

BX05 - Beneficiation Aspects of Low-grade Unutilized Materials (Partially Lateritised Khondalite and Laterite) Associated with Bauxite Mine

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Abstract

Lateritic bauxites are the products of intense subaerial rock weathering. The resources of bauxite in the Country are in the order of 3850 million tones and occupy 5th position in World. The major deposits are in East coast, Central India, West coast and Gujarat however, the occurrences of Laterite are widespread in various regions. Bauxite deposits consist of four horizons namely Duricrust (Laterite), Bauxite, Partially Lateritised Khondalite – PLK/ Saprolite (weathered) and parent rock which is responsible for formation of bauxite ore. JNARDDC has evaluated bauxite and laterite deposits of India from geo-technological point of view. The bauxite mines/ deposits are associated with various low-grade materials and it remains unutilized at mine site due to their inferior composition. For utilization of these low-grade materials, quality of the same has to be improved.

Keeping in view the improvement in quality of low-grade materials, beneficiation studies have been carried out at JNARDDC. The PLK contains high silica, iron oxide, low alumina and resembles the characteristics of aluminosilicate materials. In general, laterite is originated from various rocks and comprises iron oxide, silica and alumina bearing minerals. The beneficiation studies have been done on PLK and laterite (ferruginous, aluminous, siliceous) indicated that the ore can be upgraded with relevance to reduction in iron oxide, silica and enrichment in alumina content. At present, India is importing alumina containing raw materials required for non-metallurgical applications (refractory, chemical, etc.). The beneficiation studies have shown great promise to be developed as a substitute for the applications requiring high-grade ores. This will have a significant effect on the life of bauxite mines as well as dwindling natural resources.

Keywords: Bauxite mine, PLK, laterite, Eastern Ghats, Western Ghats, beneficiation.

1. Introduction

India is endowed with abundant resources of bauxite and the deposits/occurrences are in various parts of the Country (East coast/Eastern Ghats, Central India, West coast/Western Ghats and Gujarat). Various factors such as composition of parent rock, origin, geomorphology, process of bauxite formation, etc. are responsible for the characteristics of bauxite and laterite ore. The bauxite deposits associated with PLK and laterite (Overburden) are in East Coast region however, deposits situated in Central India, Gujarat and West Coast are associated with laterite and saprolite resources. During the bauxite mining, various low-grade materials such as saprolite, low grade bauxite, laterite, PLK are generated. However, these are discarded off due to their inferior composition. These materials have characteristics of low alumina, high silica and iron content.

Due to this inferior quality, these materials could not be used for alumina production or other industrial applications. Hence, they remain unutilized at mine site. The National Mineral Policy (NMP-2019) has emphasized utilization of small group of deposits along with mineral wealth. The occurrences and isolated deposits of bauxite and laterite are scattered all over the Country and available for economic extraction of mineral values. Keeping in view the improvement in quality of low-grade materials, beneficiation studies has been done at JNARDDC. The studies carried out on PLK, ferruginous, aluminous, siliceous laterite indicated that it can be upgraded with relevance to reduction in iron oxide, silica and enrichment in alumina content. India is having limited resources of high-grade, high alumina bauxite ore and in the current scenario, country is importing raw material required for non-metallurgical applications (refractory, chemical, etc.) to overcome the material shortage. The positive impact on cost anomaly as well as life of mine may appreciably increase by processing inferior material associated with bauxite horizon. The optimum use of in-house resources of available raw material associated with bauxite mines requires proper data and information in order to establish their suitability for industrial uses. This paper describes various beneficiation techniques attempted for upgrading quality of various materials which are not in use, because of its inferior quality with respect to the applications.

2. Sampling and Characterization

For the present study, the representative samples of PLK and laterite were collected from bauxite deposits located in Eastern Ghats (Panchpatmali, Odisha) and Western Ghats. The Eastern Ghats bauxite deposits contain 12-meter (average) thickness of bauxite with 4-meter laterite (overburden). The bauxite zone is underlying by weathered rock i.e. partially lateritised khondalite (PLK) with thickness of about 6 meter and varies. In Western Ghats and coast (Maharashtra) deposits, the thickness of bauxite is 2.5 meter (avg.). It is pisolitic in nature and contains moderate to high alumina as well as low silica [1]. The laterite (overburden) occurs above the bauxite zone and it is hard, massive in nature with red, pink and grey in colour.

