# BAUXITE RESIDUE ENHANCEMENT PROJECTS AT ALCAN ARVIDA RESEARCH & DEVELOPMENT CENTRE: STRATEGY AND STATUS

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## Abstract

Over the last years, Alcan Arvida Research and Development Centre (ARDC) has been involved in many different projects on red mud enhancement. Since the potential applications ensuing from these projects often were in areas outside our traditional businesses, the projects were carried out in partnership with universities, institutes, government or industries. In that context, a portfolio of diverse projects was built looking at applications in fields such as water and soil treatment, building materials and chemical valorization of red mud. While technology watch may benefit from this diversity, some rules must still be applied when selecting the projects to maintain a logical and focussed portfolio. This presentation aims to 1) present selected parts of the strategy used at Alcan's ARDC for selecting R&D projects on red mud/bauxite residue enhancement and 2) illustrate the application of this strategy by giving two examples.

## 1 Introduction

As can be seen from the abundant patents filed and articles published on the subject, bauxite residue has been the area of interest of many scientific studies. Papers that review such applications are already available in the literature (Prasad 1997, Andrejcak 2004). Unfortunately most of these past efforts only achieved limited success due to unfavorable economics. Recognizing that R&D activities have been prioritized over the short and long term in technology roadmaps (AMIRA International 2001) (The Aluminum Association 2000). Today, despite all the efforts invested to enhance bauxite residues, technological developments are still required to find viable alternative uses to current disposal.

At Arvida Research and Development Centre (ARDC), projects on bauxite residue enhancement are supported through Alcan's Environment, Health and Safety (EHS) Policy. The policy, issued in 2002, counts nine guiding principles, including the following: "Minimize any adverse environmental impact from operations and business practices, and use natural resources and energy more efficiently…" (Engen 2002). In that context, part of our role at ARDC is to actively search for opportunities to use bauxite residues in new, safe, and viable applications.

Historically, Alcan research centres mainly conducted their own research projects on red mud enhancement. Some of that research resulted in patents such as use of alumized red mud solids for wastewater treatment (Gnyra 1978), use of red mud for the production of refractories (Allaire 1991, Allaire 1992 and Allaire 1993) and development of a novel process to recover rare earth metals from red mud (Fulford 1991). The recent acquisition of Pechiney allowed Alcan to increase its knowledge base and experience in that field. Work carried since 1990 by Pechiney, for Gardanne and St-Thomas Bayer refineries, is very substantial and has resulted in valorization of bauxite residues for many different applications. We will draw on this expertise throughout this paper and more specifically so in section 3.2 when we present Gardanne's work on Bauxaline®. The merger created new opportunities and synergies that led to a review of the supporting policy and strategy for R&D projects related to the bauxite residue enhancement.

Nowadays at Alcan, most projects on bauxite residue enhancement are realized within tripartite partnerships and alliances (research body, end-user, Alcan) under a research programme overviewed by ARDC. Since many of the applications are in areas outside our core businesses and where our knowledge is limited, these projects are usually led and managed by external organizations that already possess the expertise required.

The object of this paper is to communicate the key selection criteria that are used when considering a research proposal on bauxite residues and to illustrate the results obtained by giving two examples thereafter.

## 2 Elements of the strategy for partnerships in bauxite residue enhancement projects at ARDC

ARDC overviews an important programme on bauxite residue enhancement partnerships. This programme counts various projects that may be organized in categories, as presented in Table 1. To better manage the project's portfolio, a strategy was established in 2000 to orient the decision making process. The strategy relies on key elements as summarized in Table 2. A brief definition of these points is given thereafter.

Table 1: Status and number of R&D projects involving ARDC

| Bauxite residue enhancement | Number of projects since 2003 |
|---|---|
| Mining Industry (Acid mine/acid rock drainage treatment ; soil remediation) | 8 |
| Water Treatment (dephosphatation ; metals removal) | 2 |
| Chemical Valorization | 2 |
| Materials (bricks ; tiles ; ceramics ; asphalt ; concrete ; plastics) | 3 |
| Others | 2 |

Table 2: Key elements considered in the selection of collaborative R&D projects on bauxite residue enhancement at ARDC

| ARDC's approach to partnerships in bauxite residue enhancement projects | Requirements for uses of bauxite residue |
|---|---|
| ✓ Alternative solutions to current storage<br>✓ Openness and transparency<br>✓ End user involvement<br>✓ Recognition of the specificity of the disposal site location to the foreseen enhancement | ✓ Long-term liability<br>✓ Economical viability:<br>• transportation costs are critical in l arge volume applications<br>• end user involvement in the project |

**2.1** *Alternative solutions to current storage*

Supported programmes must aim to offer alternative solutions to the current disposal of bauxite residue. R&D projects on current storage and site rehabilitation are managed through a distinct programme and through the technological and operational departments of the Bayer plants.

