

ORGANIC CONTROL TECHNOLOGIES IN BAYER PROCESS

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Abstract

Many Bayer plant problems originate from organics contamination of the Bayer liquor. Organics can decrease liquor productivity either by increasing alumina solubility or by covering active sites on alumina hydrate seeds. Organics also induce coloration of the liquor, cause excessive foaming, and increase liquor viscosity, density and boiling point. All these examples have deleterious effects on the Bayer process. This paper describes a full survey of patent literature including more than 60 patents filed between 1953 and 2001. Most patents in use today were issued in the early 80's. Apart from sodium oxalate control, very few patents are still in use with the sole objective of controlling organic carbon species in Bayer liquor. The most likely explanation is the poor economic viability of organics control in general. Most of the recent patents combine several different methods to reach the objective of organics control. A new innovative technology is presented. It involves treatment of Bayer spent liquor by direct contact with thermal submerged plasma. The multi-forms of energy provided by the plasma are efficiently used. Preliminary results will be given.

Introduction

The extraction and recovery of alumina as alumina trihydrate from bauxite is accomplished by the well-known Bayer process. The main characteristic is the digestion of the bauxite in a caustic liquor. However, bauxite contains organics impurities which are co-extracted with the alumina during digestion. Bauxite usually contains from < 0.1 to 0.4 wt % of organic carbon.

Source of the Organic Impurities

It is generally admitted that the organic species are present in the form of humic substances. The humic matter is gradually decomposed to lower molecular weight compounds. With recycling of the Bayer liquor, the concentration of these organic species builds up to an equilibrium concentration depending on the amount of organic carbon present in the bauxite and losses during the processing. The bulk of eventual degradation products are low molecular weight carboxylic acids, principally formic, acetic and oxalic acids as their sodium salts. Other possible sources of carbon compounds are: the flocculating agents, the defoaming agents, the carbon dioxide gas present in air, and the caustic alkali as raw material.

Impacts of Organic Impurities on Bayer Process

As stated in the references of Table I, many difficulties caused by the organic impurities include:

- lowered alumina yield;

- generation of excessive fine aluminum hydroxide particles;
- increase in density, viscosity, specific heat and boiling point of the sodium aluminate liquor;
- increased impurity content in the alumina;
- colored liquor and alumina hydroxide;
- lower red mud settling rate;
- loss of caustic due to formation of sodium organic salts;
- co-precipitation of sodium oxalate with the product hydrate;
- generation of excessive foam in the liquor process;
- increase in scale formation.

Technologies for Organic Control

Numerous methods are known for controlling and/or removing the organic species in Bayer process liquor. This paper will focus on patent literature review.

Patents issued between 1953 and 2001, from around the world, were reviewed. More than 60 patents were obtained, read and analysed. The most pertinent patents during this period are classified by number, date, author(s) and title in Table I. They are presented in chronological order. The method described in each patent is also summarised.

The patents can, as expected, be divided into two categories, namely the ones concerned with oxalate control and the others dealing with organic matters per se. It is well known that oxalate solids, if left uncontrolled, will dramatically affect the quality of alumina hydrate. The oxalate control is, however, outside the scope of this review, so all patents that deal specifically with this aspect are not presented. The various methods found in the patent literature can be summarised as follows:

- wet oxidation (partial)
- filtration, ultrafiltration, reverse osmosis (membrane)
- sorption (adsorption) with resins, carbon, alumina, ESP dust
- hydrate seed washing
- evaporation and precipitation
- evaporation by spraying
- liquor calcination
- solid-liquid calcination
- precipitation by flocculation with different additives such as POLYDADMAC, acrylic polymer, etc.
- precipitation by seeding (oxalate, sodium aluminate, lime, etc.)
- precipitation by pH variation
- liquid-liquid extraction (ethanol, methanol)
- biodegradation
- electro dialysis
- plasma treatment
- combination of methods

Most of the patents were issued in the late 70's to early 80's and are therefore now expired; although some of those technologies have been refined and patented, the improvements they represent are often not very significant, e.g. wet oxidation with catalyst (could generate impurities problem).