The samples were crushed to -25 mm size by jaw crusher. For the characterization studies, -200 mesh size samples have been prepared by universal mill/ bond mill and thoroughly mixed using homogenizer. The representative sample was drawn by coning and quartering procedure.

The chemical and mineralogical analysis of samples has been done by wet chemical method and XRD with XDB software, respectively. PLK is characterized by high silica (25-35 %), high iron oxide (14-18 %) and quite low alumina (32-36 %) content. Laterite contains high iron oxide (25-45 %), high silica (6-15 %), low alumina (25-35 %) and titania (2-4 %). In some deposits (Kolhapur), laterite contains very low silica (2%). Mineralogical analysis by XRD shows that laterite is comprised of hematite, goethite, kaolinite and gibbsite minerals. The petrology studies indicate that laterite is pisolitic and iron minerals exhibit colloform texture. The gibbsites are cryptocrystalline and pseudomorph after plagioclase feldspars. The morphology studies indicated that laterite contains undeveloped crystals of gibbsite and in some laterites, it is hexagonal in shape [2]. Our studies reveal that in most of the laterite deposits, the gibbsite is not well developed due to partial bauxitisation [3, 4]. In PLK, kaolinite is a major dominant mineral and about 70 % alumina and silica present in the form of kaolinite. The microscopy studies indicated laterite is dominant in hematite, goethite, and gibbsitic minerals and PLK shows kaolinitic texture [5, 6]. It is observed that habit of minerals, crystal shape, etc. are not prominent in low grade ores as compared to bauxite.

3. Beneficiation Studies on Laterite and PLK

The Country's abundant low-grade resources (PLK, low grade bauxite and laterite) are characterized by high iron oxide, silica and low alumina content, which restrict their use in metallurgical as well as non-metallurgical applications. Thus, any beneficiation process which

can reduce silica (mainly in reactive form such as kaolinite) and iron content are important from the processing point of view. The studies have been done by organizations/industry on beneficiation on low grade bauxite mainly for removal of impurities such as iron oxide, silica [7]. JNARDDC has done extensive studies on laterite, bauxite and PLK of various origins. Due to the reduction in iron oxide, silica and increase in alumina content, beneficiation techniques such as screening, sieving, magnetic separation, hydrocyclone and leaching were adopted. The results of beneficiation studies showed that iron and silica content can be reduced from laterite and PLK [8]. The salient features and results obtained in beneficiation studies carried out on PLK and laterite are given below.

3.1 Screening

Screening and sieving tests on laterite and bauxite samples from different geological origin have been carried out at JNARDDC laboratory. Experts opined that clay agglomerates on the bauxite surface create lot of problems in the processing of ore. Its concentration in the ore is decreased by washing the ore followed by screening in which the agglomerates are detached and are removed with the action of water [4, 9]. The wet sieving has been carried out on Western Ghats (Maharashtra) Laterite. The sample crushed to required size (30 mm) and screened into 13 fractions namely +16, -16+11, -11+8, -8+4, -4+2, -2+1, -1+0.5, -0.5+0.25, -0.25+0.149, -0.149+0.074, -0.074+0.063, -0.063+0.045 and +0.045 mm by ANALYSETTE 3 PRO vibrating screen for half an hour. The results clearly indicate that Al_2O_3 is enriched above + 2 mm size fraction and it increases proportional to the grain size. However, silica & iron oxide content gets enriched below – 0.5 mm by wet sieving [10]. In a similar pattern, the dry as well as wet sieving was carried out on Eastern Ghats gibbsitic laterite. The results clearly indicated that Al_2O_3 % is enriched above +2 mm size fraction and it increases proportionally to the grain size. However, silica and iron content get enriched below –0.5mm in dry screening, though by wet sieving the same gets enriched below –0.063 mm [11, 8]. Based on the beneficiation studies it is observed that silica and iron content enriched in fine fractions however, improvement of Al_2O_3 % particularly in coarse and middle fractions. It indicates that selective mining of a deposit can improve the overall grade of run of mine (ROM). Further similar studies were carried out on other clay minerals of interest such as PLK, saprolite, etc. The results indicate the enrichment of Al_2O_3 minerals in coarse fractions however, fine fractions contain iron and silica (kaolinite) bearing minerals.

