RE-USAGE OF DRY BAUXITE RESIDUE

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Abstract

Bauxite residue is the main by-product of alumina refining requiring treatment and disposal, significantly influencing cost. Numerous attempts have been undertaken to improve the efficiency of residue disposal or to make it available for industrial re-usage.

Bauxite residue is characterised by parameters which can be seen as advantageous/disadvantageous for industrial re-usage like:

– a typical particle size distribution ($x_{50} < 10\ \mu m$)
– a typical mineralogical composition consisting of Al_2O_3, Fe_2O_3, SiO_2, TiO_2 and others
– a pH-value in the original red mud of pH = 10–12 (soluble soda content of some 60 g/l)
– serious dewatering problems

For decades major alumina producers have undertaken research into alternatives to residue disposal and product development. This research has highlighted a large number of possible residue applications in different industries such as soil improvement, land reclamation for agriculture, regulator at cement production, sintering aids for iron and steel industry, catalyst for coal hydrogenation, top and bottom sealing of disposal areas, backfilling of underground mine etc.

To allow a further processing or a re-usage, it is required that bauxite residue is made available by the refinery with a very low soda content and a non-thixotropic and non-sticky behaviour to ensure secure transportation and problem free handling. However actual methods of filtration, washing and dewatering are not able to produce bauxite residue that is clean and dry enough to meet these requirements. This has to be seen against the background that thermal drying of wet bauxite residue is too energy and cost intensive and, therefore, not a feasible and profitable process alternative to produce dry bauxite residue for utilization. The Hi-Bar Steam Pressure Filtration is an innovative technology, which has now shown its capability to produce a really dry, easy to handle, bulk-like material.

1 Introduction

Sustainability is increasingly a major challenge facing the minerals industry, especially in the context of tailings management. Terms like ‘closing the loop’ and ‘zero waste’ reflect the environmental, economic and social importance. Increasing demand for minerals and metals are accompanied by legislative demands for environmental and social sustainability. Solving this dilemma by finding new technical solutions is a major task for the minerals industry. Implementing advanced mineral processing can help to improve raw materials efficency and to reduce residue. At the output side of the process new technical solutions are required which help closing the loop by transforming residue into valuable products.

Bauxite residue production estimates can range from 70–130 Mt/a dry solids, highlighting its significance. In some brownfield, and even for new greenfield plants, the economic and environmetal aspects of the bauxite residue are a key factor for a go or no-go decision. Under the heading of ‘Towards Zero Waste and Net Emissions’ the Cooperative Research Centre for Sustainable Resource Processing (CSRP) has elaborated in 2003 a top 20 list of industrial wastes for future investigations [Leahy, 2005]. Bauxite residue or red mud, respectively, was identified as number one ranking in this list due to its large amount and due to its good re-usage potential. Nevertheless, bauxite residue is a waste product destined for discharge on disposal sites or even by deep sea dumping, since the available methods of bauxite residue treatment do not enable its utilisation up to now. The average moisture content in disposal sites is 50% water in the residue [Aluminum Assoc.] as it is produced by deep cone thickeners. Thus, with every Mt of residue solids 1.22 Mt of water have to be transported and disposed. Modern filtration technolgies are capable to reduce the moisture content significantly to below 25% which means that 1 Mt of residue solids contain only 0.33 Mt of water. In other words: 0.89 Mt less water leave the plant which is a large step towards ‘closing the loop’. The high water content is also the reason for major disadvantages of the bauxite residue. Thixotropy, non bulk-like transportation, problematic handling and high content of soluble soda are the consequence of too high water content. Any new technical solution which makes the bauxite residue acceptable for a really dry disposal or even better for industrial re-usage is directly linked with overcoming the above mentioned disadvantages. The Hi-Bar Steam Pressure Filtration is an innovative technology which has now shown its capability to produce a really dry, easy to handle, bulk-like material that can open the doors for re-usage applications.

2 Characteristics of bauxite residues

The most important mineralogical compounds of bauxite residue are iron oxide, titanium dioxide and silicon dioxide of which the first is responsible for the colour and the name of this waste material. Further characteristic data of bauxite rresidue are given in Table 1. Some bauxites are also known for their content of radioactive materials. Their concentration, however, is below critical values but can affect the public perception and acceptance of red mud. The composition of bauxite residue varies in a wide range depending on the origin of the bauxite, the individual process design and the process conditions of a refinery. Not only the chemical composition but also the particle size distribution varies which both influence the residue characteristics with respect to filtration, washing and dewatering and consequently the residue behaviour at disposal.

