

Alteo Gardanne Refinery: 130 Years of Adaptation to Meet the Dual Challenges of Environmental Protection and Added Value

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Abstract

The Gardanne plant was the cradle of the bauxite-to-alumina refining industry through the Bayer process, 130 years ago. Throughout its industrial and entrepreneurial history, the plant has consistently reinvented itself to meet the structural and conjunctural challenges faced.

The company has been able to modernize its plant and increase its alumina production in line with growing demand from the Second World War until the 1970s. Then from this period energy costs became a major issue with the oil crises and more recently, the consequences of the war in Ukraine. The Gardanne operating configuration has been revisited several times to change its energy supply mix and its energy production and to adapt its processes (evaporation and digestion).

With the evolution of regulations and corporate social responsibility (CSR) challenges, taking environmental constraints into account has become an issue of survival. Innovative solutions have been implemented to meet environmental constraints, such as water consumption and wastewater quality, control of dust emissions and atmospheric discharges and particularly on bauxite residue management.

Regarding CO₂ emissions, the site launched a major - and much-acclaimed – reduction plan for its entire process in 2022, proposing innovative solutions to improve energy efficiency and increase the proportion of electrical energy.

Finally, the Gardanne plant has successfully implemented a new business model for higher value-added specialty alumina, and production facilities have been modernized to realise this.

This transformation has been underway for the past two decades and has accelerated since the cessation of bauxite refining in 2021 and the transformation of its Bayer process.

The oldest active alumina plant in the world, Gardanne has 130-years' experience of adaptation.

Keywords: Innovation, CO₂ emissions, Bauxite residue management, Value-added specialty alumina.

1. An Industrial Epic for More Than 130 Years

1.1 The First Years and the First Challenges

In 1893, the first alumina production plant using the Bayer process was set up in Gardanne. The site was chosen for its proximity to the bauxite deposits needed to manufacture alumina, and its coal mines, which provided an essential source of energy for the process. Then came the time of industrialization: artisanal methods were rapidly replaced by more efficient industrial processes.



Figure 1. photograph of operators working at the Gardanne plant during its start-up.

Alternative processes to Bayer's were briefly assessed but proved to be far less efficient and more costly. During the First World War, the plant faced new challenges such as production interruptions and shortages of raw materials. Despite these obstacles, the industry rebounded strongly after the war with technical innovations improving production efficiency, enabling the Gardanne plant to strengthen its market position.

1.2 The Trente Glorieuses, Period of Expansion and Modernization

After the Second World War, the plant underwent a lengthy period of expansion and modernization, as production techniques evolved and innovative technologies enabled continuous operation of the digestion process, increasing yields, and reducing costs. Benefiting from strong economic growth and increased demand for aluminium, notably with the boom in aeronautics and the expansion of the mass automotive and construction markets, the plant continued to increase production through massive investment, becoming a major production center in Europe, modernizing its facilities, and adopting more efficient management practices. In 1949, an alumina research center was set up near the production site to develop innovative technologies and improve operations.

These years were also marked by the upward social mobility of workers, with companies and employees enjoying a close and sometimes conflictual relationship. Working conditions and employee safety improved as industrial risks were prevented. On the other hand, salaries rose rapidly because of productivity gains.

Owned by the Pechiney Group, the site was a typical example of the industrial paternalism of the period, with a swimming pool open to families, housing provided and other advanced social schemes, all in the context of a town hall driven by the French Communist party, again typical of industrial and working-class sites of the period.



Figure 2. Photograph of the plant swimming pool just in front of the digestion building.

2. Adapting Production Facilities to the Energy Crisis

2.1 The Oil Shocks of the 1970s and the Ensuing Industrial Crisis

Economic growth came to a halt with the oil crises, and tougher global competition appeared in the alumina market. Despite this, the plant's annual production record was reached in 1974, with a total of almost 700 000 tonnes of Al_2O_3 . This production volume has never been reached again.

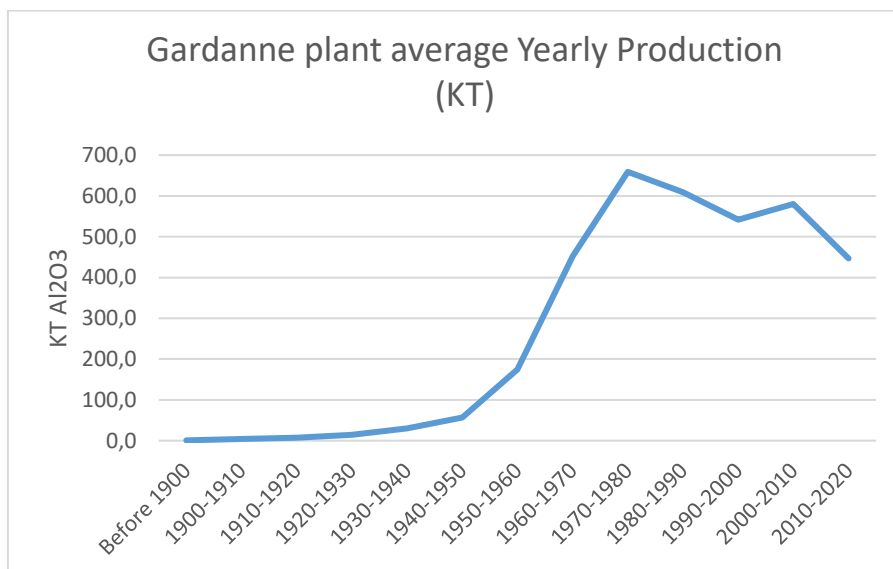


Figure 3. Average Yearly production of alumina by decades from 1900 to 2020.

