Proceedings of the XI International Seminar on
Mineral Processing Technology (MPT-2010)
Editors: R. Singh, A. Das, P.K. Banerjee, K.K. Bhattacharyya and N.G. Goswami
© NML Jamshedpur, pp. 1075–1083

SOLID WASTE PROCESSING FOR INDUSTRIAL UTILIZATION— A FEW CASE STUDIES

R. Venugopal
Department of Fuel and Mineral Engineering, Indian School of Mines,
Dhanbad - 826004, Jharkhand, India

ABSTRACT

The production of low grade materials as waste during mining and processing operations is highlighted. The need for utilization of such materials for conservation and sustainability of mineral resources is explained.

The case studies of three solid waste materials—Manganese dump ores, Sericitic Pyrophyllite and Rice Husk Ash is presented. Their characterization, processing and end-use application has been enumerated in detail to establish the fact that judicious processing can lead to sustainable resource utilization.

Keywords: *Solid waste, Characterization, Processing, End-use application, Waste to wealth.*

INTRODUCTION

During Mining and Mineral Processing operations, overburden and reject/tailings are produced which are termed as 'waste'. However, in true terms waste is a term used for materials which do not have a market (or) for which a processing and utilization route is not available/developed but materials which do contain either mineral values (or) useful ingredients that can be used in a different industrial application. Materials from other sources *viz.* low grade materials, etc. also constitute the waste. A judicious and smart processing strategy is the solution for their utilization which would lead to economic, environmental and sustainable development.

The above statement is established through case studies on 3 material systems a) low grade manganese ores b) sericitic pyrophytllite and c) Rice Husk Ash. The studies on these materials is elaborated in the following.

Manganese dump ores—A case study

In the mining process of extraction, overburden is considered to contain less of values and thus, discarded as waste. However, the manganese deposits (dump ores) of Dongri-Buzurg has relatively higher content of manganese values, which can neither be ignored nor can be effectively utilized without processing.

Two different dumps of Dongri-Buzurg were subjected to characterization, processing and based on the product quality obtained, end-use industrial application was suggested.

Dongri-Buzurg dump ore - I

The representative sample (–3.3 mm) was characterized through microscopic studies to identify the mineralogical constituents. Pyrolusite was the major manganese mineral with bixbyite in minor quantities. Hematite and bixbyite contributed to iron content, while quartz, mica constituted the gangue minerals. Preliminary tests with different combinations of process routes involving dry magnetic separation-classification, Dense Medium Separation-Jigging, Tabling-Magnetic separation were attempted. Tabling-Magnetic Separation gave the best results in terms of recovery and grade and thus selected. Detailed experiments were carried out, varying the following parameters, in the ranges mentioned below (Table 1).

Table 1: Operating Conditions for tests on Dongri-Buzurg – I ore

Tabling	
Deck Speed (Strokes/min)	300, 325, 350 and 375
Deck inclination (degrees)	3, 5 and 7
Water flow rate/feed rate/stroke length were kept constant at	6–7 lt/min, 12 kg/hr and ¼ inches respectively.
Magnetic Separation (cross belt separator)	
Magnetic current intensity	1.4, 2.6 and 3.8 amps

The results are presented in the form of a flow sheet (Fig. 1). The Dongri-Buzurg dump manganese ore could be upgraded to battery grade specifications, as weakly magnetic fraction at 3° inclination, 300 strokes/min and 3.0 amps current intensity.[1]

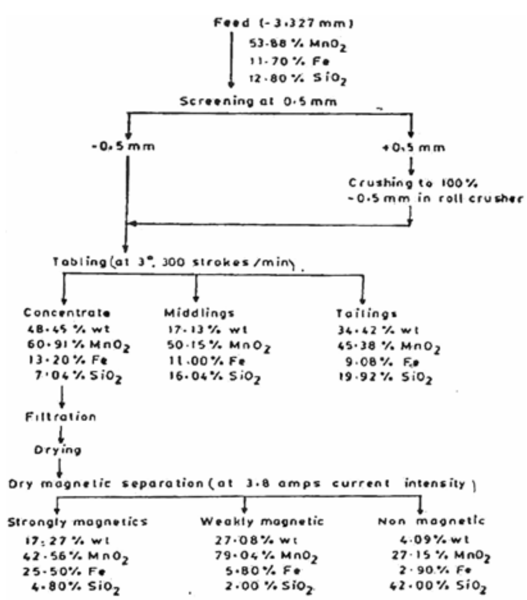

Fig. 1: Flow sheet for beneficiation of managanese ore fines of Dongri-Buzurg (dump).

