesite. Fairly coarse grains of chromite and magnetite were present in the brownish lumps of dunite.

Exploratory beneficiation studies carried out on the altered dunite rock sample indicated that a combination of magnetic separation and flotation can lead to the required enrichment. In the present study the sample was crushed to -3 mesh and sized into three fractions viz., -3+20 mesh, -20+200 mesh and -200 mesh. The two coarser fractions i.e. -3+20 mesh and -20+200 mesh were subjected to dry magnetic separation. The non-magnetics and the untreated -200 mesh fraction, comprising 77.9% by weight was ground and floated using standard reagents. A magnesite concentrate with 38.6% yield, assaying 2.08% silica was obtained. These results have indicated the possibility of producing a clean magnesite concentrate and a ferro-magnesium silicate from the sub-grade dump sample stacked in the magnesite mine heads.

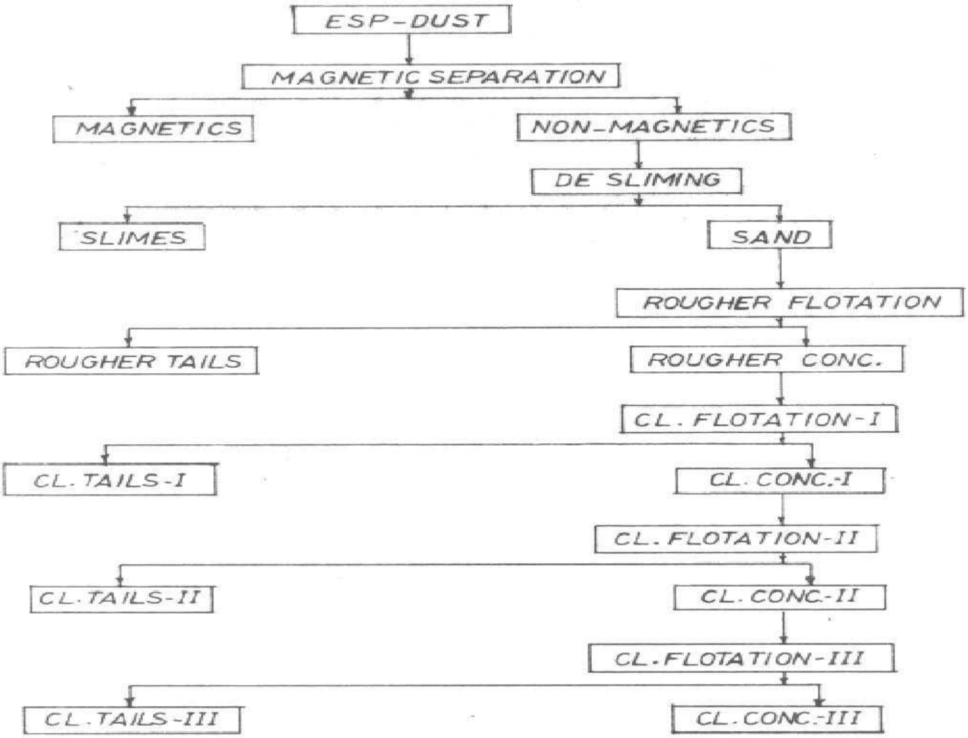

Fig. 3: Flow-sheet for processing ESP-dust

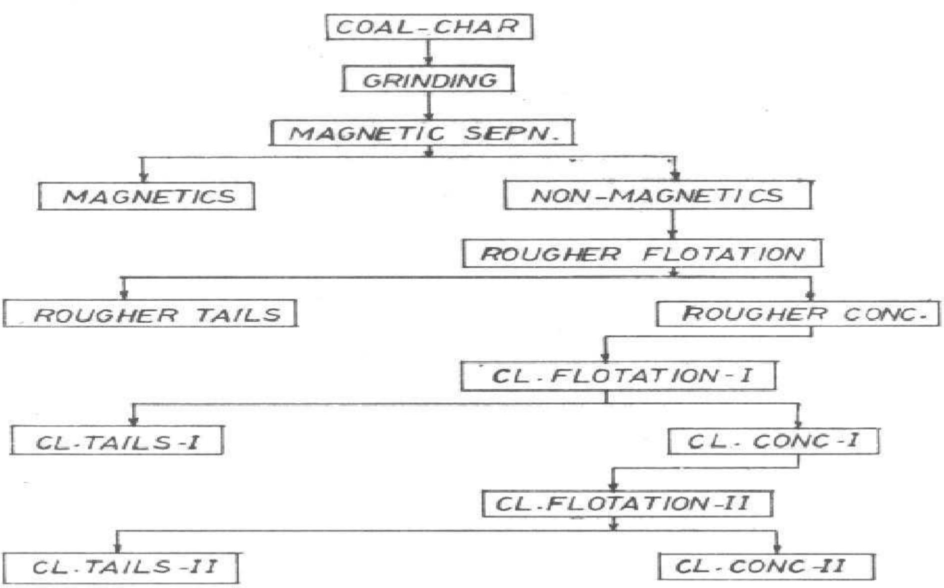

Fig. 4: Flow-sheet for concentration of coal-char sample

Recovery of coal values from sponge iron plant wastes

Sponge iron production involves reduction of iron ore with solid/gaseous reductant at around 1050°C for certain residence time depending upon particle size distribution. In case of gaseous reduction, sponge iron will be free from extraneous impurities where as in case of solid reductants, the unburnt coal and char are separated by magnetic separation.

Usually non-coking coal and iron ore are charged in a long rotary kiln. From one side, fuel oil is burned inside the kiln using controlled air blown from a blower counter current to the incoming ore and coal to maintain reducing conditions in the rotary kiln. Fine dust generated during this is carried away by flue gases from rotary kiln chimney which is collected using electrostatic precipitator (ESP). This is how ESP-dust containing partially burnt coal and ore fines is generated. From the other side sponge iron along with partially burnt coal will be coming out which is cooled. This is magnetically separated to remove magnetic sponge iron from non-magnetic char.

The ESP-dust and coal-char produced by the sponge iron plant is accumulating gradually at the plant site posing environmental problems. The two waste samples were received from such a plant at NML with a view to recovering coal values from them.

Sample characteristics

The two samples, ESP-dust and coal-char were mainly composed of coal, iron oxides, metallic iron and clay matters. The ESP dust was basically fine powder (93.7% - 200 mesh) while the char sample consisted of lumps ranging from 3 cms. down to fines. Under the microscope the polished specimen of the char sample showed heterogeneous assemblage of carbonaceous matter and slag phase with disseminated grains of magnetite/wustite and globules of metallic iron.