While other French alumina plants, such as its cousin La Barasse in Marseille or in Salindres (Ales, Gard), 180 kilometers away, were closing one after the other, Gardanne kept on running, to become the only French alumina plant still in operation at the end of the 80s. This was possible thanks to the continuous adaptations carried out to continue operating, mainly seeking greater efficiency and lower energy consumption.

In 1984, the shutdown of the energy-intensive evaporation unit was a perfect illustration of this adaptation.

2.2 Dual Adaptation: Bauxite's Changing Origin and Two-Stage Digestion Change

The pace of change accelerated in the early 1990s. To overcome the lack of competitiveness on the one hand, and the depletion of *South of France* bauxite resources (the last inland French bauxite mines) on the other, a major turning point was launched with a change of bauxite. This is also considered as the start of the development of specialty alumina.

The use of Guinean bauxite instead of French bauxite significantly improved specific consumption and reduced the quantity of bauxite residues. This was a first major process evolution by adapting the Bayer process with 2-stage digestion: this resulted in less energy and lime consumption, whereas extraction yields were significantly improved to over 99 % of recoverable alumina. This change also allowed reduction of red mud production by around a factor two, from more than one tonne of residue per tonne of alumina to 0.6 tonne.

2.3 1990-2020: Major Adaptations in Energy Fuel and Implementation of the Energy Reduction Plan

As with all plants at that time up to the mid-eighties, the Gardanne refinery progressively was producing based on an energy mix made of coal (boilers steam production) and fuel (calcination). In 1986 was first introduced the gas for calcination, both for costs as well as quality with the start of the first specialty alumina.

With the end of the coal mines in Gardanne, boilers were fully shifted to fuel in 2000 and then only gas in 2011 (both calcination and boilers) and a first co-generation was implemented in 2000. With these changes, CO₂ emissions have been cut by 2 in less than 30 years, in volume (start of production decrease); the specific consumption having been cut by one-third due to energy efficiency.

Taking advantage of the favorable French environment for electricity (ARENH: industrial electricity special price mechanism) and the stable gas prices, Gardanne stayed with gas during all the 2010s. Apart from a new co-generation unit, installed at the end of 2010, no other major changes had been done on site.

Through its successive owners, these adaptations have enabled us to maintain production at around 500 000 t per year, albeit - on an almost regular basis - at the limit of the economic equation.

2.4 2021: A Fast-Paced Decarbonization Trajectory

The invasion of Ukraine and all its consequences in 2021, just after the take-over by UMSI, forced the company to strongly develop and run a rapid change to reduce gas exposure while reducing its global energy consumption.

These actions are of course required by the need to decarbonize our industry, Gardanne being in the top 50 global energy consumers in France, but also to reduce our energy costs, a key element in the success of our transformation.

2.4.1 An Ambitious Roadmap to Reduce Our Emissions by 63 % by 2024:

Thanks to the investments allowed by its shareholder together with favourable political support in France for the industry, (France 2030 program), Alteo did start mid-2021 an important decarbonization and globally energy consumption reduction plan, both for steam and calcination.

On steam production, the plan is based on an electrification process of all possible equipment, while reducing and optimizing the energy efficiency of all process steps. Important resources and expertise have been mobilized, under a specific organization:

- **The 1st stage** was the industrial transformation plan, reducing the production of commodity alumina to conduct an up-market operation. This change allowed Alteo to achieve a reduction of over 50 % in its CO₂ emissions over a very short period.
- **The second phase**, currently being implemented, aims to optimize the most energy-intensive equipment on the heating side, through the numerous adaptations:
 - Thermal insulation (completion in June 2023),
 - Acquisition of an electric boiler (commissioning in July 2024),
 - Implementation of an evaporation system based on Mechanical Vapour Recompression, scheduled for commissioning in September 2025. This project will achieve an additional 60 % reduction in CO₂ emissions by the end of 2025 (vs. 2015). The project will cost almost 10 MEUR, and Alteo has obtained 2.5 MEUR in government aid via France 2030, being one of the 16 winning projects (DECARB IND 2022 call for projects).

This has already allowed the decarbonization of the entire steam production.

- **The third and final phase** is currently being launched: it includes the installation of a new type of digestion unit (called Digestion KX), currently being developed in collaboration with an exclusive partner company operating with patent, combined with a second mechanical vapor recompression (MVR) unit.

Through yet another significant investment, this device will allow us to reduce by more than 70 % our energy needs for heating. This equipment, supported by the France 2030 innovation and decarbonization program, will be operational in 2026.

This phase also includes the investment in Power Purchase Agreement (PPA) and global electricity production through renewable energy projects, on-site and outside Gardanne.