Of all the methods quoted above, to the authors' knowledge, only three have been applied to plants, namely wet oxidation, precipitation by additives (DADMAC) and liquor calcination.

Only one of these patents has seen worthwhile applications for the main purpose of controlling organics and this is the liquor calcination. This method, used in Western Australia, is facing problems of odour emanations. The only other method used was the wet oxidation in stages which has more to do with keeping hydrate product as color-free as possible. AOS from Germany has continuously used wet oxidation in tube digesters since 1989. The bases for wet oxidation in tube digesters were developed by VAW (see patents US 4,668,486 and EP 0384272). In this case, the benefits of a low organic contents are a higher throughput of filtering operations, precipitation yield, brightness of hydrate, etc. From these observations, one has to conclude that the organics control per se is difficult to justify economically, except in extreme cases (like high organics with low alumina content bauxite).

In the wake of what has been said in the previous point, the more recent patents (e.g. WO 00/10918, Worsley, 2000) are combining more than one method to presumably achieve better economics. It appears as the most probable route to make organics control process economically viable.

Innovative Plasma Treatment

As indicated above, technologies that combine many methods for control of organic impurities have more chances of economic viability, specially when it is performed in one step. The plasma treatment (WO 97/22556) presents all of these characteristics. The application of this innovative internally recirculating direct current (DC) thermal plasma reactor allows the degradation of organic by using a submerged plasma torch in combination with a draft tube. The advantages of this submerged plasma are: 1) plasma gases do not form carbonates from hydrocarbon combustion of flues gases (control of the chemistry); 2) fouling is avoided as heat transfer takes place at plasma-liquid interface and 3) dilution by steam injection is avoided. The heat transfer mechanism allows rapid and direct processing of Bayer liquor by submerged plasma plume which gives high thermal gradients ($> 4\ 000^{\circ}\text{C}$), high thermal efficiency and presence of UV radiations. The conditions accelerate the rate of organics decomposition at mild conditions in comparison to typical wet oxidation. The mass transfer mechanisms are supported by the liquor recirculating plasma reactor and by the intense gas-liquid mixing (convection). This reactor configuration helps control the residence time.

The experimental set-up is shown in Figure 1. To place energy in direct contact with the solution to be treated, a thermal plasma generated by a DC plasma torch is submerged in the solution, at the bottom of the reactor. The torch, fed with plasma gas is cooled down by tap water. To control both the liquid and gases flow patterns in the reactor and to obtain an adequate contact time between the gas and liquid phase, a draft tube is placed above the

torch. During the test, make-up water is added using a tap water line, at a known flow rate to keep the solution volume constant. The volume level is verified by the magnetic indicator in a side tube. Treatment is carried out under pressure (690 kPa) to reduce foaming problem and to increase boiling temperature of the system. Liquid samples are taken by the sampling line at half-height of the reactor, the reactor is drained by a line at the bottom and the gases leaving the reactor at the top are cooled in the heat exchangers. The condensate from the gases is recuperated in a reservoir and the cooled gases are sampled.

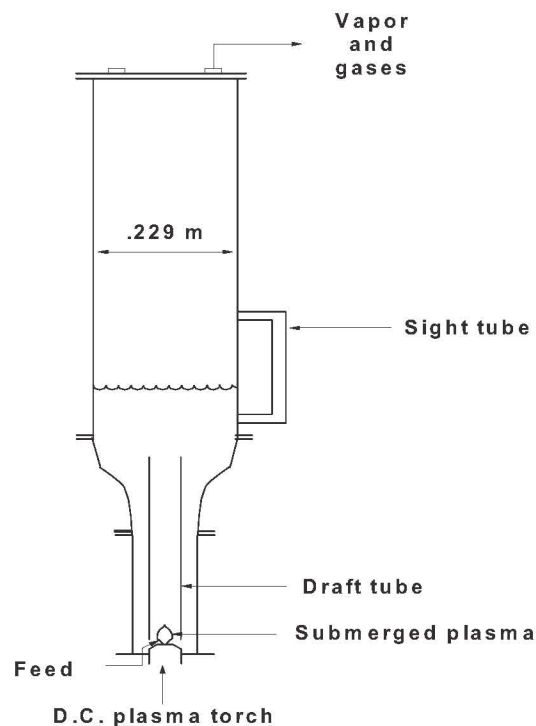


Figure 1. Experimental Set-up

Typical results obtained with this submerged plasma reactor are: the Total Organic Carbon (TOC) decreased from 7.4 g/L to 5.9 g/L in 10 minutes. The carbonate from the degraded organics increased from 22.6 to 28.1 g/L. Foaming was considerably reduced and color changed from opaque dark brown to clear orange.