Dongri-Buzurg dump ore - II

Dongri-Buzurg manganese dump ore – II is soft and spongy with an average composition of 52% Mn, 4% Fe and 0.3% P. The R.O.M. dump ore is screened over 25 mm screen, with the + 25 mm size fraction of about 0.125 MT (received from different sources) sorted to different size and grades and marketed. The – 25 mm material (0.101 MT) is further sized at 6 mm. the + 6 mm material, assaying around 42% Mn is used by ferrous industries. About 0.055 MT of – 6 mm material with an average Mn O_2 content of about 72% is left unutilized. The Schematic illustration of the then existing flowsheet of operation is shown in Fig. 2.

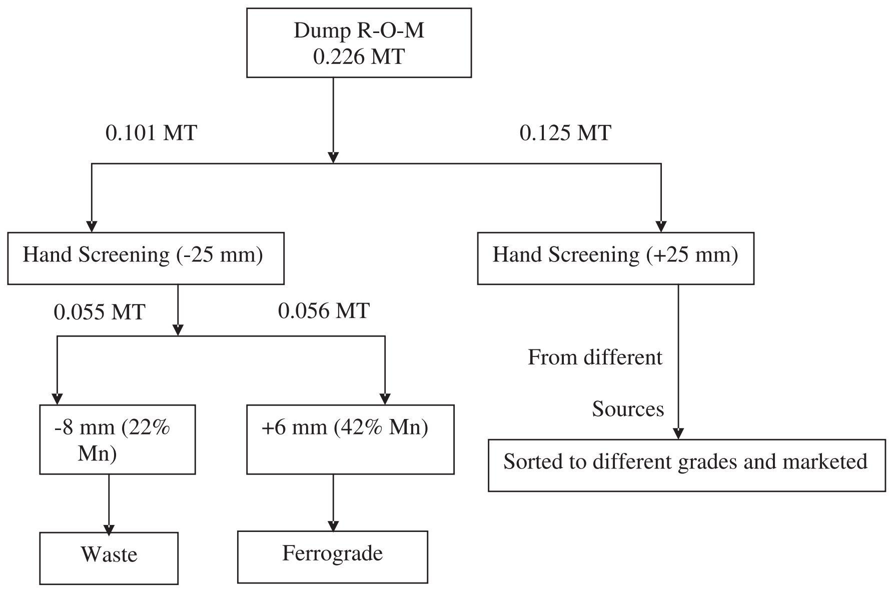

Fig. 2: Existing Flowscheme for Dongri-Buzurg manganese dump ores - II.

Characterization and beneficiation studies

The sample collected was subjected to systematic sampling and characterization. The polished sections studies under reflected light identified Pyrolusite and Psilomelane as the main manganese minerals, with jacobsite, hollandite and braunite in minor quantities. Quartz, Feldspar, Hematite, Goethite in major proportion and Mica, Magnetitie, Clay, etc in minor proportions form the gangue minerals, Size and size-wise chemical analysis indicated that there is no preferential distribution of MnO_2 and Fe contents, although the grades are relatively better in the coarser fraction. The weight distribution does not allow any quality improvement through size separation.

The liberation studies showed that there is sufficient liberation at – 10 mesh and hence all the material was reduced to –10 mesh through controlled crushing and screening. Representative samples were individually subjected to closed-circuit comminution to get samples of 100% passing 10, 35 and 60 mesh respectively.

Two sets of experiments (a total of 6 experiments) were carried out on the three feeds, using magnetic separation. The optimum results obtained with – 10 mesh feed material is summarized Table 2.