Bauxite residue consists of very fine, lamina-shaped particles in the range of $x_{50} < 10\ \mu m$. An especially problematic characteristic of bauxite residue is the thixotropic behaviour which impairs the possibilities of utilisation. Under mechanical stress, which may occur e.g. by shaking during the transportation, bauxite residue which seems to be of a firm consistency is liquefied again and becomes sticky. This phenomenon leads to very poor bulk characteristics and complicates the handling significantly. Thixotropy disappears when the moisture content is reduced below a value of <25–28 wt%. However vacuum filters, which are the established and only available continuous filter technology for bauxite residue, are limited in their dewatering capability and produce thixotropic filter cakes with moisture contents = 35–50 wt%. The high liquid content in the cakes and poor washing results in the bauxite residue possessing a high amount of soluble soda of some 6–12 g/kg.

Table 1: Characteristic Data of Bauxite Residue

Characteristic Data of Bauxite Residue		
Separation Technology	moisture content	amount of water per t solids
deep thickener	50 – 55 %	1,220 kg/ t solids
vacuum drum filter	35 – 50 %	540 kg/ t solids
Steam Pressure Filtration [Langeloh, 2002]	< 25%	330 kg/ t solids

3 Disposal of bauxite residue

Bauxite residue management is the issue with the the most environmental relevance for refineries Although bauxite residues have no particular toxic characteristics, the disposal of this residue material is an important technical and economic challenge. Available methods of bauxite residue treatment do not enable an economic utilisation up to now. Therefore, this residue is still a waste product destined for disposal despite of numeous possibilities of re-usage. Some refineries that are located at or near the coast dispose of their bauxite residue by pumping the residues into the sea, which is the still practised method e.g. in Japan.

The largest amount, however, is pumped or transported to open disposal sites, of which five different methods of disposal exist [Hausberg, 1999]. Some 66% of the disposed bauxite residues world wide are pumped to different types of storage sites in a liquid state with a solids content of only 20–30 wt% (wet discharge). To this category the typical red mud lagoons belong which receive some 33% of the world wide quantity. About one third of the residue is stored by 'dry stacking' with the higher solids content of vacuum filter cakes of some 50%–65%. Worldwide, the average solids content of bauxite residues discharged on disposal sites is 50% solids [Aluminum Assoc.] as it is produced by deep cone thickeners which are the common technology. Every Mt of residue solids then contains 1.22 Mt of water which leaves the plant togerther with soluble soda and has to be transported and disposed together with the solids. Modern filtration technolgies are capable to reduce the moisture content significantly to below 25% – i. e. the solids content increases to >75%. Since 1 Mt of such dewatered residue solids contain only 0.33 Mt of water a difference of 0.89 Mt or nearly 75% less water would leave the plant.

Central aspects of actual disposal methods are the loss of valuable product, the large required area and the costs for the construction and operation of the disposal site. A typical procedure for bauxite residue disposal by 'dry stacking' includes the following cost creating measures and process steps:

- transportation to disposal site usually by pumping through pipelines with positive displacement pumps fed by screw conveyors (up to 2 km the residue with a mc of some 45wt% can be pumped without liquifiers or dilution water, longer distances require liquifying or dilution)
- building of a secure bottom sealing of the disposal site
- preventing of alkaline water escape by secure surrounding dams of some 30 m in height
- providing for an even and fast drainage of the residue e.g. by construction of drainage towers
- operation of the disposal site including good distribution of the residue, control of the sealing, groundwater, the water balance and consolidation, treatment of drained water and rain water
- protection of the sun-dried surface against wind-erosion to avoid red-coloured dust pollution
- financial reserves for recultivation of the storage site.

