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UTILITY OF OVERBURDEN FROM CHROMITE MINES*

R B RAO, S PRAKASH, G V RAO, M I ANSARI *and* K S NARASIMHAN
Regional Research Laboratory, Bhubaneswar 751 013, Orissa

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Substantial amount of overburden material, 10 tonnes per tonne of chromite mined, is generated in the chromite mines in Orissa, India. The material roughly contains 5.0 per cent chromite, 0.5 per cent nickel and 0.05 per cent cobalt. Investigations carried out with samples of overburden generated from each of the operating quarries reveal that such material from 7 out of the 13 operating quarries can be treated to obtain preconcentrate containing nickel above 0.9 per cent with recoveries above 60 per cent. Cobalt concertration varies upto 0.06 per cent. It appears also possible to obtain concentrates containing chromite around 20.0 per cent with high recoveries. A conceptual flow sheet is suggested for processing such overburden material amenable to physical beneficiation on which further large scale studies are required to establish the viability.

Key Words : Chromite Mines; Overburden Material; Trevorite; Bartles-Mozley; Organic Liquid

INTRODUCTION

IMPORTANT chromite deposits are concentrated in the state of Orissa between lattitudes of 21°6′0″ and 21°17′40″ and longitudes of 85°45′0″ and 86°22′00″ (Kasipathi *et al.*, 1978; Ziauodin *et al.*, 1979). These deposits are either siliceous or ferruginous and the latter are concentrated in the Sukinda valley. The reserves now stands at near 100 million tonnes, which are operated by Orissa Mining Corporation (OMC), Tata Iron & Steel Co. (TISCO) and M. L. Jain & Co (MLJ) to mine chrome ore.

It is roughly estimated that for every tonne of chrome ore mined nearly ten tonnes of overburden is removed and rejected (M/s. OMC Ltd., Bhubaneswar, 1982, Bulletins IBM). This overburden material is on a rough approximation, (Rao, *et al.*, 1982) estimated to contain 25 per cent iron, 5.0 per cent chromium, 0.5 per cent nickel and 0.05 per cent cobalt. On this strength, the existing overburden dumps can be considered as a potential source for 4 million tonnes of iron, 750,000 tonnes of chromite, 75,000 tonnes of nickel and nearly 7,500 tonnes of cobalt. Similarly, the raisings every year can be a source for 0.8 million tonnes of iron, 150,000 tonnes of chromite, 15,000 tonnes of nickel and 1,500 tonnes of cobalt.

The economics of extraction of nickel and cobalt from lateritic deposits in the experience of contemporary technological practice is known to heavily depend upon the nickel and cobalt content in the feed and to be profitable the concentration of

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nickel and cobalt should be at least 0.9 per cent and 0.03 per cent respectively (Jena *et al.*).

In view of these, any practical methods to pre-concentrate the abundantly available overburden material to render extraction of nickel and cobalt would be beneficial both from the point of view of conservation and ecology and help in utilising otherwise a waste material generated during mining of chromite.

Experiments and Results

Preliminary Studies

Elemental distribution studies carried out with a random sample of overburden material obtained from Saruabil area revealed that nickel tends to concentrate into finer fractions rendering adequate enrichment with substantial recoveries. Prompted by such findings a study at the instance of the Mineral Development Board was initiated to assess such a behaviour in a systematic manner. Accordingly, *in-situ* samples from all of the 13 operating quarries representing 0 to 10m, 10 to 30m and below 30m placers on both hang wall and foot wall side of the existing chromite band was obtained. A larger sample of 2 tonnes were first recovered by carving vertical trenches at uniform distance on the benches from which a 20 kg representative material was sampled for further studies. Similarly, samples representing four of the existing dumps were also obtained for studies.

A five kg sub-sample from each of the lot so obtained was taken up for the experiments. A few of the larger lumps present in such sample was crushed in a jaw crusher set to 25 mm and the bulk was wet screened successively to obtain products in the +4.0 mm, −4 mm +0.045 mm and −0.045 mm fractions. Each of these fraction was analysed for nickel and cobalt. The results of such investigation are given in detail in an internal report. The results and bulk analysis are summarised in tables I and I(A). These results indicate that by and large the −45 micron fraction is enriched with respect to nickel to values more than 0.9 per cent which is of economic significance. This was particularly apparent with samples obtained below 10m from the top. On the basis of such a study the recoverable weight and grade of the material wherever enrichment is possible is computed and indicated in table II.