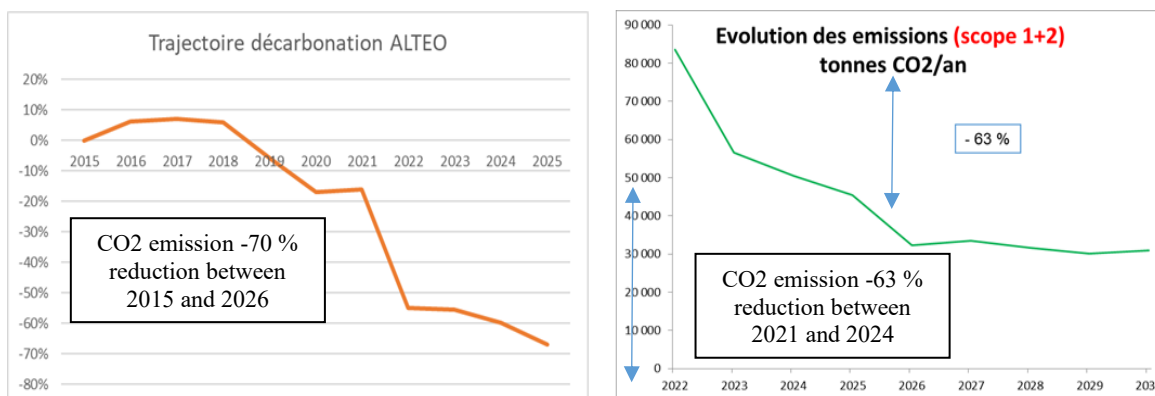


Figure 4. Alteo's decarbonization results and projection

2.4.2 Total Decarbonization by 2050

Our biggest challenge remains the use of gas for calcination; we thus engineered a multiple decarbonisation path, based on alternative fuels and technologies, to keep on running our 3 big rotary kilns, our key market advantage.

The main actions underdevelopment are:

- PPA on green gas fuels, either by contract or supporting bio or syngas plant developments on-site. This approach is strongly pushed again by French and EU authorities, to reduce the global dependency on gas,
- The co-development with multiple partners, under the EU H2 initiative, of hydrogen in our kilns; this is under development, with a quantity today not overpassing 20 % of the fuel required due to safety and quality issue,
- Another way involves CO₂ capture and, for instance its use for soil decontamination (a study is underway with the ERM company),
- And of course, for specific applications only, the development of electrical batch-kilns.

With all these actions underway, and despite the uncertainties with such game changers, we are confident in our ability to meet our objectives.

3. Environmental Transformation: A Condition to Operate

The environmental impacts of alumina refineries, both real or perceived, have been a major challenge in recent years, and often represented the biggest threat to the existence of industrial plants, such as Gardanne. Strong pressure has been made towards the site and its owners since 1980. But the game changer came in 2015-2016 in France under the Ministry of Mrs Royal, the then Minister of Environment who demanded an immediate halt to the dumping of red mud into the Mediterranean Sea. This decision was also motivated following an International Accord that from 2016 bauxite residue would no longer be disposed of at sea – this affected not only Gardanne but others including Japanese producers too.

Aside energy consumption and Greenhouse Gas (GHG), the well-known stakes of our industry are:

- Emissions of various pollutants such as NO_x and SO_x from steam production and calcination, including dust from bauxite, alumina, or bauxite residue,
- Bauxite residue management and process water treatment,
- Water consumption and water management,
- And control of ground and underground water pollution based on soda.

All these issues have been or are major survival issues for an industrial site over 130 years old, located in the heart of Provence and the town of Gardanne.

3.1 Chimney Emissions and Dust

Following industry standards and French / EU regulation, significant improvements have been made on chimney emissions over the past 20 years, subject of continuous improvement and monitoring.

The main point here is the management of dust coming from both bauxite and alumina, the plant being in the immediate proximity of Gardanne city center and surrounded on all its sites by private housing, in a context of high gentrification and general real estate price increases in the sought-after and attractive South of France.

Not only a question of community management but also to answer claims from administration, a resolute team was set up in the 2000s - regularly reinforced - to address, monitor and treat the question of dust, having a significant impact on operations:

- At Mange-Garri, the Bauxite Residue Disposal Area (BRDA): installation of water cannons, strict operating, and wind-dependent procedures on the BRDA, as well as the application of a thick layer of compost on areas awaiting or fully covered in vegetation... the Mange-Garri site's operating teams have invested in numerous actions;
- In Gardanne plant: installation of hedges, but also regular cleaning of installations with dedicated, equipped, and specialized external partners.

This subject is also particularly sensitive in a place where more than two hundred days per year people live outdoor but also with the presence of regular high winds.

With the stop of bauxite refining in March 2022 we saw, after the first 2021–22 winter, a real change in the color of the surrounding building walls and structures. Health, safety and environment (HSE) and production teams now have only to face risks from alumina dust, which is nowadays limited.

3.2 The Thorny and Controversial Subject of Wastewater Management and Bauxite Residue

The main issue that the industry faces though is the handling of the massive quantities of “red mud” generated by the Bayer process. Several significant spills and incidents have raised awareness from the public about this waste, and it is perceived as “hazardous” although it is most of the time not the case for the solid part.

The Mange-Garri site is the historic storage area for bauxite residues (BRDA) coming from the Gardanne refinery: it is also the oldest deposit area in the world. The Mange Garri site comprises two valleys located in the neighboring commune of Bouc-Bel-Air, 2.5 km away from the plant. The site received red mud from the early 1900s, stored in various basins formed by dams.

As mentioned above, alumina production increased significantly after the Second World War, and one of the bottlenecks became the bauxite residue storage facility. Thus, in 1966 and for almost 50 years, the red mud was then evacuated via a 55 km pipeline to a discharge point located 7 km offshore and 320 m deep in the Mediterranean Sea, as shown in the figure below. This massive investment, impossible to do today in a densely inhabited region, would be impossible today for many reasons.