4 Influencing factors for re-usage of bauxite residue

All major aluminium producers have made serious efforts in the last decades for finding new uses for bauxite residue and for developing new treatment methods to turn bauxite residue into a valuable and marketable product. Numerous proprietary names exist for treated residues like Bauxsol™ (Virotec), Cajunite™ (Kaiser Aluminium), Bauxaline® (Aluminium Pechiney) etc.. Also cooperations of aluminium/alumina producers together with independent technical experts are founded for pre-competitive research activities [Aluminum Assoc.]. The large volume of bauxite residue and the cost of handling and treatment, however, have been affecting its use in commercial applications and no industrial bulk application has yet been realised.

Any option of treatment and re-usage of bauxite residue has to be seen against the background of economical as well as environmental, health and saftey aspects. The main issues for the re-usage of bauxite residue as a valuable product are [Aluminum Assoc.]:

- the cost of processing/converting it to a valuable product
- the large volume
- the public perception of it as a harmful waste.

4.1 *Requirements on product characteristics*

Generally, different alternatives of recycling exist but each of them requires a special product quality. From an economic view these utilization possibilties are only feasible if bauxite residue complies with following requirements

- minimum soda content
- sandy material characteristic, i. e moisture content <25%
- problem-free handling and secure transportation.

Available methods of processing like deep cone thickeners or vacuum drum filters [Langeloh, 2002] are not capable of producing a residue which meets these demands. The reasons for this unsatisfactory situation are special product characteristics which make filtration, washing and dewatering of bauxite residue a challenging task.

4.2 *Treatment of bauxite residue*

Actual methods of filtration, washing and dewatering do not produce bauxite residue that is clean and dry enough to ensure the required characteristics [Langeloh, 2002]. Therefore, problems occur during transportation, storage and further processing (e. g blending with other raw materials) which make bauxite residue treatment difficult and expensive. In some cases bauxite residue is dewatered on filter presses to produce test material for re-usage application. This is performed e. g. in Japan where residue is de-moistured on a filter press to a moisture content of mc = 30% for producing a residue material for the cement industry. However, the transportation and the blending of this residue with the raw material is difficult and problematic since the filter cake sticks at the equipment and blocks the chutes.

For producing BauxalineR the residue is also dewatered on a filter press to a moisture of mc = 30% – even a lower moisture content is expected – and dried in a thermal dryer [Alcan, 2002].

Thermal drying of wet bauxite residue is energy intensive and cost intensive and therefore bauxite residue normally is discharged on disposal sites and has then to be dug up for further treatment when it is dry enough. The main factors influencing the econmics of re-using bauxite residues are the cost of digging the residue out of disposal areas, the cost of washing and treating the residue, the transportation costs and the relatively low cost of competing materials [Aluminum Assoc.].

Therefore, new solutions are necessary for delivering adequate dry bauxite residue material. New methods of treatment must be capable of improving the product characteristics of this residue to such an extent that utilization becomes a real alternative to disposal and that the loss of valuable content is minimised. This requires a significant improvement in bauxite residue washing and dewatering by an economic process solution. The main targets are:

- reducing the moisture content down to 25 % or less by an improved filter cake dewatering in order to achieve a non-thixotropic and non-sticky product with
  - sand-like bulk characteristics
  - good transport and handling characteristics
  - a high utilization potential.
- reducing the soluble Na_2O content far below the actual values of 6–8 [g/kg] by improved washing
  - to minimise the loss of soluble soda
  - to achieve a better product quality for bauxite residue utilization possibilities
- ensuring an economical process for achieving the above mentioned targets by avoiding/reducing crack formation in the filter cake by a minimum input of thermal energy.

The Steam Pressure Filtration is an innovative separation technology which now offers the possibility to produce a clean, dry and sandy bauxite residue of the required quality in an economic manner.

5 Clean and dry bauxite residue by Hi-Bar Steam Pressure Filtration

The patented Hi-Bar Steam Pressure Filtration is an advanced filtration process based on the continuous pressure filtration process, originally developed by Prof. Stahl at the University of Karlsruhe in the early 1980s [Bott, 1985]. This innovative version of the continuous pressure filtration is already applied in the chemical industry and has now shown its capability to produce a really dry, clean and easy to handle sandy bauxite residue material in an economic way [Langeloh, 2002].

Furthermore, the continuous pressure filtration is the chosen technology for the dewatering of the worldwide first pipeline transported bauxite at the Barcarena alumina refinery of Alunorte (Alumina do Norte do Brasil S/A) in Brazil. The continuous pressure filters will achieve a moisture content of some 14% which can be improved by application of steam pressure filtration to mc ≤12%. Five pressure disc filters of 168 m² each will be commissioned in 2006. The supply of these filters will be managed within a consortium between Andritz AG, Graz (Austria) and BOKELA based on a comprehensive feasibilty study done by BOKELA.