From the results it is observed that overburden material obtained from 8 quarries, out of the 13 quarries being operated at present, is amenable to physical beneficiation. These include largest quarries like Sukarangi AC and Sukarangi D. Nickel recoveries however varied widely between 44 and 80 per cent. It is necessary to improve recovery figures with respect to nickel besides attempting to recover other valuable minerals like cobalt, chromite and iron, to make the findings to be of commercial significance.

Detailed Studies

Further studies were therefore conducted to assess the possibility of (i) improving the recovery of nickel into a workable concentrate and (ii) beneficiating those samples not amenable to simple classification.

TABLE 1

Behaviour of overburden samples to classification at 45 microns

Sl. No.	Quarry	No. of samples studied	Enrichment observed with respect to		Range of content in enriched sample %		Range of recovery observed %		Level of enriched sample in quarry	
			Nickel	Cobalt	Nickel	Cobalt	Nickel	Cobalt	Nickel	Cobalt
1	2	3	4	5	6	7	8	9	10	11
A. Orissa Mining Corporation										
1.	Kaliapani 1	6	4	2	1.01—1.05	0.121—0.166	51.2—70.7	40.6—54.6	Below 10 m	Above 10 m
2.	Kaliapani 2	6	3	3	0.92—1.11	0.126—0.268	57.6—82.0	41.1—65.7	Below 10 m	Above 10 m
3.	Kalipani dumps	1	1	1	0.94	0.604	24.4	60.8	Bulk	—
4.	Kalarangi B	2	2	—	0.13—0.98	—	56.2—57.0	—	0.10 m	—
5.	Kalarangi D	2	—	2		0.23—0.562	—	74.1 94.3	—	0.10 m
6.	Kalarangi E	4	—	2		0.106—0.133	—	78.5—80.8	—	10-30 HW 0-10 FW
7.	Sukarangi AC	6	5	4	1.01—1.30	0.092—0.117	63.6—70.8	20.5—44.4	0.30 m	0-30 m
8.	Sukarangi D	4	4	2	1.11—1.21	0.09—0.17	65—90.3	32.1	Below 0 m	Below 0 m
9.	Sukarangi dumps	1	1	1	0.94	0.214—0.625	17.0	71.0	Bulk	—
B. *M. L. Jain & Co.*										
10.	Saruabil 1 & 2	3	—	1	—	—	—	47.2	—	0-10 m
11.	Saruabil 4	4	4	—	0.95—1.15	—	58.1—76.4	—	0-30 m	—

(*Continued*)

TABLE I (*Continued*)

1	2	3	4	5	6	7	8	9	10	11
12.	Saruabil 5	4	3	1	0.93—1.17	0.14—0.257	70.7—86.7	45.8	0-30 m	10-30 m
13.	Saruabil dumps	1	1	—	1.04	—	80.3	—	Bulk	—
C. *TISCO*										
14.	TISCO 1	4	1	—	1.08	—	73.0	—	Below 10 m	—
15.	TISCO 2	3	—	—	—	—	—	—	—	—
16.	TISCO 3	2	1	—	1.17	—	68.2	—	Below 0 m	—
17.	TISCO dumps	1	—	—	—	—	—	—	—	—
		54	30	19	0.92—1.30	0.09—0.625	17.0—90.0	15—94.0	Mostly below 10m	Mostly above 30m

Nickel and Cobalt were analysed by Perkin-Elmer, AAS, 372 sensitivity is 0.15 μg/ml for 1 per cent absorption and limitations are 0.005 and 0.01 μg/ml for Ni and Cu respectively.