This practice, acceptable at this time, became year after year an increasingly controversial choice, becoming intolerable in the 2010s.

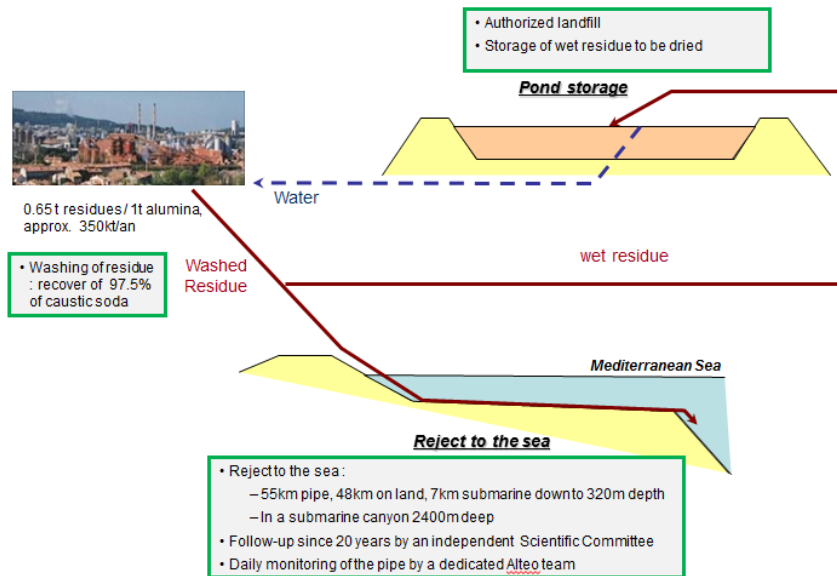


Figure 5. Management of bauxite residue and wastewater from 1966 to 2015.

Indeed, since 1995, Alteo Gardanne Alumina Refinery has launched a significant environmental program to improve its management of bauxite residue as well as wastewater disposal. This investment and process change did accelerate with the decision from the owner at that time (HIG investment fund, US) to stop sea disposal by end of 2015, strongly pushed, challenged, and threatened with closure by French regulators and environmental associations.

Until 2005, 100 % of the bauxite residue was going through the pipe into the sea; this figure fell to 60 % in 2010, the rest being stored again in Mange-Garri, then completely stopped since 2016. Important investments have been made by the company at that time, in a brief period, to ensure the continuation of the production. The risk of administrative closure had never been so close as at that time. Alteo had to completely rethink its methodology by implementing five major operational changes; the first two for the management of red mud and the three others for wastewater management:

- Red mud bauxite residue dehydration with press filters:** this method of managing bauxite residues reduces the surface requirements of the storage area and, consequently, improves site safety from an environmental point of view, particularly the risk of dam failure. It also offers the possibility of reusing dry residues. The first filter press was installed at the Gardanne plant in 2006, and 2 others placed in Mange Garri next to the residue storage basins in 2012 and 2015.



Figure 6. Press filters in Mange Garri bauxite residue storage facilities.

Removal of suspended solids from wastewater by pressure filtration with filter aids to ensure a solids content of less than 35 mg/L in wastewater,

- b) **Waste water pH reduction and dissolved metal removal by CO₂ neutralization:** by lowering the pH of wastewater, aluminium levels can be reduced by a factor of 5 to 10, and arsenic by twenty. Carbon dioxide was selected mainly because the precipitated solids can be mixed with bauxite residue without changing its chemical properties (still non-hazardous waste) and any sodium carbonate recycling in the Bayer process could be easily removed by a causticization process. Moreover, the treated water presents no corrosion risk for steel piping. This unit was commissioned in March 2019.



Figure 7. CO₂ neutralisation unit.

- c) **A biological treatment plant to deal with the remaining excessive organic compounds:** excess BOD₅ (five-day biochemical oxygen demand) and COD (chemical oxygen demand) in wastewater are due to the presence of organic compounds, oxalates and humates. In the treatment unit developed by our partner VEOLIA, these compounds are digested by a bacterial biofilm that develops on small plastic balls floating in the wastewater. A large biomass is progressively produced, and excess biomass is regularly released.



Figure 8. Biological treatment unit.

Thanks to these investments, not only the Mange Garri site has become one of the most efficient BRDAs in the world, but the quality of its wastewater now complies with the most restrictive international regulations and standards.

Table 1. Evolution of wastewater quality between 2015 and 2021:

	2015	2021
pH	12.5	8.5
Suspended solids (mg/l)	75 000	35
Dissolved Al (mg/l)	400	1
Dissolved As (mg/l)	0.35	0.04
COD (mg O ₂ /l)	200	50
BOD5 (mg O ₂ /l)	100	10

This unit was commissioned in July 2020.

These elements, once again implemented in a noticeably brief period, specifically position Gardanne as a forerunner plant in the environmental treatment of waste and residue.

This paper could also have detailed extensive work concerning the re-use of bauxite residues. Alteo at that time did invest important resources in teams, experts, tests, and investigations, in parallel with the described treatment: road sub-base materials, extraction of rare earths, sealing/waterproofing layers, etc. The developments have been important, covering the whole spectrum of the subject, from technology to product safety. Unfortunately, the principles applicable in France and Europe based on the application of the precautionary principle have never really demonstrated the relevance of these uses. They would certainly have been limited at first but would have opened possibilities.