5.1 *The Process and Plant Design of Hi-Bar Steam Pressure Filtration*

The continuous Hi-Bar Steam Pressure Filtration is realised on rotary drum or disc filters and applies filtration pressure differences up to 6 bar and superheated, pure steam for filter cake treatment (thermal heating and mechanical pore emptying). The application of overpressure instead of vacuum with pressure differences up to 6 bar ensures a high specific throughput and dewatering capability even with filter cakes with fine particles such as bauxite residue filter cakes where high cake resistance and capillary forces in the cake have to be overcome. The treating of the cake with dry, superheated and pure steam is performed in a specially designed steam cabin which the cake enters immediately when emerging out of the slurry. Here, the steam condenses on the colder cake surface and forms a layer of condensate that is forced into the cake by the pressurised steam like a ‘condensate front’ and displaces the mother liquor. The piston like flow of this ‘condensate front’ through the cake effects a highly effective displacement of the mother liquor which leads to an intensive cake washing. When the ‘condensate front’ arrives at the filter cloth the heated cake leaves the steam cabin and now compressed air is forced through the cake pores which causes an effective thermal drying. Due to the stored energy in the heated cake a great part of the residual liquid is evaporated. These thermal/mechanical phenomenon inside the cake lead to a homogeneous and intensive washing and demoisturing of the cake and can also prevent or reduce the formation of cracks in the filter cake.

The plant design is based on rotary disc or drum filters, which are installed inside a pressure vessel that is filled with compressed air from a compressor. Drum filter areas are available up to 40 m² and disc filter areas up to 168 m².

5.2 *Steam pressure filtration of bauxite residue at the AOS Refinery*

At the refinery of Aluminium Oxid Stade GmbH (AOS), Germany, test trials were carried out on the mobile Hi-Bar pilot plant of BOKELA during a period of 6 months. The Hi-Bar pilot plant is a mobile unit which allows pilot test operation on a technical scale with filtration pressure differences of up to 6 bar. While the running vacuum drum filters produce a filter cake with a moisture content of some 35% to 37% and with a soluble soda content of 0.5% to 0.9% which is sticky and difficult to handle and to transport, the Hi Bar Steam Pressure Filtration produces a really dry, clean and easy to handle sandy bauxite residue (see Figure 1). In table 2 a short survey of the results of the Steam Pressure Filtration are shown. A comprehensive report as well as a cost calculation based on a scale up calculation for a 40 m² Hi-Bar drum filter (turn key plant including pumps and compressor) is given in Langeloh [2002].

Table 2: Invest and operation costs of a Hi-Bar steam pressure filtration plant; cost calculation for a 40 m² Hi-Bar drum filter

	[€ / t residue]	[€ / t residue]
	soda content = 0.5%	soda content = 0.3%
Moisture content mc	23%	23%
operating costs mc = 23% / mc = 25%	9.73 / 8.03	10.23 / 8.33
return of invest: 2 years	12.40	14.40
return of invest: 5 years	5.80	6.70
return of invest: 10 years	3.50	4.10

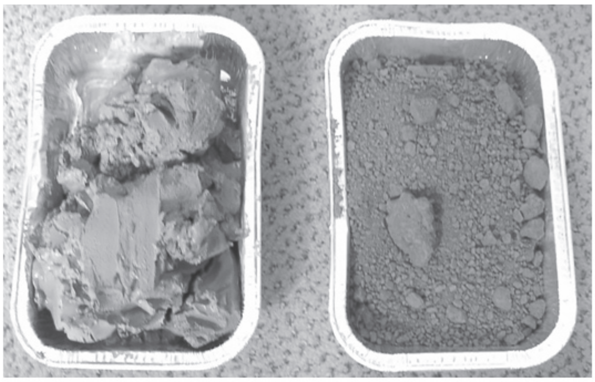

Figure 1: Filter cakes of bauxite residue: pasty and sticky with moisture content mc = 35% (vacuum filter) and sandy material with mc = 23% from Hi-Bar Steam Pressure Filtration

The total costs for producing a clean dry, sandy bauxite residue are attained as the sum of the investment and operating costs, which depend strongly on the required moisture content, purity and investment return period. Whilst a moisture content of 23%, excellent washing (soda content = 0.3%) and a short 2 year period for return of investment lead to costs of 24.6 EUR € per t bauxite residue the product costs can be halved if a 25% moisture and 10 years for return of investment are accepted.