TABLE I(A)

Bulk analysis of overburden materials

Sl. No.	Name of the quarry	No. of samples studied	Cr_2O_3	Fe_2O_3	FeO	Al_2O_3	MgO	SiO_2	Ni	CO
	OMC									
1.	Kaliapani 1	6	7.54	25.5	3.47	9.88	1.22	48.45	0.55	0.029
2.	Kaliapani 2	6	7.21	43.33	2.32	13.58	1.33	28.57	0.64	0.046
3.	Kalarangi B	2	23.3	22.35	1.9	12.9	0.55	38.55	0.38	0.02
4.	Kalarangi D	2	5.9	31.8	1.7	22.95	0.75	32.6	0.36	0.123
5.	Kalarangi E	4	3.98	27.8	1.68	12.23	0.25	51.1	0.40	0.038
6.	Sukarangi AC	6	8.8	37.75	3.48	11.55	0.4	34.22	0.7	0.022
7.	Sukarangi D	4	7.68	61.2	3.23	11.5	0.28	10.9	1.13	0.039
8.	Kaliapani dumps	1	7.6	55.7	3.1	—	—	—	0.59	0.039
9.	Sukarangi dumps	1	7.4	—	—	12.0	0.5	12.5	0.67	0.034
	TISCO									
10.	TISCO 1	4	9.5	43.5	5.3	17.8	0.32	8.1	0.75	0.027
11.	TISCO 2	3	12.83	30.53	4.5	9.9	0.87	31.8	0.31	0.032
12.	TISCO 3	2	18.4	40.0	5.45	16.35	1.6	10.7	0.66	0.023
13.	TISCO dumps	1	20.2	39.1	5.7	14.4	0.2	11.1	0.66	0.014
	MLJ									
14.	Saruabil 1 & 2	3	11.97	43.47	6.03	14.47	0.75	17.37	0.56	0.047
15.	Saruabil 4	4	14.93	28.38	5.4	11.75	0.38	35.98	0.62	0.037
16.	Sarubil 5	4	10.63	31.93	5.08	9.35	0.25	38.33	0.74	0.038
17.	Saruabil dumps	1	8.9	46.1	7.7	10.0	0.3	22.3	0.82	0.036

TABLE II

Quarry wise amenability to beneficiation through classification

Sl. No.	Quarry particulars	Proportion of −45 fraction, %	Nickel, %		Recovery of nickel into −45, %
			Bulk	−45 micron	
A	*OMC*				
1.	Kaliapani 1	27.3	0.55	1.02	50.6
2.	Kaliapani 2	27.6	0.64	1.04	44.8
3.	Kalarangi B	22.6	0.38	0.95	56.5
4.	Kalarangi D	40.8	0.36	0.25	n.e.
5.	Kalarangi E	35.2	0.40	0.59	n.d.e.
6.	Sukarangi AC	35.3	0.70	1.09	55.0
7.	Sukarangi D	72.1	1.13	1.18	75.3
8.	Kaliapani dumps	79.3	0.59	0.56	n.e.
9.	Sukarangi dumps	82.7	0.67	0.65	n.e.
B	*TISCO*				
10.	TISCO 1	53.6	0.75	0.84	n.d.e.
11.	TISCO 2	28.5	0.31	0.51	n.d.e.
12.	TISCO 3	39.1	0.66	1.07	63.4
13.	TISCO dumps	46.6	0.66	0.75	n.d.e.
C	*MLJ*				
14.	Saruabil 1 & 2	58.4	0.56	0.61	n.d.e.
15.	Saruabil 4	52.4	0.62	0.98	67.0
16.	Saruabil 5	55.9	0.74	1.04	78.6
17.	Saruabil dumps	63.3	0.82	1.04	80.3

(n.e. : no enrichment; n.d.e. : no desired enrichmert)

Subsequent tests showed the presence of magnetic fractions having specific gravity as high as 5.0 which was attributed to the presence of *trevorite*, a nickel bearing magnetic mineral. The possibility of a portion of nickel being associated with silicates was also ascertained.

Based on these indications, magnetic light and magnetic heavy components of both −45 micron and +45 micron fractions were obtained by employing a laboratory wet low intensity magnetic separator and a Bartles-Mozley concentrator. These studies indicated that −45 micron fraction could be enriched into a heavy and magnetic fraction containing nickel around 1.2 per cent. No enriched fraction could be obtained from +45 micron fractions.