3.3 Water Consumption and Water Management

An alumina refinery, designed as Gardanne is, has a tremendous impact on the water resources of its environment with more than 180 m³/h in 2022. Fortunately, the plant is connected to major water network build in Provence in the early 20th century with “canal de Provence”, a huge investment made by the State to bring water to Marseille as well as develop the important agricultural potential of the entire region.

Despite the current period of careful water management, pushed by past years of drought, there is a pressure on the plant to better use its water resources. Included inside the global French “water sobriety plan,” the process teams of Alteo, supported by the French Water Administration and specialized engineering companies, have started a “zero discharge” project. Aside the industrial challenge linked, this project will lead to the closure and dismantling of the 55 km pipeline which is currently evacuating our treated water to the sea under a specific environmental authorization, strongly monitored by nongovernmental organizations (NGOs) and French State Environmental Authorities.

This project is based on the implementation of the equipment described in the previous paragraph CO₂/ GHG (concentrators, KX, evaporators), allowing limited freshwater recycling as needed by the reduced Bayer loop. This project is scheduled to be functional by 2029 at the latest, as we agreed to the NGOs and the French authorities. The first steps will be to reduce by 20 % by the end of 2024 the consumption thanks to the first projects concerning the pipeline itself. Aside from the amount of water saved and thus secured for other uses, this project is crucial for Alteo: this discharge pipe closure being the last step demonstrating the major changes operated by the company and its strong commitment to limit its disturbances.

As a side consequence, the site will soon be net soda producer, a process by-product. We are currently investigating its use in other industries.

Inherited from its ancient design, there is no separated networks in Gardanne between sodic and non-sodic rainwater plant areas. In fact, the site had to engineer an autonomous water management system, collecting, and managing rainfalls. Rainfalls are an issue in autumn with heavy storms which can happen suddenly and must be stored. Important Capex is currently under investment (pumps, storage areas, basins, etc.) to complement the water network and water management before its release into the pipeline after the different wastewater treatment plants (WWTP) are installed.

3.4 Ground and Underground Water Quality: An Historic Agreement

The Gardanne site is built on a former swampy area, with the presence of active underground water tables. Industrial activities, rules and regulations have changed incredibly during the past 130 years, as have construction standards and operation rules.

This also includes the BRDA, built in early 1900, when the Global Industry Standard on Tailings Management (GISTM) regulations did not yet exist. Concerning Mange-Garri, several upgrades have been done, including the dams, carefully controlled, and monitored following French regulations. Whilst the last fills of dry residue since 2015 have been installed following the latest technical developments (especially linked with neutralization and dewatering), this of course was not the case before.

With this in mind, and as fully responsible companies concerned by their impact, Alteo together with Rio Tinto France (former owner and ultimate responsible body for site remediation through an historical agreement) conducted in 2023 a large campaign to qualify the status of the water and soil conditions, at Mange-Garri and at the Gardanne plant. The results have been presented recently to the authorities and communities, together with a clear settlement of the current legal situation which entered into force in July 2024. Following this agreement, Rio Tinto France becomes the last operating company for the BRDA in charge of its closure; Alteo on its side will manage, with full ownership, the industrial site of Gardanne, benefiting from support for site dismantling and remediation operations.

This approach was particularly well received by the communities, not only settling the Mange-Garri site but also giving Alteo the means to fully assume its industrial past and thus the future of its site.

4. The Numerous Business Adaptations of Gardanne

4.1 130 Years of Existence and... Several Owners

The Gardanne site has been experienced every aspect of an industry's life, from great profitability to bankruptcy, industrial model to ecologists' nightmares. First refinery in the world, cradle of the Bayer technology, the site design did influence other plants in the world: today ADG, Fria, Maiden, Hindalco plants, and many others.

Property of Pechiney until the acquisition by Alcan and the acquisition from Rio Tinto, the last 20 years have been very demanding for the site and its teams among all this investment and disinvestment processes.

Used to corporate organization and strict rules, its last major owner Rio Tinto sold it to HIG, a US investment fund with the last Gardanne key management team in 2012. Before this milestone, the site moved from many divisions, being too small and not profitable enough compared to

massive smelter grade alumina (SGA) plants but insufficiently specialty alumina oriented and still too “commodities oriented,” having the inertia of its Bayer process.

The HIG period of 9 years should have been on one side a real game changer, giving the opportunity to the new owner to develop this new growing and more profitable market of specialty alumina. Yet, with most of its investments being dragged down due to the heavy environmental constraints imposed and not professionally managed, Alteo was not able to survive the consequences of the last 2010s crisis on alumina price index (API). It entered bankruptcy procedure in November 2020 and was acquired in January 2021 by United Mining Supply (UMSI), a group established in West Africa, historically rooted in Guinea.

4.2 1990s, First Specialty Alumina up to the 2010s and the Strategic Move

The acquisition of the Reynolds process, imported from the United States, was the first technical investment at Gardanne, and the start of specialty alumina there. This new calcination process, which eliminates soda by adding silica, was installed on kiln #3.

This new system made it possible to produce our first technical alumina for the following uses: mainly the ceramics market and grinding media.

This was followed by new workshops in every corner of the plant as continuous mills, air-jet mills, batch ball mills and packaging. More specifically, continuous grinding (ACB type) was first conducted at Salindres (until the plant closed), then at Caudies and finally internalized at Gardanne in 2015 (start-up). Alcan's takeover of Pechiney in the mid-2000s strengthened the product range with the transfer of additional production from Vaudreuil plants to Gardanne, enabling the plant to conquer new markets, particularly in Asia (where part of the grinding process is now done), and in the US.