Table 2: Final Results of Magnetic Separation Tests on – 10 mesh feed (Dongri-Buzurg – II ore)

Experimental Conditions	Products	WI(%)	MnO_2	Fe(%)	Remarks
Feed rate : 3.26 (kg/hr)	Magnetic	51.69	57.69	13.84	EMD Feed Grade
Field Intensity 4350 (Gauss)	Non-magnetic	48.34	78.35	5.00	Battery grade

It is interesting to note that the processing scheme produces to products which are both amenable for utilization in user industries. The non-magnetic fraction, constituting 48.34% of the feed assays 78.35% MnO_2, 5% Fe and conforms to grade requirement for dry battery manufacture. The magnetic fraction of 51.66% yield assays 57.59% MnO_2 and 13.48 Fe and conforms to feed quality requirement for preparation of Electrolytic Manganese Dioxide (EMD). Fig. 3 shows the final beneficiation and utilization flowscheme for Dongri-Buzurg waste dump - II ore.[2]

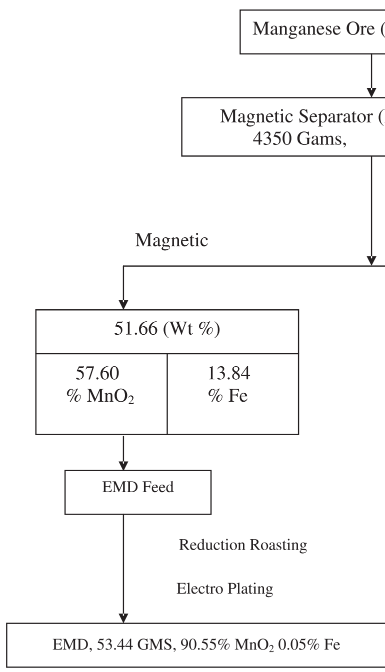

Fig. 3: Final Flowsheet for Beneficiation and Utilization of Dongri-Buzurg Dump Manganese Fines - II

SERICITIC PYROPHYLLITE

Introduction

Whiteware manufacture involves use of China clay, Ball clay, calcined quartz and Potash Feldspar as raw materials to prepare green bodies whish are dried and fired to finally obtain a marketable product. Sericitic pyrophyllite an alumino-silicate material, is available abundantly in India, and had not been subjected to use in whiteware manufacture. Since it contains both alumina and silica, it could be incorporated in the mix to replace high grade Feldspar and Quartz so as to conserve them. The mineral, if incorporated in the whiteware composition, could be expected to have a similar effect on the piece properties and may be beneficial in many ways in countries like India due to its extensive availability and potential for conservation of high grade raw materials.

In the present investigation, quartz and feldspar were progressively replaced by sericitic pyrophyllite and the effects on the physical, thermal, and mechanical properties were studied and compared with a conventional whiteware mix. The phases present in the fired specimens were determined by XRD analysis, and microstructural features were studied by SEM.

Experimental

The raw materials selected were Ahmedabad chine clay (Ashwin), Bikaner ball clay, calcined quartz, potash feldspar, and sericitic pyrophyllite (KH-2). Crushed quartz and feldspar and sericitic pyrophyllite were separately wet ground in a ball mill with porcelain balls as grinding media to, 53 um (–300 meash), demagnetized, and dried. The particle size distribution of ground materials and clays was determined, and chemical and mineralogical analyses of the raw materials were carried out according to standard procedure. A traditional whiteware mix (PB-1) was used as the starting composition and sericitic pyrophyllite (KH-2) was gradually incorporated as a replacement for quartz and feldspar (Table 3).

Table 3: Composition with progressive replacement of quartz and potash feldspar with sericitic pyrophyllite in a conventional whiteware composition [mass-%]

Mix No	Ahmedabad China clay (Ashwin)	Bikaner bail clay	Ground calcined quartx	Ground potash feldspar	Ground sericitic pyrolphyllite (KH-2)
PB-1	25.0	25.0	25.0	25.0	0.0
PB-2	25.0	25.0	20.0	22.5	7.5
PB-3	25.0	25.0	15.0	20.0	15.0
PB-4	25.0	25.0	10.0	17.5	22.5
PB-5	25.0	25.0	5.0	15.0	30.0
PB-6	25.0	25.0	0.0	12.5	37.5

Plastic and dry properties such as water of plasticity and Atterberg’s number of the plastic body, dry linear shrinkage, dry strength, and bulk density of the unfired test specimens were determined as per standard procedure.

Fired properties such as fired linear shrinkage, water absorption, apparent porosity, bulk density, true porosity, fired strength (M.O.R) at room temperature, modulus of elasticity (MOE) and linear thermal expansion were determined by standard methods, Chemical analyses of fired specimens were also carried out.

Results and discussion

The whiteware bodies with 22.5% sericitic Pyrophyllite (PB-4) and 37.5% (PB-6) showed better plastic and fired properties than the conventional body composition and that too with economic benefits due to faster firing mode (less energy for same throughput).