3.2 De-ironing Studies by Wet High Intensity Magnetic Separator (WHIMS)

Keeping in view the reduction of iron oxide content, tests were carried out using wet high intensity magnetic separator (WHIMS). The trials have been done on laterite samples with various size, such as -50, -100, -200 & -325 mesh and different magnetic intensity (5000 to 19,800 gauss) with 20 & 30 % solids. It is observed that as magnetic intensity increases, alumina content in the non-magnetic fraction increases and iron decreases with varying recovery of ore (non-magnetic fraction).

The de-ironing tests were carried out on laterite of Western Ghats (Maharashtra) and Eastern Ghats deposit by WHIMS on 10000 gauss magnetic intensity and various mesh size sample. The Laterite of Western Ghats (Kolhapur) is ferruginous (high iron oxide) in nature. However, Eastern Ghat laterite contains quite high alumina. The results indicate a 10-18 % reduction in iron oxide and a 10-15 % enrichment in alumina content in non-magnetic fraction of Western Ghats laterite (Figure1). However, Eastern Ghats laterite shows considerable reduction in iron oxide (10-25 %), as well as an increase in alumina content by using the same magnetic intensity and feed size. The recovery of ore after processing in Western Ghats laterite (weight % of non-magnetic fraction) is 35 % however, in case of Eastern Ghats sample, the recovery is 47 % (Table 1). It indicates that characteristics of ore are the main considerable factors during beneficiation processes. It is

observed that with the same magnetic intensity and laterite size, two kinds of laterite deposit show significant difference in ore and alumina recovery, as well as reduction in the iron content [11-13]. The studies indicated that in the beneficiation process (physical separation), magnetic intensity, grain size and ore characteristics of laterite play an important role.

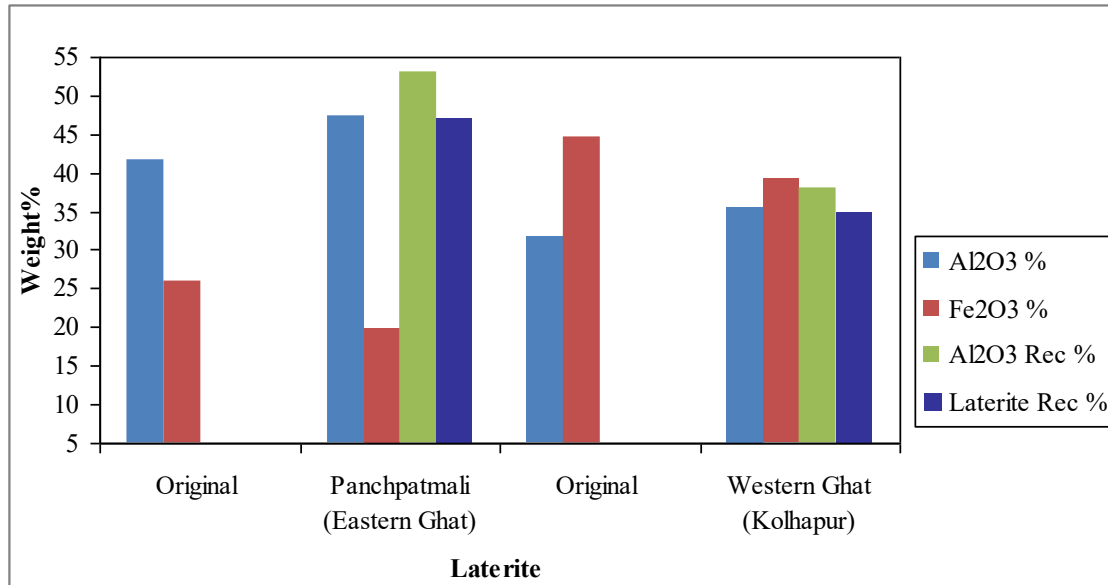


Figure 1. De-ironing by WHIMS of two different laterite with 10000 gauss intensity and grain size (-50+100 mesh).