Far from being a game changer for the plant due to the weight of the Bayer process, it nevertheless showed the teams and the management the attractiveness of these products, able to be sold at more attractive prices than classical commodity alumina.

This was this strategy foreseen by HIG with the disinvestment operation of French alumina plants (including Gardanne) by Rio Tinto in 2010, finalized in 2012. Although the investments were mainly concerned with survival and environmental issues, Alteo nonetheless reached new milestones during this period:

- Creation of the calcined alumina post-processing unit as an autonomous department,
- Expansion of the first grinding mill workshop dedicated to super-ground products (SB), in Gardanne and in Asia,
- Development of the research and development department,
- Structuring of a central marketing department,
- And important developments in East Asia, in sales and in production.

A dense sales network has been established with more than sixteen offices, the installation of a network of selected representatives as well as the opening of two new post-treatment plants in Taiwan and South Korea.

A particular breakthrough should be highlighted, which we owe to one of our distribution partners: the first alumina for battery separators, as part of a development carried out in early 2016 with an Asian industrial major, which opened the battery market and the developments currently being pushed forward.

Thanks to its excellent characteristics, coupled with significant production capacity, this period saw the acquisition of key customers for the business, some of whom work with Alteo on a single-source basis.

Pushed by these initial successes and its unique set-up (2 large rotary kilns for specialty and semi-specialty alumina) Alteo has become a developing leader in this specialty alumina niche market with a growing product portfolio addressing products fitting a wide range of industrial needs.

However, this well-thought-out strategic move towards specialty alumina had to contend with the economic difficulties of the period, successive crises linked to environmental issues at Gardanne, and Bayer Plant's still excessive influence. In 2018, whilst a good year in production, the specialty alumina represented less than 30 % of the sales volumes, commodities keeping an important role – again to sell off production from the Bayer loop.

Another challenge concerned the management of sales teams, who were more used to selling high-volume commodities than to pushing long-term development projects into a market which, while growing, was still too small in relation to production. It is based on this observation that Alteo – producing in France in a globalized market – badly hit in 2019 entered insolvency proceedings.

4.3 New Industrial Model by Alteo Under UMSI

UMSI acquired Alteo in January 2021 after 4 months of acquisition process at the commercial court, with the following strategy:

- to accelerate the plant migration to specialty alumina,
- to stop the refining of bauxite at Gardanne, no longer feasible in view of the environmental issues involved (the storage of bauxite residues and its acceptability),
- to modify the Bayer loop in order not to be dependent on the SGA commodity market and to have an industrial process that would guarantee an equivalent quality of hydrate, the base for the promising developments in high value specialties.

4.3.1 Specialty Alumina Market and Alteo's Strategy: Current Situation

Thanks to its various properties, such as good mechanical resistance, refractoriness, non-conductivity or even corrosion resistance, alumina can be employed in a wide number of advanced industrial applications and many industries are interested in this versatile material.

Furthermore, the extraordinary cost-benefit ratio places alumina as a reference material in high-tech industries (Aerospace, Automotive, Semiconductor to mention only the majors) where the material performance needs to be associated to the capacity of reduced operational costs.

The market rational towards specialty alumina, despite erratic moves driven by a global economic situation that we are currently still experiencing, are by a large consensus considered as favourable, driven by the decarbonization industry and the mega trends of the ecological transition. On all its parameters, alumina, in specialties or semi-specialties, is present.

In this context, the Alteo acquisition is part of the diversification strategy pushed by UMSI Group (a major bauxite mining operator, and major mining services contractor in Guinea).

This acquisition strategy was based on the simplification of the old Bayer loop, stopping bauxite refining, and thus giving the company a full shift towards specialty alumina, freed from the volume constraints of the Bayer process.

Under the new impetus, Alteo has also stepped-up product development with new separator coating materials or thermal interface management products, for instance (product with high technicity and thus good added value), supported by solid market trends. UMSI brought not only

the strategic leadership, but also the missing financial support as well as the project management expertise to take up this industrial challenge.

Together with an ambitious decarbonization plan, this new industrial model for high performances alumina (low soda, low impurities, low iron, etc.) is designed to – despite a cost increase with this new loop – transform Alteo into a purely specialty alumina producer and developer, with a profitability level driven by added value products, ensuring its sustainability.

This approach has been backed by a solid networking job done at France and European level; in recent years, these initiatives have seen alumina recognized as a strategic input, and the company as a strategic asset. This allowed the company to benefit from aid for its transformation, both in the innovative industrial aspect, in decarbonization but also with energy aid linked to the war in Ukraine.

This strategy has been underway since 2021; as well as the Bayer transformation, twelve more ball mills have been installed, in France and in Asia, together with new high purity units and other specific workshops linked with specific product developments for new customers. Therefore, the center of gravity of the plant moved from the red part to the calcination part and post-treatment. Besides new production equipment, Alteo reinforced both its laboratories (production and application) and its technical expertise with high level profiles recruited over the last three years. These social and organizational impacts have also touched the sales and business development departments, with important changes made to support the change of strategy on the ground.

In a still difficult context, the transformation is nevertheless on the right track.