Progressive incorporation of Sericitic Pyrophyllite (a waste material) into the whiteware composition in place of the conventional quartz and feldspar raw materials, resulted in whitewares of much better physical and thermo-mechanical properties at a more economical and faster production rate.

RICE HUSK ASH

Introduction

Rice husk ash (RHA) contains an active form of silica (SiO_2) and is available in large quantities in India. It has been estimated by the Department of Agriculture, Government of India that the production of paddy will be about 200 million tonnes by the year 2010. Paddy consists of 72% of rice, 5–8% of bran and 20–22% husk on average. Thus, 200 million tonnes of paddy will give us about 40 million tones of husk. Presently about 35 million tonnes of rice husk is produced in India per annum. Rice husk contains ash from 13 to 29% by weight depending on the variety, climate and geographic location. About 6.0 million tonnes of rice husk ash is produced in India, which is mostly thrown away as waste. The ash is largely composed of silica (87–97%) with small amounts of alkalies and other trace elements. The presence of silica as SiO_2 in rice husk ash has been known since 1938. The silica in rice husk is in hydrated amorphous form, either opal or silica gel. The use of rice husk ash in the form of silica in the ceramic field was also reported by Samanani *et al*.[4] Borthakur *et al*.[5] also investigated physico-chemical properties of RHA for its application or utilization.

Experimental

The raw materials selected were Amrapali china clay (Supra grade), potash feldspar and calcined quartz. All the raw materials are abundant in India and are being used for the production of whiteware ceramics in the country. Rice Husk Ash incorporated in the whiteware body was prepared by controlled burning of raw rice husk in air so as to avoid the presence of carbon (<5 wt.%) as far as practicable. Calcined quartz and potash feldspar were wet ground separately in a ball mill using porcelain balls as grinding media to around 300 mesh. The slurry was sieved, passed through a magnetic channel and dried.

Rice husk ash was wet ground in a ball mill using porcelain balls as grinding media for 35 h. The particle size distribution of ground material as well as that of the Amrapali china clay, and the chemical and mineralogical analyses of the raw materials were carried out according to standard procedures. A standard whiteware body mix (CSR-1) was selected as the starting composition and rice husk ash was gradually incorporated into the body by replacing calcined quartz (Table 4).

Table 4: Body composition with progressive replacement of quartz by rice husk ash in a standard whiteware composition (mass %)

Mix No.	Chine clay (supra grade)	Ootash feldspar	Calcined quartz	Rice husk ash
CSR-1	50	25	25	0
CSR-2	50	25	20	5
CSR-3	50	25	15	10
CSR-4	50	25	10	15
CSR-5	50	25	5	20
CSR-6	50	25	0	25

The test specimens were extruded in a vacuum extruder in the form of cylindrical bars 1.5 cm diameter and 1.5 cm length. All the test specimens were dried and then fired between 110- and 1300°C at temperature intervals of 50°C in an electric furnace. The heating rate in the furnace was 3.5°C min^{-1}. The specimens were soaked for 1 h at the respective peak firing temperatures.

Plastic and dry properties such as water of plasticity, dry linear shrinkage, dry strength, and bulk density of dried test specimens as well as fired properties such as fired linear shrinkage, fired strength (M.O.R.), water absorption and bulk density were determined by using standard procedures. Percent thermal expansion of matured specimens of different bodies was also measured under a heating rate of 10°C min^{-1}.

The major crystalline phases were identified by XRD and the microstructural features were studied by SEM on fracture-etched surfaces. The fracture-etched specimens, etched in 10% HF for 3 min were studied for existence of various phases in the fired specimens.

Results and discussion

The chemical and rational analyses of Amrapali china clay (Supra grade), potash feldspar, quartz and rice husk ash are presented in Table 5.

The results of wet sieve analyses and particle size distribution of ground and processed raw materials showed that the non-plastic materials, viz; feldspar, quartz and rice husk ash had coarser particles of about 1.5–2 wt.% on 53µm and that the distribution of particles was almost identical.

Plastic and dry properties of body mixes altered marginally when quartz was progressively substituted by RHA in the traditional whiteware composition.

When quartz was partially replaced by RHA, micrographs showed recrystallised secondary mullite needles in the matrix along with some quartz crystals which are small in size as well as less in number. Micrographs for CSR-3 containing 10 wt.% RHA showed extensively interlocked secondary mullite needles embedded in the glassy matrix. Hence, the reported improvement in the fired strength by 7.2% in CSR-3 over the reference body (CSR-1) was probably due to the well-interlocked structure of mullite needles in the microstructure. The CSR-6 specimens also showed the presence of short as well as intensively interlocked mullite needles which appeared to be uniformly dispersed in the matrix along with a few small quartz crystallites and the glassy phase.