Conclusions

Choosing a method of organics control will stay a difficult task because it is very dependent of each plant condition. The economics will need to be carefully addressed. The more recent patents address this issue more closely. However, more work will be needed for emerging technologies (such as plasma treatment) and for the improvement of our fundamental knowledge about organic degradation.

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References

See Table I.

Table I. Details on the Most Pertinent Reviewed Patents

PATENT	DATE	AUTHOR (ASSIGNEE)	TITLE	METHOD
US 2,806,766	Sept. 17, 1957	Anderson et al. (Kaiser)	Process of Purifying Caustic Aluminate Liquors	Aluminate liquors are heated to 150°C prior to their further processing.
US 3,649,185 (HU 146,023)	Mar. 14, 1972	Sato et al. (Showa)	Method for Removing Impurities in the Bayer Process	Precipitation of Na oxalate by raising the soda concentration (NaOH) (reducing the solubility of the oxalate). Oxalate solubility figures available.
US 3,899,571 CA 1082729 GB 1404709 JP 49078700	Aug. 12, 1975	Yamada et al. (Sumitomo)	Method for the Removal of organic Substances from Sodium Aluminate Solution	Seeding with activated crystals of Na oxalate (stimulate precipitation) make uses of poor solubility of oxalate. T = 0 - 75°C (20-60°C) C = 30 - 30 000% wt of Na oxalate in spent liquor
US 4,036,931	July 19, 1977	Roberson et al. (Kaiser)	Bayer Process Production of Alumina	Carbonation of a blow-down stream at 40-100°C to produce sodium dawsonite. This compound is then heated for thermal decomposition to sodium aluminate.
US 4,038,039	July 26, 1977	Carruthers et al. (Alcan)	Production of Alumina	Production of alumina. Removal of oxalate from spent liquor by evaporating and spray dryers on packing in an enclosed space (precipitation above critical supersaturation)
US 4,046,855 GM 2,518,431 AU 1326776 EU 188268	Sept. 6, 1977 (April 25, 1975)	Schepers et al. (Gebrüder Giulini GmbH)	Method for Removing Harmful Organic Compounds from Aluminate Liquors of the Bayer Process	<i>Magnesium</i> addition (2 to 20 g/L Kieserite) Precipitation, separation of humates Organic: humic acid derivatives T = 60-70°C; Time : 1 hour
US 4,101,629	July 18, 1978	Mercier et al. (Pechiney)	Purification of Solutions Circulating in the Bayer Cycle	<i>Barium</i> compound addition T = 1400 - 1500°C no alumina added T = 1000 - 1100°C with alumina