On the basis of such findings detailed investigations were carried out on a composite low nickel bearing material composed from samples of OMC mines except sukarangi D, all ground to below 45 microns. These studies indicated that from a feed containing 0.57 per cent nickel, 0.044 per cent cobalt and 23.7 per cent iron, a magnetic fraction containing 1.2 per cent nickel and 0.06 per cent cobalt, a non-magnetic heavy component containing 0.25 per cent nickel and a non-magnetic light component containing 0.67 per cent nickel could be obtained. Nickel recovery at high nickel percentage did not however exceed 40 per cent.

Therefore, to maximise nickel recovery at high nickel concentrations, it was thought to adopt the magnetic and gravity separation on samples after recovering the easily obtainable −45 micron enriched fractions referred to earlier and indicated in Table II.

In order to assess the response to such a treatment location wise and also establish the variation in behaviour, samples representing each quarry as per Table II were treated separately.

It can be seen from the data in Table II enrichment of nickel occurs in −45 size fraction for some samples. In such cases the −45 and +45 size fractions of the individual samples treated separately. In other cases a composite sample is prepared by mixing materials from all the quarries. The +45 micron size fractions of all the samples are further processed after stage grinding to below 45 micron size in wet batch ball mill of 150 mm × 150 mm size, with 60 per cent solids. In all separation experiments 1.5 kg/hr through a SALA low intensity wet magnetic separator and the non-magnetic fraction so obtained was processed at 10 per cent solids concentration at 20 kg/hr on 600 mm × 1500 mm Bartles-Mozley concentrator. These conditions were optimised earlier while working with the composite sample.

Each of the magnetic, non-magnetic heavy and non-magnetic light were analysed for nickel, cobalt, chromium and iron. Results in detail are available in an internal report. These studies indicated that nickel recovery can be further enhanced by mixing the magnetic fraction with the −45 micron classified fraction containing enriched nickel as indicated in Table II. In Table III the composition of such concentrates obtainable is indicated.

Tests were also conducted separately on a composite sample of +45 micron fraction obtained after classification to get nickel rich fractions and to assess the possibility of recovering chromite by gravity separation before processing the same to −45 micron and subject to the above treatment. In these tests, a known weight of composite feed was crushed in roll crusher set at 0.5mm and the product ground in batch ball mill to different interval of times and the product separated to heavy and light components using an organic liquid of specific gravity 2.9 and fractions analysed for nickel, cobalt and chromium. The results are indicated in table IV.

These studies indicate that at an optimum size of grind, $d_{80} = 640$ microns, a concentrate containing 20 per cent chromite with more than 85 per cent chromium recovery is possible. Figure 1 indicates the efficiency of separation of nickel (alongwith iron) into finer fractions and chromium (alongwith cobalt) into coarser fractions as a function of 80 per cent passing grind size. The efficiency term is the composite effect of recovery and enrichment of the component defined by $R(C_p - C_f)/(C_m - C_f)$. Where R is per cent recovery of component, C_p, and C_f are per cent of the component in product and feed and C_m is maximum per cent of the component obtainable. It is also observed that the magnetic portion of naturally occuring − 45 micron fraction assays higher nickel, upto 1.5 per cent compared to any other nickel rich fraction obtainable.