Table 5: Chemical analyses and mineralogical composition (rational analysis) of raw materials (mss%)

Constituents	Amrapali chine clay (supra grade)	Potash feldspar	Calcined quartz	Rice husk ash
Chemical analysis				
SiO_2	46.24	65.65	96.80	88.44
$A1_2O_3$	35.46	17.84	1.90	1.21
Fe_2O_3	1.16	0.16	1.10	0.40
TiO_2	0.76	Trace	Trace	Trace
CaO	1.58	0.20	0.15	1.20
MgO	0.08	0.24	0.02	1.82
Na_2O	0.10	0.24	0.02	1.82
K_2O	0.42	2.75	0.46	0.50
L.O.I.	14.10	0.84	0.40	4.63
Mineralogical composition (rational analysis)				
Kaolinite	88.63	–	1.43	–
Quartz	3.10	2.70	93.47	–
Feldspar	3.33	63.47	5.00	–
Calcite	2.84	0.30	–	–
Magnesite	0.17	0.30	–	–
Heamatite	1.16	0.51	–	–
Routile	0.76	0.16	0.10	–

Hence, it is evident that in all the micrographs, the major phases present were quartz and mullite, apart from the glassy phase and pores. The presence of quartz relicts decreases on replacement of quartz by RHA. It has thus been possible to eliminate, to a large extent, the inherent defects in the microstructure of a conventional whiteware, and improvement in the mechanical and thermal properties of RHA incorporated body mixes have been achieved.

Progressive substitution of quartz by RHA in a conventional whiteware composition resulted in an early vitrification of the mixes. A reduction in the maturing temperature of about 50°C to 100°C was noticed in the body mixes containing RHA compared to the reference body. The increase in the fired strength and the substantial decrease in per cent thermal expansion of the body mixes containing RHA are attributed to the sharp decrease in the quartz content and also to the increase in the content of the glassy phase. However, the content of mullite appeared to be unaffected due to the addition of RHA in the compositions. The reduction in the vitrification temperature of the mixes would also contribute significantly to the economical production of whitewares.

CONCLUSIONS

The above case studies illustrate that low grade raw materials can be gainfully utilized through smarter and judicious processing strategies for better economics and sustainability.

ACKNOWLEDGEMENT

The author gratefully acknowledges the scholarly work carried out by Mr. Vinod Kumar, Mr. Rama Mohan, Dr. C.S. Prasad under his supervision and the technical inputs from Dr. K.N. Maiti the then Scientist & Head of CGCRI, Naroda Centre of CSIR, INDIA.

Acknowledgements are due to Director, Indian School of Mines, Dhanbad for permission to submit and present the paper.

The secretarial help rendered by Mr. S.K. Dey is sincerely acknowledged.

REFERENCES

[1] Kumar, C. Vinod, Venugopal, R., Kundargi, G.P. and Rao, T.C., 1987, Beneficiation of Dongri Buzurg dump manganese ore fines to battery grade, *Journal of Mines, Metals and Fuels, Spl issue on Mineral Beneficiation*, p. 110.

[2] Venugopal, R., Mohan, K. Rama and Choudhary, B.B., 1995, Waste Utilization Studies on lowgrade Dongri-Buzurg dump ore fines- All India Symp. on "Converting Waste into Wealth", p. 79.

[3] Prasad, C.S., Maiti, K.N. and Venugopal, R., 1996, Incorporation of Sericitic Pyrophyllite in place of potash Feldspar and Quartz in whiteware manufacture INTERCERAM, V. 21.

[4] Samandani, S.G., Ali, A. and Allla-Laximikantham, 1978, *Bull, Am. Ceram. Soc*. 57, p. 1054.

[5] Borthakur, P.C., Saikia, P.C. and Dutta, S.N., 1980, Physico chemical characteristics of silica from paddy husk, its reactivity and probable field of application, *Indian Ceramics*, **23** (2), p. 25.

[6] Prasad, C.S., Maiti, K.N. and Venugopal, R., 2001, Effect of rice husk ash in whiteware compositions, *Ceramics International*, **27**, p. 629.