US 4,201,749	May 6, 1980	Yamada et al. (Sumitomo)	Method for the Separation of Precipitated Aluminium Hydroxide from Sodium Aluminate Solution	Improvement for effectively and economically recovering caustic components which consisting essentially of sodium aluminate from aluminum hydroxide cakes as seed classified from the product aluminum hydroxide by washing the seed with a washing liquor having a substantially saturated concentration of sodium oxalate and little content of caustic and then removing organic substances such as sodium oxalate from the washed seed by secondly washing said seed with hot water, thereby recovering caustic components without the dissolution of sodium oxalate from the seed into the recovered caustic solution and attaining the removal of sodium oxalate contaminant with high efficiency.
US 4,215,094	July 29, 1980	Inao et al. (Sumitomo Al Smelting)	Method for the Removal of Organic Substances from Alkali Metal Aluminate Solution	Contacting aluminate solution with O ₂ gas or O ₂ containing gas in the presence of Cu ions at an elevated temperature; T _{wet oxidation} = 180 - 300°C T = 50-70°C precipitation ; P = 20 to 150 kg/cm ² ; Cu ion : 100 - 5 000 mg/L ; Time : 1 hour
US 4,263,261	April 21, 1981	Yamada et al. (Sumitomo)	Method for the Removal of Impurities from Sodium Aluminate Solution	Removal of organic substances (Na oxalate, inorganic impurities, Na salts of Vanadium, phosphorus or double salts of sodium) by adding Na oxalate seed crystals following by a precipitation ; T = 0 - 75°C
US 4,275,042	June 23, 1981	Lever, G. (Alcan)	Removal of Oxalate from Bayer Process Liquor	Treatment with cationic sequestrants (quaternary nitrogen compounds); T = 50-70°C Precipitation on Na oxalate from supersaturated Bayer liquors can be stimulated O ₂ removing humic matter.
US 4,275,043	June 23, 1981	Gnyra (Alcan)	Removal of Oxalate from Bayer Process Liquor	Adsorption of humic material with an adsorbent (<i>activated carbon</i>).
US 4,280,987 CA 1,130,536	July 28, 1981	Yamada et al. (Showa)	Method for Treatment of Bayer Liquor	Adjustment of molar ratio Al ₂ O ₃ /Na ₂ O between 1 to 5 by dust or by alumina trihydrate addition. Conversion Na ₂ CO ₃ + Al ₂ O ₃ sodium aluminate + CO ₂ (NaAlO ₂) : Ignition of the liquor. Heating the resultant Bayer liquor ; T = 500 to 1 350°C