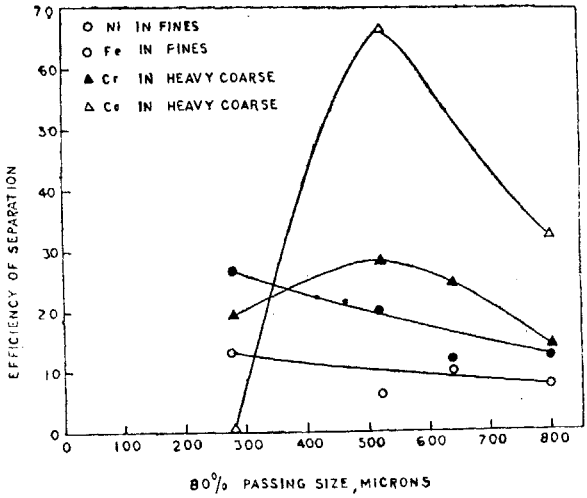

FIG. 1. Effect of grinding on efficiency of sink-float separation

TABLE III

Quarry wise amenability of overburden material to beneficiation

Sl. No.	Name of the quarry	Nickel, %		Recovery, %	Increase in recovery of nickel, %
		Bulk	Conc.		
A	*OMC*				
1.	Kaliapani 1	0.57	1.06	71.3	20.7
2.	Kaliapani 2	0.66	0.93	63.3	18.5
3.	Kaliapani dumps	0.60	0.85	29.0	16.6
4.	Kalarangi B	0.38	0.95	56.5	—
5.	Kalarangi D		not amenable		—
6.	Kalarangi E		not amenable		—
7.	Sukarangi AC	0.83	1.08	69.9	14.9
8.	Sukarangi D	1.50	1.57	94.1	19.2
9.	Kalarangi dumps		not amenable		—
10.	Sukarangi dumps		not amenable		—
B	*TISCO*				
11.	TISCO 1		not amenable		—
12.	TISCO 2		not amenable		—
13.	TISCO 3	0.56	0.93	77.4	14.0
14.	TISCO dumps		not amenable		—
C	*MLJ*				
15.	Saruabil 1 & 2		not amenable		—
16.	Saruabil 4	0.70	0.86	60.4	—
17.	Saruabil 5	0.69	0.91	78.7	—
18.	Saruabil dumps	0.65	0.87	72.3	—

TABLE IV

Distribution of +45 micron composite sample at different grind

(57% of bulk analysed Cr_2O_3, 9.7%; Nickel 0.49% Cobalt 0.04% & Iron 23.5%)

d_{80} microns	800			640			520			280		
	Sink	Float	—45	Sink	Float	—45	Sink	Float	—45	Sink	Float	—45
Weight, %	45.8	38.2	16.0	41.8	35.1	23.1	41.6	31.6	26.8	30.2	27.4	42.5
Chromite												
Grade	15.7	1.0	3.6	21.0	1.4	4.0	22.9	1.2	4.9	21.3	1.3	6.6
Distribution	87.7	4.7	7.0	86.9	4.9	9.1	*85.0*	3.4	11.7	67.0	3.7	29.2
Nickel												
Grade	0.61	0.16	0.91	0.44	0.17	0.77	0.48	0.12	0.89	0.32	0.10	0.85
Distribution	*57.5*	12.6	30.0	*43.8*	14.2	42.3	*41.9*	6.8	50.1	19.9	5.6	74.4
Cobalt												
Grade	0.064	0.018	0.002	0.044	0.016	0.032	*0.094*	—	0.055	—	0.023	0.048
Distribution	80.2	18.8	11.00	58.6	17.9	23.5	73.6	—	26.4	—	24.8	75.2
Iron												
Grade	26.9	8.1	35.3	27.4	9.8	35.3	30.5	8.4	30.5	25.2	5.9	32.5
Distribution	58.7	14.7	26.9	48.7	14.6	34.7	*54.0*	11.3	34.8	33.1	7.0	60.0

Discussions

From the investigations so far carried out, it is observed that nickel is essentially concentrated in the finer fractions of the overburden material generated during chromite mining particularly from points below a certain level on either side of the chromite band. In a majority of cases, including such large size quarries like Sukarangi *AC* and Sukarangi *D*, classification of the overburden material at 45 micron provides a concentrate rich in nickel to a point of economic interest and nickel recoveries can be further increased by processing the +45 micron to obtain the magnetic component after recovering most of the chromite into a heavy fraction by gravity separation.