Table 1. Chemical composition of raw and beneficiated Laterite.

Sample	Composition %					
	Raw (original) Laterite		Beneficiated Laterite			
	Al ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃ Recovery	Laterite Recovery
Western Ghats	31.61	44.80	35.70	39.20	38.00	35.00
Eastern Ghats	41.80	26.00	47.50	19.90	38.00	47.00

The possibility of separating iron bearing mineral ores in PLK has also been explored by WHIMS with different particle size in 25, 50, 72,100 mesh and magnetic susceptibilities of 7,500, 10,000 and 15,000 gauss. Experimental studies on WHIMS for iron oxide removal from PLK (- 50 + 72 mesh) at 15,000 gauss magnetic intensity with variable size fractions is shown in Figure 2. It was concluded that % Fe₂O₃ recovery is higher in the 50-mesh size fraction (almost 2.5 % more than the 100-mesh size fraction).

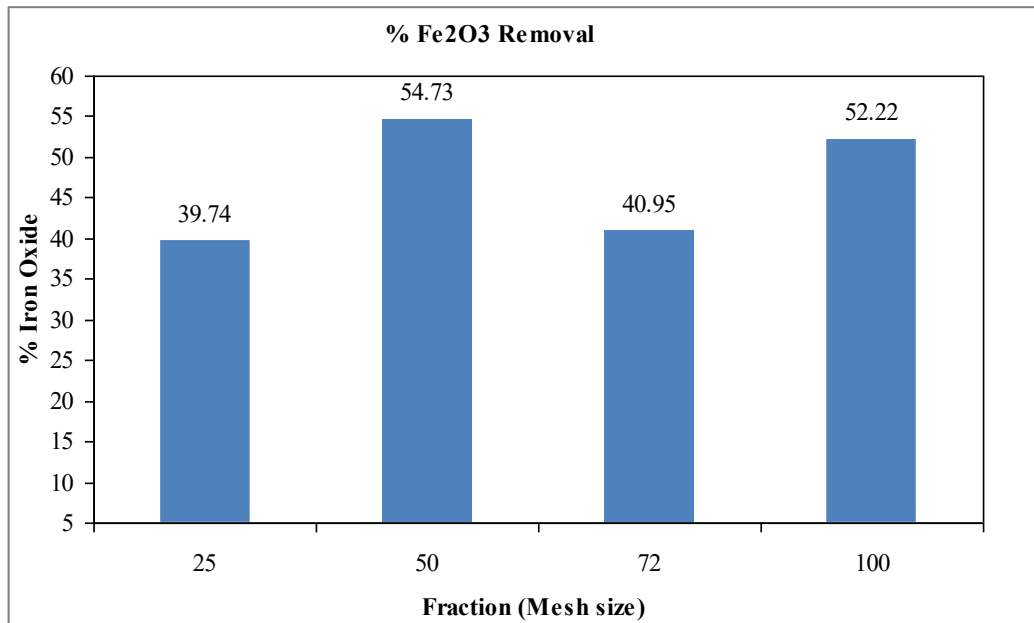


Figure 2. Iron oxide removal from PLK at different size fraction.

3.3 Separation Studies by Hydro Cyclone Test Rig

The study has been taken up for beneficiation of laterite and PLK by using hydro cyclone test rig. The Laterite sample contains high iron oxide (37.32 % Fe_2O_3), silica (14.91 % SiO_2) and low alumina (27.03 % Al_2O_3).