PATENT	DATE	AUTHOR (ASSIGNEE)	TITLE	METHOD
US 4,282,191	Aug. 4, 1981	Bird et al. (Reynolds)	Zinc Removal from Aluminate Solutions	Removal of zinc impurities from a caustic aluminate solution using zinc sulphide seed to cause precipitation of the zinc in the liquor. $ZnO + NaOH \rightarrow Na_2ZnO_2$ $Na_2ZnO_2 + Na_2S \rightarrow ZnS (> 0.15 \text{ g/L})$
US 4,335,082	June 15, 1982	Matyasi et al. (Magyar, Hongrie)	Method of Decreasing the Organic Substance Content of Alum Earth Production Cycle Performed According to the Bayer Technology	Hydrate wash/soda salt solution is caustified with lime solution is evaporated to reach total sodium oxide (Na_2O) of 200-400 g/L pref. 240-320 g/L. Precipitated solid is separated, removed and liquid is recycled.
CA 1,137,760 (HU 3, 395,63) DE 29,45,152 AU-B-5266/79 GB 2037722	Dec. 21, 1982 (25/5/1980) (1980)	Feher et al. (Magyar, Hongrie)	Process for the Removal of Organic Compounds from Alum Earth Production Cycle	Organic impurities can be converted into oxalate and carbonate when oxidation is performed under appropriate condition. O_2 or O_2 containing gas injected into the liquor $P_{O_2} = 3 - 30 \text{ atm.}$ $T = 120-350^\circ\text{C}$ preferably 210-300°C $P = 3-30 \text{ atm.}$ preferably 10-25 atm. ; Before digestion
US 4,430,310	Feb. 7, 1984	Malito et al. (Kaiser, USA)	Purification of Impure Bayer Process Liquor	Treat the liquor with an organic solvent of relative low boiling point (methanol). $T = 18-75^\circ\text{C}$; Cause precipitation of inorganic carbonate, sulfate salt.
US 4,443,416 (AU 2703584)	April 17, 1984	Donaldson et al. (Kaiser)	Purification of Bayer Process Liquors	Na oxalate impurities is removed by gradual increase of caustic concentration of the liquor in the range 400-730 g/L following by precipitation (salting out) To obtain resultant Bayer liquor above 250 g/L Na_2CO_3 $T = 20-85^\circ\text{C}$ Time = 35 to 180 min Wash freshly precipitation hydrate with hot water
US 4,496,524 US 4,581,207	Jan. 29, 1985 April 8, 1986	Bush et al. (Alcoa)	Process for the Removal of Sodium Oxalate Compounds from Bayer Spent Liquor	Treating the liquor with ethanol in a amount up to 50% vol. (30-50% better range) Filtrate the Bayer liquor to recover sodium oxalate 180 to 250 g/L TC ; $T = 50^\circ\text{C}$
US 4,578,255 AU 3863185	March 25, 1986	Roe et al. (Kaiser and Nalco)	Purification of Bayer Process Liquors	Liquor treated with an organic polymeric water-soluble cationic quaternary ammonium salt (POLYQUAT salt) - 50% humate carbon removal with 200 mg/L POLYDADMAC
US 4,581,208	April 8, 1986	The, P.J. et al. (Alcoa)	Lower Organic Contaminant Content in a Sodium Aluminate Solution by Oxidation in a Packed Bed	Wet oxidation of Na aluminate soln. is contacted with a gas containing molecular O_2 (air or O_2) at an O_2 partial pressure $\geq 345 \text{ kPa}$ and $180-300^\circ\text{C}$ The heated soln' is then passed through a bed of metal packing comprising Ni or alloy containing $\geq 45\%$ Ni Packing can be Rasching, lessing or Pall ring
US 4,597,952 AU 4398285	July 1, 1986	Fabre et al. (Pechiney)	Purification of Solutions of Sodium Aluminate in the Bayer Cycle by Removal of Sodium Oxalate	Fraction of the Bayer cycle treated to cause Na oxalate to precipitate by adding an agent for destabilization of the supersaturation of the Na oxalate (Ca oxalate, Ba oxalate) + an anionic synthetic polyelectrolyte of high molecular mass: (polyacrylic acids; polyacrylamides; sodium polystyrene sulphonate; sodium polyacrylate; polyacrylamide copolymer); $T = 20-80^\circ\text{C}$ 0.5-15 g/L calcium oxalate or 0.5-25 g/L barium oxalate
US 4,608,237	Aug. 26, 1986	Roe et al. (Nalco)	Use of Polymers in Alumina Precipitation in the Bayer Process of Bauxite Beneficiation	Liquor treated with an organic polyacrylic acid with a MW of 1,000,000 and a % of <i>acrylic acid monomer</i>
US 4,663,133	May 5, 1987	Malito et al. (Kaiser)	Removal of High Molecular Weight Organic Compounds from Bayer Process Caustic Liquor	High molecular weight organics (HMW) such as humic acid derivatives are removed by partial wet oxidation by adding as much oxygen as is soluble in the liquor $T > 140 - 300^\circ\text{C}$ (about 243°C) $t = 10$ to 60 min.