Processing of ESP-dust

Considering the composition of the sample and the nature of the impurities, probing studies were conducted employing gravity, magnetic and froth flotation processes in order to evolve a suitable process route. Bartles Mozley vanner was used as gravity separator while magnetic separation was carried out in laboratory wet magnetic separator at 0.5 Amp. A laboratory Fagergren cell was used for flotation studies. Light diesel oil, pine oil and sodium silicate were used as collector, frother and gangue dispersant/depressant respectively.

It seems due to excessive fine nature of the ESP dust sample gravity separation results were not encouraging but magnetic separation could remove magnetics assaying 97.7% ash. Taking these results in account a process flow-sheet, involving magnetic and flotation processes was developed and the same is shown in Fig.3 while the material balance is presented in Table-7. Thus we can see that the final product from the ESP dust contained 33.2% ash.

Table-7 : Results on processing of ESP-dust

Products	Wt. %	Assay % ash	Dist. % ash
Cl. Conc. III	17.9	33.20	8.8
Cl.Tails III	8.6	42.04	5.3
Cl. Tails II	18.4	51.54	6.2
Cl. Tails I	18.4	58.18	15.8
R. Tails	28.8	89.21	37.9
Slimes	0.5	57.12	0.4
Magnetics	17.7	97.70	25.6
Head (Calc)	100.0	68.40	100.0

Processing of coal-char sample

On the similar line as that for ESP dust the process route for coal-char sample basically involved magnetic separation and froth flotation. Since the sample was coarse, so it was ground in stages to -35 mesh and then subjected to wet magnetic separation. The non-magnetics from this step was further floated and the rougher float was cleaned twice to produce the final concentrate assaying 32.5% ash with 34.7% yield. The results are shown in Table-8 while Fig.4 shows the flow-sheet for processing the coal-char sample.

Table-8 : Results on beneficiation of coal-char sample

Products	Wt. %	Assay % ash	Dist. % ash
Cl.Conc. II	34.7	32.48	22.4
Cl. Tails II	26.3	50.50	26.3
Cl. Tails I	16.6	55.50	18.3
R. Tails	12.2	89.20	21.6
Magnetics	10.2	56.40	11.4
Head (Calc)	100.0	50.40	100.0

CONCLUSION

1. The two samples namely 'waste dump' and 'altered dunite rock' from magnesite mines contained silica and iron as the major impurities. As observed under microscope the liberation of magnesite from the associated gangue minerals was indicated below 150 mesh. Froth flotation of the 'waste dump' sample resulted in lowering the silica content below 1%. The results on 'altered dunite rock' sample was also encouraging.

2. A combination of magnetic separation and froth flotation route could reduce the ash content to ~ 33% in the waste samples (ESP-dust and coal-char) from sponge iron plant.

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