The laterite sample (-50+100, -100+150 and -150+200 mesh size) was prepared for the present study. The tests were carried out using various parameters, such as solid %, pressure (psi), size of sample (mesh), vortex finder (mm) and apex (mm). The results show significant enrichment of alumina (32-34 % Al_2O_3) from original 27 % and reduction in the iron oxide (Fe_2O_3 30-24 %) content from the original 38 %. The beneficiated fraction (overflow) contains high alumina however, the underflow fraction was enriched with high iron oxide minerals (Figure 3). The overall recovery of laterite is in the range of 40-50 %. The trials show encouraging results with respect to reduction in the SiO_2 content (9-11 %) [4, 8].



Figure 3. Fractions of beneficiated Laterite.

The separation tests have been done on a PLK sample with various parameters such as size of sample (-50+100 mesh), solid %, pressure (psi-5,10,15,20), vortex finder (14 mm) and apex (6.4 mm). The results show significant reduction of iron oxide (11-13 %) from the original 17.65 % with slight reduction in the silica content (24-26 %) content from the original 29 %. The overall recovery of PLK is 60 %. The test indicated that separation of minerals was achieved by using

low pressure (5-PSI). The process flowsheet for physical beneficiation techniques is given in Figure 4.

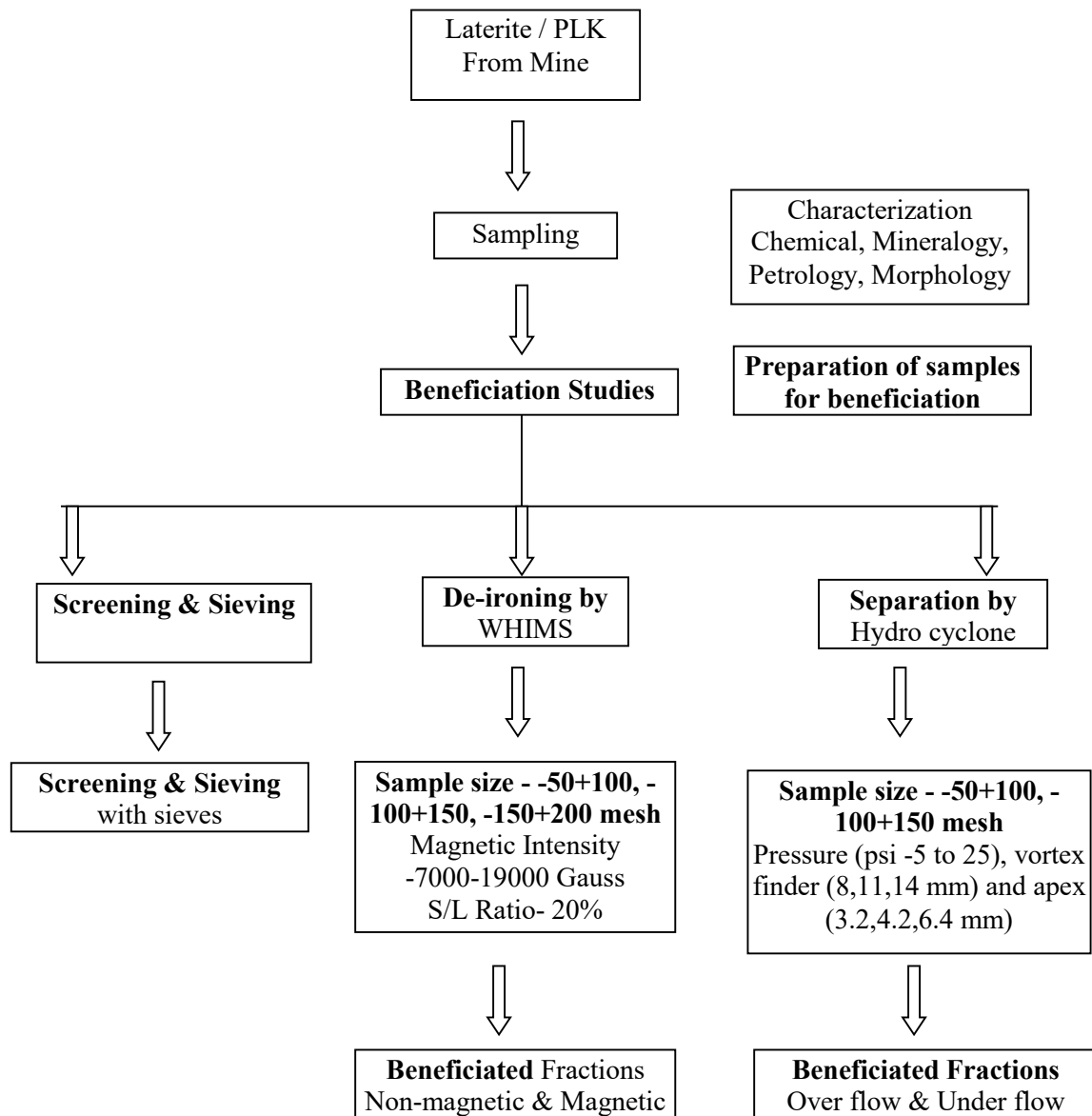


Figure 4. Flow sheet (physical beneficiation).

3.4 Beneficiation of PLK Based on Chemical Treatment

The chemical composition of PLK composite originating from the Eastern Ghats of India contains a fair amount of iron bearing mineral phases. Various reports [14, 15] confirmed the PLK consists of Fe_2O_3 in the range of 17-19 %. Chemical leaching of iron mineral phases in natural minerals are one of the known procedures adopted by many researchers. The maximum removal of iron bearing minerals is possible with chloride salts, mineral acids and certain organic reagents at elevated temperature and pressure. Similar studies were carried out for exploring the possibility of lowering iron oxide minerals from PLK matrix. The average chemical composition of PLK contains 36.36 % Al_2O_3 , 17.50 % Fe_2O_3 , 27.22 % SiO_2 , 1.92 % TiO_2 and 15.46 % of loss on ignition. Residence time, concentration of leaching reagent and reaction temperature plays significant role in any of the chemical processes. To optimize the best suitable time duration