PATENT	DATE	AUTHOR (ASSIGNEE)	TITLE	METHOD
US 4,668,486 DE 1985 3512404	May 26, 1987	Brown et al. Vereingte Al. (VAW)	Method for Removing Organic Substances from Caustic Aluminate Liquors	Contacting the liquor with O ₂ at elevated pressure in presence of metallic ions (Cu) P > 40 bar ; T > 120 – 300°C (about 270°C) t = 10 to 60 minutes ; Precipitate Cu ions with bayerite Concentration : 1-5000 mg/L ; Coprecipitation of Cu/bohemite; Catalyst : Cu oxide
US 4,676,959	June 30, 1987	The, P.J. et al. (Alcoa)	Bayer Process for Producing Aluminum Hydroxide Having Improved Whiteness	Purification with semi-permeable membrane T = 72°C
US 4,678,477	July 7, 1987	The, P.J. et al. (Alcoa)	Process for Lowering Level of Contaminants in Bayer Liquor by Membrane Filtration	Plurality of porous hollow fibers coated with semi permeable membrane. Preferred : porous hollow polysulfone fibers coated with a semi-permeable sulfonated polysulfone membrane
WO 88/07975 EP310553 EP309509 EP310554	Oct. 20, 1988	Brown, G.P. et al. (Alusuisse)	Process for Reducing the Impurities in Lyes in the Bayer Process	Electrodialysis using anion-permeable membrane and /or one cation-permeable membrane to reduce dissolved inorganic and organic impurities.
US 4,786,482	Nov. 22, 1988	The, P.J. et al. (Alcoa)	Bayer Process for Producing Aluminum Hydroxide Having Improved Whiteness	Part of the patent has been disclaimed See US 4,676,959
US 4,789,485	Dec. 6, 1988	Field et al. (Allied Colloids Ltd.)	Clarification of Bayer Process Liquors	Flocculation with polymer CH ₂ (CIR ¹ CONHR ² NR ³ R ⁴) (MAPTAC ⁻³) Using Kelly filter ; Using comonomer acrylamide (DMAEA.MeCl) Sodium acrylate homopolymer
US 4,836,990 WO 85/05095 AU 2700092 AU 429785	June 6, 1989 (1993)	Swinkels et al. (Broken Hill)	Removal of Organics from Bayer Process Streams	Contact the liquor with <i>manganese dioxide</i> (15-35 g/L); no O ₂ addition T = 100 – 200°C MnO ₂ fluidised bed (100-270°C) ; t = 0.5 – 4 hres
EP 0384272	Feb. 14, 1990	Brown (Vereingte Al.)	Improvements to the Catalyzed Oxidation of Bayer Liquor Organics	Contacting the liquor with O ₂ at elevated pressure in presence of metallic ions (Cu, Cu sulphate, Co) (improved); Use of a tubular reactor P > 40 bar ; Step 1 T = 260-280°C; Step 2 T=290-320°C t = 10 to 60 minutes ; Side stream treatment Cu catalyst effective for acetate, succinate , formate and humic type (Low Mol. Weight)
US 4,902,425	Feb. 20, 1990	Keeney et al. (Com. Scientific & Industrial Research)	Removal of Humates from Bayer Process Liquors	Ion exchange process Cationic compound as polymer (poly – DADMAC) to extract humates Quaternary ammonium polymer
US 4,999,170	March 12, 1991	Brown (Vereingte Al.)	Method for Removing Sodium Oxalate from Caustic Aluminate Liquors	Remove Na oxalate by initially washing all the product Al trihydroxide to dissolve Na oxalate. Used the washed Al trihydroxide as seed in the precipitation circuit. Adding Na oxalate crystals as seed to the side-stream, separating the crystalline Na oxalate without evaporation and returning the depleted liquor in bauxite digestion step. Adding an organic polymer can be done
US 5,041,269	Aug. 20, 1991	Moody et al. (Allied Colloids)	Recovery of Alumina Trihydrate in the Bayer Process	Flocculate the alumina trihydrate by a combination of dextran and synthetic polymer usually a homo- or copolymer of acrylic acid <i>Better if organics are present 0.1 to 30 g/L (4 g/L)</i> 0.1 to 10 mg/L of dextran; 0.2 to 20 mg/L synthetic
US 5,133,874	July 28, 1992	Spitzer et al. (Am. Cyanamid Co.)	Removal of Humate from Bayer Alumina Liquors	Reducing turbidity containing a cationic polymer/humate complex by adding a high molecular weight cationic polymer 0.1 to 500 mg/L of a second cationic polymer 0.8 to 1.4 NTU (AMD/DADM)