6 Target industries and application possibilities for bauxite residue utilization

6.1 *Bauxite residue as material for cement production*

Bauxite residue can be added to cement kilns for both its aluminium and its iron content and to reduce scale on the kiln. This possibility of re-usage has been primarily tested in Jamaica, Germany, Greece and Japan, whereby special efforts are currently made in Japan.

Motivated by Japan's policy to require and support activities which may help to develop a recycle-oriented society Japan's three alumina producers are trying intensivley to find alternatives for the practised deep sea dumping of red mud. Besides the environmental problems this way of disposal also causes cost of some 30 USD/t dry solids. On the other side Japanese cement producers are trying intensively to substitute natural raw materials by wastes such as bauxite residue [Japan Aluminium, 2003]. So, some plant trials were started in 2002 with filter press dewatered bauxite residue at one of the largest cement production plants in Japan to utilize coarse residue for the cement production. The amount of the coarse fraction in the total residue is only about 10%. Thus, plant scale tests were started in 2003 to confirm the possibility of using the whole bauxite residue as material for cement and to find out the optimum amount that may be added with respect to the product quality [Japan Aluminium, 2003]. For that, the bauxite residue is dewatered and then mixed with other raw materials like lime, clay, silica, iron source, etc. and finally fed to a cement kiln. The tests confirmed that residue added cement, as well as mortar and concrete made from this cement meet Japanese Industrial Standards.

The dewatering of the bauxite slurry to a moisture of mc = 30% happens in a large filter press (temporarily installed at one of the alumina plants in Japan). It was found to be necessary to reduce the moisture of the filtered cake to improve its handling properties especially for achieving better transportation. During the transportation and during the blending with the raw material adhesions of the filter cake at the equipment and blockage in the chutes occurred. To avoid these problems and in order to improve the characteristics of the bauxite residue pilot tests with the Hi-Bar Steam Pressure Filtration will be carried out at one of the Japanese alumina refineries. During these test trials 1000 t of dry bauxite residue filter cake shall be produced.

Alcan is also performing tests together with the cement industry with the aim of delivering the bauxite residue as additive for the cement production. Tests in France will start with the prospect of a yearly sales of 20,000 t. Furthermore, it is expected that a large amount can be sold to the east Mediterranean area.

Aluminium de Grece (AdG) has made an agreement with Lafarge for delivering of 200,000 t/a dewatered, dry bauxide residue in 2006 for cement production in Greek cement factories. While AdG enters a new aera of bauxite residue management, it is the intention of Lafarge to preserve its natural resources and to lower the cost of cement production. For the future AdG expects to promote the complete yearly amount of 700,000 t/a bauxite residue this way.

6.2 *Agriculture*

6.2.1 *Soil improvement*

Alcoa World Alumina Australia in corporation with the Department of Agriculture have investigated the potential to use bauxite residue as soil amendments for the poor, acidic, sandy soils of the Swan Coastal Plain in Western Australia [Summers, 1996 & 2002; Snars, 2002]. The reason for doing research work with red mud as a fertilizer additive was the leaching of phosphorus (nutrients) from the sandy soils which has caused eutrophication in estuaries and consequently the incidence of nuisance algal blooms. The research has shown the ability of red mud to increase phosphorus retention resulting in an increasing of the crop and pasture yield.

Greenhouse experiments have identified the red mud as effective amendment for *in situ* fixation of heavy metals. Further investigations to evaluate the efficiency of red mud as a fixing agent for heavy metals were carried out in an outdoor pot experiment to assess the influence of red mud on the metals [Friesl, 2002]. The use of red mud as fixing agent for heavy metals and metalloids provides a cost-effective solution for soils contaminated with heavy metals [Lombi, 2002].