required for acid leaching process, sets of leaching experiments were carried out by varying time intervals (30, 60, 90, 120, 150 minutes) keeping other parameters uninterrupted. Similarly, the trials were carried out for optimizing acid concentration, as well reaction temperature at specific solid liquid ratio of PLK and leaching reagents. Accordingly, the experimental conditions were optimized as shown in Table 2 and 3.

Table 2. Experimental conditions used for optimization.

Sample weight	Acid /Acid concentration	Acid volume	Time (Minutes)	Temp, °C
10 gms	HCl/6M	100 ml	30,60,90,120,150	80-100
M: Molar concentration				

Table 3. Analysis of residues after leaching.

Sample (residues)	Weight (g)	Composition %				
		Al ₂ O ₃	Fe ₂ O ₃	SiO ₂	TiO ₂	LOI
PLK	7.990	40.80	1.85	34.24	2.80	16.22

HCl concentration ranging 5-7 M was found optimum for best results that confirmed lowering of Fe₂O₃ in PLK from average 18 to 2 percentages after chemical leaching (Figure 5). The process flowsheet for chemical leaching is given in Figure 6.



Raw PLK - 18% Fe₂O₃ Chemically treated PLK ≤ 2% Fe₂O₃
Figure 5. PLK before and after beneficiation.

Based on the above studies, it is concluded the acid treatment process developed and optimized for removal of iron oxide from PLK is reliable and efficient for generating low iron PLK residue for ceramic and paint/pigment applications as well as paper industry, functional coatings, nano-silicates, white mineral binders, etc. By adopting a leaching technique, high alumina low iron bauxite can be developed from low grade bauxite or Laterite. The specification required for use in non-metallurgical industries is given in Table 4. By using beneficiation techniques low grade ore can be used for non-metallurgical applications (refractive, abrasive, etc.).