4.3.2 Basic Process Principles of the Alteo Transformation

To minimize the quality and product behavior risks for its customers, the decision was taken when preparing the transformation process to produce the “same” Gardanne hydrate quality. This strategic choice enabled this transformation to proceed at a limited Capex level with the collateral difficulties of producing “high-tech” hydrate in an “old plant, old bowls,” which has led Alteo’s team to face some important constraints on certain chemical impurities such as iron.

Thanks to good preparatory work done by the process teams, and a strong project management team in place, it was therefore decided in March 2021 to shut down the Bayer plant within 12 months, while carrying on its production and deliveries to maintain the cashflow.

This transformation faced four challenges:

1. Technical: reducing and then “cleanly” stopping the red side of Bayer in less than 12 months, while continuing to guarantee the quality of its products,
2. Project and operations management: building the new facilities for the new production model - implementation of the new dissolution / reprecipitation loop, hydrate supply and kiln feeding, including new investments done on the secondary treatment (ball mills),
3. Commercial: not stopping the plant and managing the re-approval of the products, in a post-bankruptcy and new ownership period,
4. Guaranteed social cohesion: despite the massive change imposed to the teams, with more than 120 job positions modified, cancelled, and created without any restructuring plan.

As a reminder, the core steps of a Bayer process are:

- To dissolve aluminium hydrate from bauxite, using concentrated caustic soda at high temperature in sodium aluminate liquor,

- To precipitate aluminium trihydrate in a controlled manner from sodium aluminate liquor, decreasing both temperature and caustic concentration, and to separate this solid from the liquor.

For the most value-added alumina, and to ensure to keep the same quality of the hydrate, a new process flow sheet has been followed. This new flowsheet, using “commercial” hydrate as a raw material instead of bauxite, has been simplified as this feed stock does not generate any solid residue to be washed and discarded: settling and washing residue areas have thus been shut. Other parts of the process (digestion and precipitation) have been conserved, ensuring the production of the same product for the calcination step, in term of both morphology of hydrate and impurity content.

This new loop has been designed to guarantee an alumina feedstock “made in Gardanne” that continues to be well appreciated with particularly good performance and characteristics, low soda and low iron, medium size and well adapted for various industrial uses.

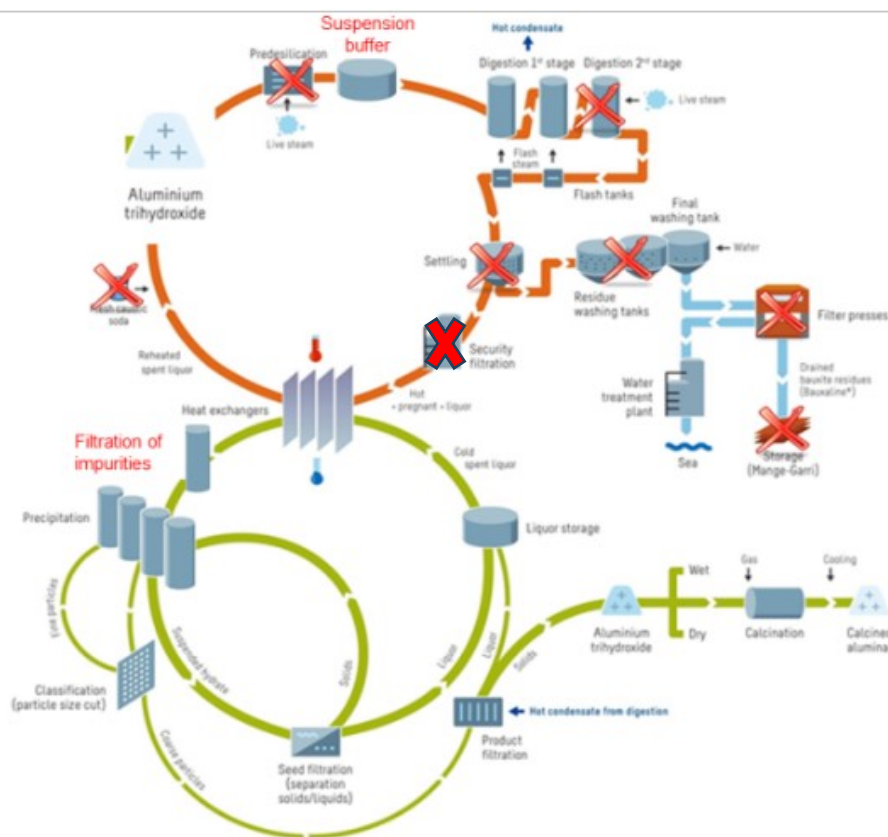


Figure 9. Schematics of Bayer Process vs Alteo new Process.

4.3.3 Process Control, Project Management and Sales Actions

The nominal production level has been designed for 100 000 tonnes per year for this new loop vs the 550 000 to 650 000 t/y capacity of the historical Bayer Process. Depending on market conditions, this loop can be re-extended quite easily.

This transformation lasted not more than 12 months, during which not only did the various pieces of equipment no longer used in the new plant have to be shut down, drained and cleaned, but also the soda and alumina hydrate inventories had to be significantly reduced, while guaranteeing a compatible level of impurities.