6.2.2 *Land reclamation*

Research projects e.g. from Alcan (Aluminium Pechiney) are carried out to use the bauxite residue for land reclamation as an alternative solution to the storage [Gesamtverband, 2003; Mordini, 1997]. This requires pre-treating of the red mud (e.g. to lower pH-value and to a lower moisture content). Pilot projects in experimental parcel of land found several suitable plants for planting on the residue instead of using a layer of top-soil to get grazing land. The plant growth is improved by mixing residues with organic by-products (e.g. residual mud from water treatment plants or coffee grounds) [Mordini, 1997].

The good results obtained from the use of residue in horticulture led to its usage as material for covering and for planting garbage dumps [Mordini, 1997]. Aluminium Pechiney made tests on the garbage dump for Marseilles city at Entressen which showed normal plant growth.

6.3 *Industry of building materials*

6.3.1 *Concrete, mortar and road construction*

Red mud can be converted into a cementitious binder in conjunction with rice husk, clay and lime for use in mass concrete, masonry mortar and road construction. In view of comparative low cost there exists a good potential for the manufacture of this binder at small scale in areas around aluminium industry [Nerdatabank].

Test work with red mud was made to show the possibility for using it as the main component of new construction material. The experiments showed that this new material can be used for road and airfield bases, levee core, dumps, foundations etc. and to make bricks, tiles, and similar items due to its high strength values [Mymrin, 2001].

6.3.2 *Support material for pigments of applications in coatings and material manufacture*

Results of studies with red mud converting into pigment form and then incorporated into porcelain tile bodies are shown in the paper 'Euro Ceramics VIII'. It was found that red mud pigment addition decreases the pigment costs and supplies homogenous shades of black, green colours originated from pigments themselves and incorporations of red mud base pigments into porcelain tiles do not have detriment to physical properties of final products [Euro Ceramics].

6.4 *Industry of filling materials*

Dewatered and optimal particulate sized red mud can be used to solidify liquid wastes (e.g. liquid industrial waste) for disposal in landfills. The addition of a small amount of bauxite residue can improve the handling and solidification characteristics of the composition under certain situations. In comparison to other absorbent or solidification agents red mud can absorb liquid hydrocarbon wastes without the water normally required. When the bauxite residue is dried to greater than 95% solids, the material makes a good absorbent for the landfilling of liquid waste. It has been shown to be a good filler/building material and can be used instead of clay to extend the height of the levees (dikes in the disposal area). It has also been used as a filler for plastics (mainly in India and Taiwan), where it can have some advantages in sunlight applications (to impart strength, resistance to UV, heat and chemicals and colour). It also can have some advantages in sunlight applications.

6.5 *Mining Industry*

Another application of using bauxite residue is the treatment of acid rock drainage and mine tailings [McConchie, 2003]. Acid mine drainage (AMD), or acid rock drainage (ARD), is a common problem wherever sulphidic waste rock or mine tailings are stored. Seawater neutralized red mud has the capacity to neutralize acid and trap trace metals associated with acid mine drainage. Virotec International Ltd. (Australia) optimised the process of red mud treatment [Davis-McConchie, 2002]

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6.6 *Red mud as catalyst*

6.6.1 *Coal hydrogenation plants*

Sulfur-promoted red mud catalyst is used as catalyst for hydroliquefaction of Göynük oil shale in Turkey. In Yanik [2003] it is reported that this sulfur-promoted red mud catalyst shows the best reaction condition.

6.6.2 *Catalytic combustion of methane*

Three iron-based catalysts were prepared from red mud and its activity and stability for the catalytic combustion of methane were studied from the Department of Chemical and Environmental Engineering at University of Oviedo in Spain. The red mud catalysts show in comparison to commercial catalyst a higher catalytic activity and a good thermal stability for the catalytic combustion of methane [Paredes, 2004].

6.7 *Bauxite Residue as a Filtration Medium*

A commercial use being investigated in Australia from Alcoa World Alumina Australia is sewage effluent treatment systems. Refineries in Western Australia are located on sand plains with limited water resources, leading to problems with biological pollution. To remove phosphorous and nitrogen from sewage effluent in domestic and industrial septic systems a blend of bauxite residue, sand residue, and gypsum is used in a filter for sewage effluent before it soaks into the ground. Effluent treatment systems containing bauxite residue have also been used for home sewage treatment systems and at pig farms and dairies [Japan Aluminum, 2004].

