

Impurity Removal in the Bayer Process

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Abstract



A wide range of impurities enter the process streams of alumina refineries, most of which originate from the bauxite ore. These impurities, primarily in the form of sodium salts, accumulate in the refinery's liquor streams until a steady state is achieved between the inputs and the various outputs that exist within a typical refinery. Unchecked, these impurities can significantly impact the productivity and/or product quality of the refinery. Not surprisingly, over the 130 year history of the Bayer process, a large number of impurity removal processes have been proposed, and in some cases, implemented. The introduction and operation of these processes has rarely been trouble-free, for reasons of performance, safety or public perception: sometimes all three at once. In this paper, the major impurities present in most Bayer circuits and the various removal mechanisms and strategies that exist to manage them are reviewed, and some of the issues and challenges that have arisen as a result are discussed. The influence that impurities have upon the characteristics of bauxite residue is also described.

Keywords: Organics, oxalate, sulfate, causticisation, bauxite residue

1. Introduction

In the Bayer process, bauxite ore is digested in a highly concentrated caustic soda solution, usually at elevated temperatures and pressures. The process relies upon the lower solubility of the hydroxides of most metals relative to aluminium, but under these conditions it is inevitable that small amounts of a wide range of materials are extracted, typically as the corresponding oxy-hydroxide or hydroxide anions. Due to the cyclic nature of the Bayer process, these anions can accumulate to quite high concentrations in the refinery's liquor stream over time, if not controlled. Apart from possible effects upon digestion behavior or precipitation performance, the formation of these anionic species also represents a loss of caustic soda.

Certain impurities (such as carbonate, oxalate, various organic species and sulfate) are common to most refineries, due to their ubiquitous presence in almost all bauxite deposits, but others can present special problems due to the relative abundance of particular minerals in bauxite from particular regions. While other materials that are added to assist the refining process (such as flocculants) add slightly to the impurity load, they are minor compared to the input with bauxite and rarely accumulate to a level where they cause operational problems.

A comparison of the elemental compositions of bauxite from various locations is shown in Table 1. These data are drawn from various sources, including Lapin et al. [1], Anand et al. [2], Ball and Gilkes [3], Rao and Goyal [4], See and Feret [5] and Wellington [6]. Bauxite composition can of course vary greatly within a region and even a specific deposit, and is further dependent upon the mine plan and cut-off grades, but the data in the table provides an indication of the typical issues that can arise from the processing of bauxite from each of these regions.

Karst bauxites, such as those from Greece and Jamaica, have high inorganic carbon content due to their formation over carbonate minerals such as limestone or dolomite. Western Australian bauxite deposits derive from two quite different parent rock types, but nevertheless underwent similar laterization events. They both contain slightly elevated organic carbon and sulfur contents that, when combined with low extractable alumina content, contribute to high inputs of sulfate, organic salts and oxalate to the refineries that process them.

Guinean, Indian and especially Jamaican bauxites possess a relatively high phosphate content, which can require specific control steps to avoid product contamination. Many Indian bauxite deposits contain high titanium and vanadium content; requiring special removal techniques [7].

Jamaican bauxite is infamous for its high and very fine goethite content, making it difficult to settle during clarification [8], but it also presents special issues with organic carbon, zinc and manganese. See and Feret [9] have suggested these latter elements derive from zinc-substituted lithiophorite ((Al,Li)MnO₂(OH)₂) within the deposit.

Table 1. Composition of various Bauxite deposits.

Species	Guinea	Brazil	Weipa	Greece	Trombetas	W. Australia (1)	W. Australia (2)	India	Jamaica
Al ₂ O ₃ Tot.	49.41	53.4	55.7	56.6	53	37.2	38	48.5	46.8
SiO ₂ Tot.	1.7	4.2	5.8	4.2	5.1	15.5	2.8	2.7	1.98
Fe ₂ O ₃ Tot.	19.06	13.9	11.9	21.9		24.5	35	17	19.2
CaO	0.01		0.01		0.01	0.01	0.01	0.02	1.13
C inorganic	0.06	0.01	0.03	0.41			0.1		0.4
C organic	0.11	0.03	0.23	0.08		0.2	0.2	0.11	0.2
C total	0.17						0.3		0.6
S total	0.032	0.04	0.03		0.06	0.09	0.1	0.05	0.08
P ₂ O ₅	0.14	0.02	0.07		0.01	0.02	0.015	0.13	0.38
TiO ₂	2.94	1.1	2.7	2.8	1.2	2	2.7	5.32	2.25
Na ₂ O	0.01	0.02	0.01		0.02	0.004		0.02	0.03
MnO	0.02	0.01	0.03			0.006	0.003	0.04	0.32
K ₂ O	0.03	0	0.01		0.01	0.06		0.03	0.01
MgO	0.01	0.01	0		0.005	0.006		0.05	0.08
V ₂ O ₅	0.05	0.04	0.06		0.05	0.06	0.05	0.19	0.11
ZnO	0	0	0			0.002	0.003	0.008	0.03
F						0.08	0.06		
LOI	26.7	27	23.2	12.2	27	19.8	21	25.7	26

Guinean bauxite is generally benign with respect to impurity input, although its relatively high goethite content coupled with the need to digest at high temperature to extract the boehmite content can result in problems with iron contamination in the product. Refineries processing this bauxite also tend to produce alumina with elevated gallium content. The comparatively high

sometimes referred to as pH “bounce-back” or “reversion”). In the case of DSP, this also constitutes a mechanism for the slow release of soluble sodium into the residue as the DSP decomposes. While the minimization of DSP has been a goal of the industry for many decades, for residue use it is necessary to either reduce its input or find new ways to destroy it.

Alternatives already exist for TCA. The high efficiency causticisation processes described earlier can greatly reduce TCA content in residue, and other sources, such as filter aid, can be isolated from the residue and potentially re-used. The practice of sodium oxalate causticisation, due to its inefficiency, also contributes to the presence of unstable quaternary calcium aluminate species in residue, along with unreacted lime. Alternatives, such as the recent developments in biological oxalate destruction, hold promise as a means of reducing this.

The presence of zinc sulfide can result in odours (due to biological activity), and contribute to the toxic content of the residue (although it could be argued that this is simply returning the zinc to its source). Similarly, sulfates, when present with an organic source such as oxalate, can be reduced and create odour problems.

4. References

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