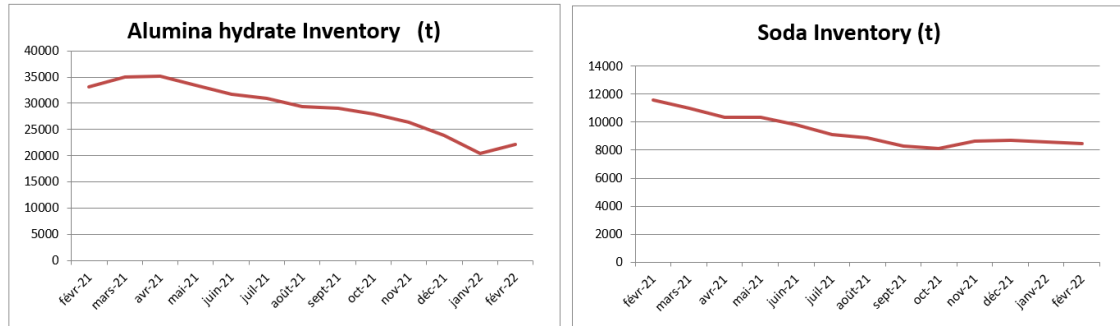


Figure 10. Alumina Hydrate and Soda inventories evolution during transformation.

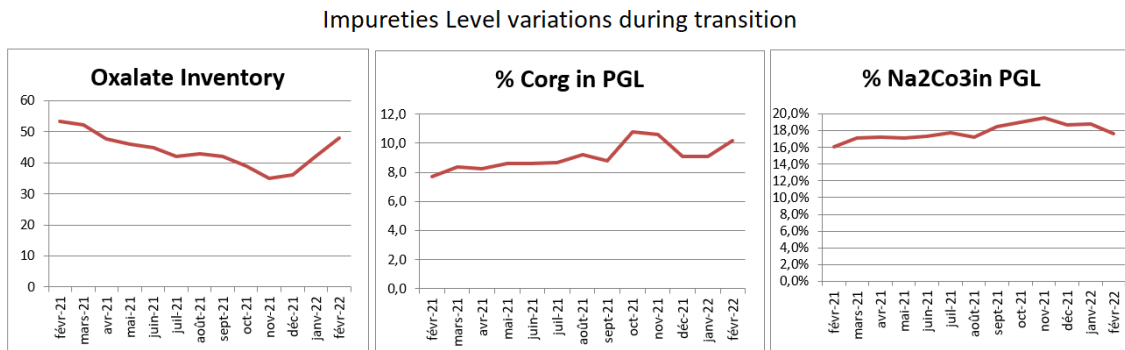


Figure 11. Impurities evolution during transformation.

To do so, a resolute team was set up, to specifically run the project and all its linked aspects: engineering, purchasing, planning and construction site management. The link with the production was also strengthened to ensure an efficient coordination and keep the process under control. We also had to increase resources in the laboratory, as the level of measures and controls did explode.

4.3.4 Sales in the Frontline Too

On the customer side, the sales teams also had to face significant challenges with a high level of activity with our customers to support this industrial change, all in a post-acquisition period.

To allow time for the necessary approval processes, Alteo built up a strategic stock of “legacy” aluminium trihydrate (ATH) from its former Bayer Plant to provide up to a year's supply of products to its customers with the most sensitive uses. This approach, necessary but very costly, made it possible to conduct all the reapprovals within fourteen months, while retaining all its customers.

4.3.5 Social Adaptation

This transformation also involved a fundamental change in the management of the Gardanne plant: more than one hundred and fifteen job positions have been modified, impacting more than 30 % of the plant personnel (and 50 % of the production team).

With the objective to propose a solution for everyone, the company had to provide extensive training and social support to the operators and workers offered new positions; Alteo also decided to open new roles, with a decision to adapt and internalize the operations undertaken by subcontractors.

This important workflow had to be conducted in parallel with the industrial transformation. Our constant concern was to maintain dialogue with the employees and the unions throughout this transition. This demanding but compulsory approach enabled us to pass through this period without any major clashes, with only one night of complete shutdown of the plant for social reasons at the early beginning of the transformation.

This social project was welcomed by the relevant authorities.

Another challenge continues to occupy not only the managers but the entire company: to make this strategic change percolate, throughout the organization and right down to the workstations: in behaviour – the importance of the value of the product produced, quality over quantity, specialty alumina vs. commodity alumina.

A in-depth work and support for the teams. Another challenge was the management of Bayer operators, technicians, engineers, and managers: closing (adapting) a Bayer was also a human operation for these professionals who currently have four generations at work in Gardanne.

For these unique profiles, some were redeployed for the smaller Bayer loop and in the factory; the vast majority were brought together under a dedicated entity, *Alteo Technologie®*, which provides expertise for the outside and primarily works on the new refinery project in Guinea.

Together more than 250 people have been involved on a global 25 MEUR investment project, following budget commitments, and with zero lost time injury (LTI). All Alteo teams took up this challenge, which turned out to be a great success.

5. Conclusion

The Gardanne plant has constantly gone through challenging times to meet technical, political, economic, social, and environmental requirements. Some of the challenges the company went through could have closed it, as has happened to comparable plants in the world.

Its recent and latest transformation, launched under the impetus of the UMSI Group, is based on a deliberate shift towards specialty alumina. This approach was implemented quickly thanks to the financial contribution of its shareholder, with consideration given to the social impacts, environmental history and current and future carbon footprint of its production and products.

Alteo is convinced that its future can only be imagined by continuing to improve the performance of its products while continuing to reduce their carbon footprint, by collaborating closely with its customers and all its partners, particularly institutional ones.

130 years of existence and 130 years of adaptation; long live, Alteo!