6.8 *Extraction of metals from bauxite residue*

Useful metals that can be extracted are iron, aluminium, sodium, and titanium. More valuable metals present in traces include niobium, gallium, thorium, scandium, and vanadium. Many companies have conducted R&D on recovering titanium, iron, and heavy metals from the residue but either the metal purity was insufficient or the process was too costly. In general, the recovery of most of these metals is not competitive with their extraction from natural sources [Japan Aluminum, 2004].

6.9 *Survey of application possibilities for bauxite residue utilization*

The following Table 3 gives an overview of tested application possibilities for bauxite residue. A comprehensive overview of the most promising approches for treatment and use of bauxite residue is also shown in a 'Bauxite Residue Technology Roadmap'-Report [Japan Aluminum, 2004] of a meeting with representatives from Alcoa, Alcan, and Kaiser. The paper discusses various approaches for collaborative development in bauxite residue treatment. The key factors (technical, economic, environmental, market) influencing the success of these approaches were determined and priorities for research efforts assigned.

Table 3: Application possibilities for bauxite residue utilization

Agriculture
Soil improvement ▪ Ability to increase/ to improve P retention (fertilizer additive) ▪ Ability to reduce eutrophication and to increase crop and pasture yield ▪ To help retain nutrients and adjust soil pH ▪ Additive to compost to aid the retention of trace metals ▪ Amendment for *in situ* fixation of heavy metals
Land reclamation ▪ With a layer of top-soil to get grazing land ▪ Without using top-soil => using selected types of grass ▪ Material for covering and for planting garbage dumps
Other environmental applications ▪ Creating artificial marine reefs of blocks ▪ Reinforcing sea walls
Industry of building materials
Cement production / brick material ▪ Cementitious binder ▪ Main component of new construction materials ▪ Brick and tile manufacture, both fired and non-fired ▪ Raw material for the production of cement alternatives, such as mineral polymers and ceramics ▪ As a pigment for a range of applications in coatings and materials manufacture Support material for pigments ▪ Red mud pigment addition
Industry of filling materials
▪ Solidifying liquid wastes for disposal in landfills ▪ Fillings for road installation and road base ▪ Filler for plastics (mainly in India and Taiwan), to impart strength, resistance to UV, heat and chemicals, and colours ▪ The residue has been added to cement kilns (primarily in Jamaica and Germany)
Mining industry
Treating of acid mine drainage ▪ neutralizing of acid and trap trace metals ▪ amendment of acid producing soils ▪ neutralizing of acid and trap trace metals with seawater neutralized red mud
Red mud as catalyst
Coal hydrogenation plants ▪ Sulfur-promoted red mud catalyst is used as catalyst for hydroliquefaction Catalytic combustion of methane
Red mud as a filtration medium
▪ To remove P and N from sewage effluent in domestic and industrial septic systems
Extraction of metals from bauxite residue
▪ Useful metals that can be extracted are iron, aluminium, sodium, and titanium
Using a caustic red mud suspension as a scrubbing agent
▪ To neutralize acid forming gasses produced during coal combustion or similar processes

7 Summary

All major aluminia producers have made serious efforts to turn bauxite residue into a valuable and marketable product and to find new applications for bauxite residue. Although it contains valuable components and although there exist a lot of re-usage possibilities bauxite residue is still a waste product that is discharged on disposal sites or by deep sea dumping. A main reason for that is the poor dewatering with the actual methods of separation and filtration. The too high water content is responsible for important disadvantages like thixotropy, non bulk-like transportation, problematic handling behaviour and high content of soluble soda which make processing insedure and converting bauxite residuet to a valuable product cost intensive. Any new technical solution which improves the bauxite residue properties also improves the possibilities for industrial re-usage and is directly linked with overcoming of the mentioned disadvantages. While running separation technologies provide an average moisture content of some 50%, modern filtration technolgies are capable to reduce the moisture content significantly to below 25% which means that nearly 75% less water have to be processed, transported and/or discharged. This is a large step towards 'closing the loop'. A modern filtration technolgy which has shown its capability to produce a really dry, easy to handle, bulk-like material is the innovative Hi-Bar Steam Pressure . This filtration process provides a clean filter cake with low soda content and a moisture content of only 23% that can open the doors for re-usage applications.

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