Conceptually, the overburden material generated from eight of the thirteen quarries can be processed commercially as per flow diagram indicated in figure 2. The process in essence would consist of size reduction to an optimum size and classification

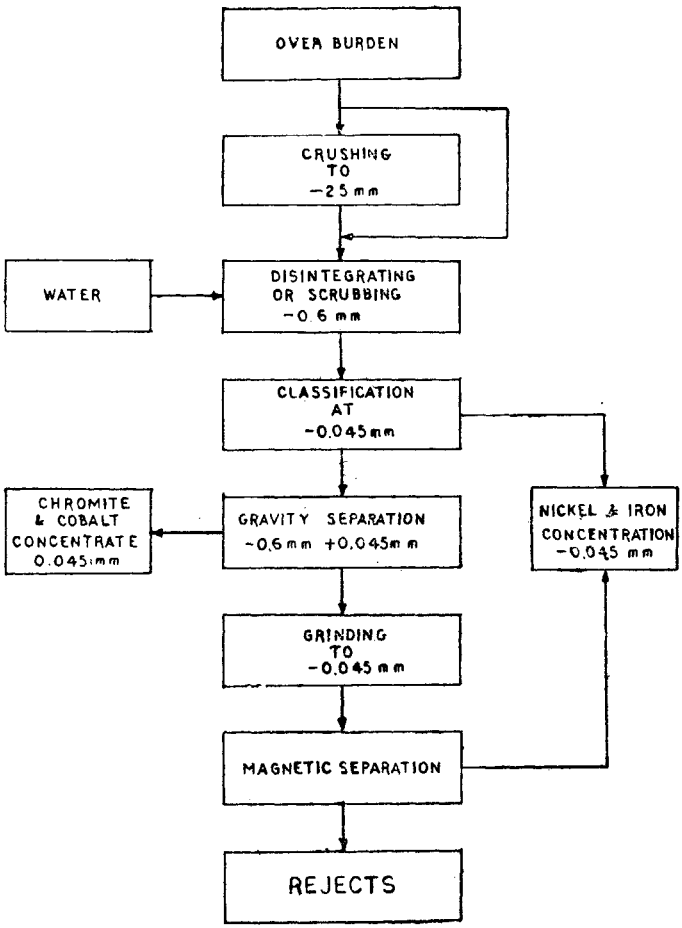

Fig. 2. Conceptual flow sheet for processing overburden

at 45 microns to recover nickel rich fraction and processing the +45 microns fraction to obtain chromite rich fraction by gravity separation. Chromite lean fraction can further be processed for magnetic and gravity separation to recover more of nickel wherever possible. The behaviour of cobalt is not as distinct as nickel and more or less is uniformly distributed. As a result by classification at 45 microns more of cobalt reports into +45 micron fraction which ultimately gets associated in the chromite rich component. Large scale studies are required to establish the viability of such concept.

Further investigations are also necessary to understand the reasons for failure of certain samples to beneficiation. By implication, the entire overburden material can be classified into two major categories with one in which nickel is distinctly accumulated into finer fractions and the other with a low content of nickel. A more detailed chemical and mineralogical examination is necessary to establish the form in which nickel, chromium and cobalt are associated to find ways of recovering these in an enriched form.

It is also worthwhile examining the possibility of enrichment of chromite by flotation from a 20 per cent grade obtainable with gravity separation of +45 micron fraction.

Conclusions

The overburden generated during mining of ferruginous chromite in the Eastern section of Orissa has chromite, nickel and cobalt and associated roughly in concentration of 5.0, 0.5 and 0.05 per cent respectively. Nickel in general tends to be rich in finer fractions whereas chromite and cobalt in coarser fractions.

From the tests so far carried out it is seen in majority of cases these chromite overburden can be processed to obtain nickel rich concentrate associated with iron and a chromite rich concentrate associated with most of cobalt.

A conceptual flow sheet is suggested for such a processing on the basis of which further proving studies are to be conducted. The process in essence involve (a) classification at 45 micron of ore crushed to optimum size to recover below 45 micron fraction enriched with nickel (b) gravity separation of +45 micron fraction to obtain chromite rich fraction and (c) further magnetic and gravity separation of chromite lean fraction.

Further work is also considered necessary to (i) increase the grade of chromite from such concentrates (ii) improve nickel recoveries further and to understand the behaviour of nickel, cobalt and chromite minerals present in samples which are not amenable to physical beneficiation.

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