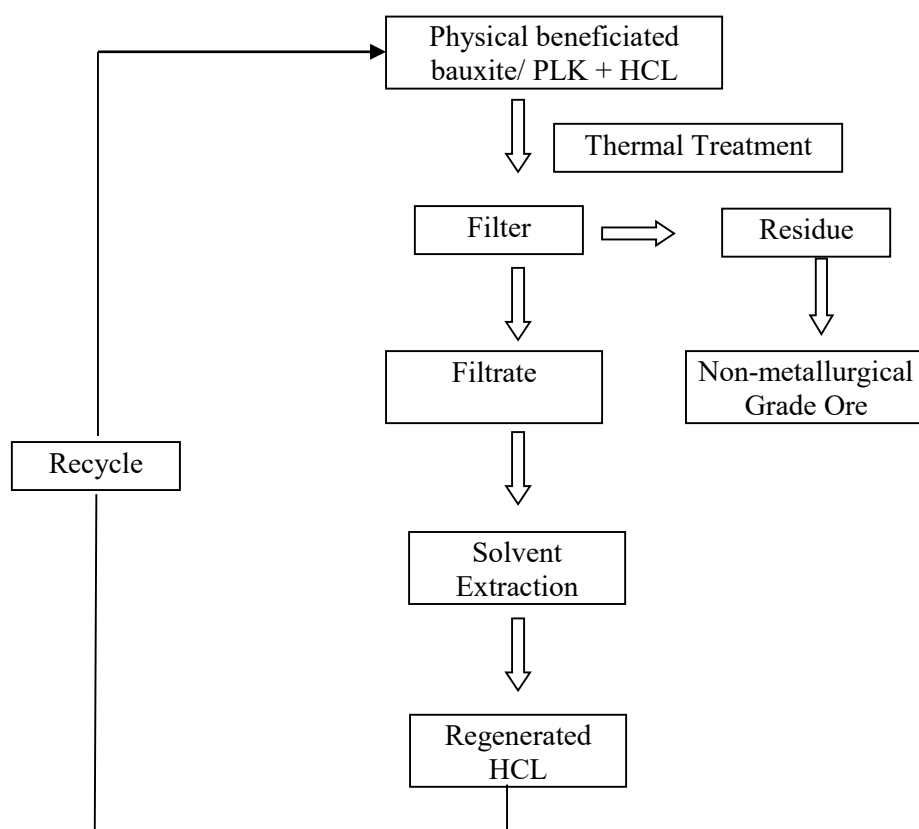


Figure 6. Process flow sheet (chemical leaching).

Table 4. Specification of bauxite.

Grade	Major Oxides (%)			
	Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	TiO ₂
Metallurgical	40 - 52	1.5 - 10	5 - 30	1 – 6
Abrasive	Min. 55	Max. 5	Max. 6	Min. 2.5
Chemical	Min. 55 - 58	Max. 5 -12	Max. 2	0 – 6
Refractory	Min. 58 - 61	Max. 1.5 - 5.5	Max. 3	Max. 2.5
Low grade bauxite / Laterite after beneficiation (JNARDDC)	> 58.00	< 5.00	< 3.00	< 4.00

4. Conclusions

The quality of low-grade materials (laterite, PLK) may be improved by using beneficiation techniques for making it suitable for an array of industrial utilizations.

Ore characteristics and grain size play an important role during beneficiation. The results showed reduction in iron oxide and silica as well as enrichment in alumina content.

The life of mines may appreciably increase by using weathered unutilized materials associated with lateritic bauxite profile.

In India, mine owners located in Central India and Western region are adopting a simple beneficiation technique (screening, sieving) for improving the quality of ore. The advantage of

this technique is that it can be done at mine site, without much environmental impact, with insignificant energy use. The hydro cyclone and WHIMS are good techniques for removal of impurities however, the process requires water. The chemical leaching process is very effective for reduction of iron oxide content. The only disadvantage is that HCl is corrosive in nature. By using minimum acid concentration followed by physical beneficiation, this problem can be solved to a greater extent.

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