PATENT	DATE	AUTHOR (ASSIGNEE)	TITLE	METHOD
US 5,270,278	Dec. 14, 1983	Misra et al. (Alcoa)	Alumina Coated with a Layer of Carbon as an Absorbent	Adsorption of humic material and oxalate with an hybrid adsorbent (alumina+ ultrathin layer of carbon)
US 5,271,844	Dec. 21, 1993	Chinloy et al. (Alcan)	Processes for the Alkaline Biodegradation of Organic Impurities	Utilize a bioreactor by use of Pseudomonas genus micro-organisms.
US 5,284,634	Feb. 8, 1994	Strominger, et al. (Nalco)	Purification of Bayer Process Liquors Using Cationic polymeric Quaternary Ammonium Salts	Removal of the organics impurities by treating the liquor containing dispersed solids with a high vinylic viscosity polymer (diallyl dimethyl ammonium monomers) 1 tp 500 ppm POLYDADMAC
AU3297895	Sept. 29, 1995	Harrison et al. Alcoa of Australia	Process for the Removal of Organics Poisons	Na oxalate derived from Bayer process liquor is dissolved in water to form a low alkalinity solution which is then subjected to an organic removal step
AU 673306	Oct. 10, 1996	Southwood-Jones et al. (Worsley)	Removal of Impurities in Bayer Process	Precipitation of sodium salts (sulphate, oxalate) from a concentrated feedstock of sodium aluminate (400-500 gpl caustic)
WO 97/22556	June 26, 1997	Bernier et al. (Alcan)	Thermal Plasma Reactor and Wastewater Treatment Method	Degradation of organics by using submerged plasma torch in combination with a draft tube Power = 100 kW ; T= 160°C ; Pressure= 6.8 atm.
US 5,728,180	March 17, 1998	Williams et al. (Alcoa)	Adsorbent Combinations for Enhanced Removal of Sodium Oxalate from Bayer Process Spent Liquor	Precipitation of Na oxalate by treating Na oxalate seed solution with two or more adsorbents (activated carbon, ESP dust, Calcium oxide and magnesium oxide) Total alkali – 100g/L of more T = 25- 145°C (80-110°C) Caustic = 100-400 g/L Al ₂ O ₃ /Na ₂ CO ₃ = 0.25-0.5
US 5,888,461	March 30, 1999	Soirat (Pechiney)	Process for Purifying Sodium Aluminate Solutions Containing Sodium Oxalate	Precipitation of Na oxalate by treating Na oxalate seed solution with an agent that destabilises the supersaturating state.; T= 40 – 60 °C Agents: Calcium aluminate (ATC6) (20-40g/L) Al ₂ O ₃ .3CaO.6H ₂ O; metal oxides(Fe, Al); metal hydroxide (Al, Fe)
US 5,902,560	May 11, 1999	Farquharson (Nalco)	Method for Inhibiting Precipitation of Sodium Oxalate in a Bayer Process Liquor	Inhibition of Na oxalate precipitation by adding a hydrocarbon-substituted amine oxide compounds or hydrocarbon-substituted amine betaine compounds 1- 1000 ppm (5-25 ppm)
WO 00/10918	March 2, 2000	Rosenberg et al. (Worsley)	Organic Impurity Removal Process for Bayer Liquors	Wet and dry oxidation are linked together Wet: 175°C and 4 atm O ₂ Dry: liquor burning ; Caustic 200-600 g/L pref: 300 g/L
WO 00/29328	May 25, 2000	El Kadi et al. (Pechiney)	Method for Purifying Sodium Aluminate Liquors Containing Sodium Oxalate	Removal of Na oxalate from non concentrated aluminate liquor in cold mini series vessels ; T= 40°C Use additive to promote agglomeration of fines.
WO 00/56660	Sept. 28, 2000	Rosenberg et al. (Worsley)	Process for the Removal of Oxalate and/or Sulphate from Bayer Liquors	Removal of aluminate ion through the formation of a carbonate-bearing hydrocalumite and/or sulphate-bearing hydrocaluminite. Treat the liquor with sufficient lime to remove carbonate ions and oxalate ions.
US 6,156,186	Dec. 5, 2000	Mueller et al. (HW Proc. Tech.)	Method for Removing Contaminants from Process Streams in Metal Recovery Processes	Removal of various contaminants (organics, metal, spectator ions, colloidal solids) by membrane filtration systems (nanofilters, ultrafilters, microfilters).
WO 00/75073	Dec. 14, 2000	Clerin et al. (Pechiney)	Method for Purifying Sodium Aluminate Liquors Containing Sodium Oxalate and Enhancing Residues	Solid residus (AC3.6) e.g. Al ₂ O ₃ .3CaO.6H ₂ O from the deoxalation of the liquor which is recycled as an alkaline leaching liquor for bauxite desolation residues are use to decarbonate and deoxalate industrial water.