**2.2** *Openness and transparency*

At ARDC, agreement with third parties on bauxite residue R&D partnership programmes is eased when compared to typical R&D projects. The need to develop sustainable alternatives to the current disposal of bauxite residue is recognized and allows more openness and transparency in these applications.

**2.3** *End user involvement*

To bring enhanced bauxite residue products into the market, there must be a demand from a credible client with a solid business case. ARDC will prioritize solutions where there are clearly identified needs from an end user rather than promoting potential applications with no clearly recognized end users. This approach is found to be more efficient in terms of quality and cost of the product developed. We always prefer to embark on R&D collaboration with the end user also involved as a partner in the programme.

**2.4** *Specificity of disposal site location*

Bauxite residue enhancement is strongly linked to the site where the residue comes from. For large volume applications, bauxite residue is mostly in competition with other already available low price commodities. In that context, transportation costs of bauxite residue may be substantial, which limits its use to a radius of approximately 100 km around the refinery. Also, applicable legislation or product certification may vary from one country to another. Sometimes the bauxite residue will be mixed with another material prior to being used by the end user. In that case, having that other material in the vicinity of the Bayer plant represents an opportunity for one alumina producer and a disadvantage for another. Knowledge of the local context is very important in bauxite residue enhancement applications.

**2.5** *Long-term liability*

All possible long-term liabilities related to bauxite residue uses must be investigated and addressed. As the producer of bauxite residue, we have the responsibility to strictly control every usage that is made of it. This criteria is favorable to applications where bauxite residue uses are recognized as safe whereas it is very unfavorable to applications where potential liabilities exist.

**2.6** *Economical viability*

Many potential applications of bauxite residue find technical success, but only a few are economically viable. To increase the probability of developing a viable application, the end users must be involved, as soon as possible, in the partnership with the research body under contract and ARDC. Association with potential end users offers the benefit of steering the project in a direction where the product in development will meet its specific needs. Even though the applications developed do not have to bring a profit, they have to be at least neutral when compared to the current disposal of bauxite residues. Finally we must remember that what is not economically viable in the short-term may become so as equipment, technology and disposal costs will evolve.

**2.7** *Others*

Other criteria that are taken into consideration before supporting a programme are scientific knowledge advancement as well as promotion of public support to the aluminium industry.

## 3 Examples of R&D projects realized in partnership

Over the last years, the projects in which we have been involved were grouped under different categories, as already shown in Table 1. Some of these projects are in their first stage while others are at the pilot scale. For every project, go/no go decisions are taken all along the development phase at different milestones to bring the project to full implementation. Table 3 gives an example of these milestones for a typical research project.

To concretely illustrate the kind of results that are obtained through partnerships programmes, two examples are given below. One is taken from ARDC portfolio and the other is taken from a study that was previously done at Alcan Gardanne.

**3.1** *Example 1 – Remediation of industrial soil: Rothamsted Research*

In 2002, ARDC participated in a research program under the co-ordination of Rothamsted Research. Rothamsted Research is the largest agricultural research centre in the United Kingdom, employing more than 350 scientists. Their work covers the whole spectrum of agricultural research, from studies of genetics, biochemistry, cell biology and soil processes to investigations at the ecosystem and landscape scale. For this project, the study was managed by Pr. Steve McGrath, Co-ordinator of the Soil Protection and Remediation Programme. Pr. McGrath and his team, using the methods and protocol that they have selected, obtained all experimental results shown in this paper.

The aim of the study was to remediate in-situ a contaminated industrial soil using bauxite residue and to allow revegetation of the site. Phytotoxic levels of heavy metals polluted the area. The testwork was realized in two phases: laboratory phase and field experimentation. The work being done in United Kingdom, Alcan provided bauxite residue from its Burntisland plant for the study. Other participants to the projects were Britannia Zinc Ltd. (BZL) who provided the site for the tests and contributed to its agricultural maintenance, and Contaminated

Table 3: Milestones for a typical collaborative bauxite residue enhancement project at ARDC

| | | | | | |
|---|---|---|---|---|---|
| Research proposal agreement | Preliminary investigation | Detailed investigation | Industrial testing/ prototype evaluation | Demonstration/ business development | Implementation |

Land: Applications in Real Environments (CL:AIRE) who co-funded the work. Some results from the study are given below although the complete programme included much more than what is shown.

**3.1.1** *Field Experimentation: Methodology*

A surface (62 x 41 m) of contaminated industrial soil was made available for field test. That area was divided into blocks (14 x 25 m) and treatment plots (6 x 10 m). Soil treatments were as follows: a) untreated, b) limed to pH 6, c) 3% bauxite residue (soil weight basis) and lime to pH 6, and d) 5% red mud. The amendments were applied and mixed into the soil top layer by ploughing to a depth of around 20 cm, as can be seen in Figure 1. In late June 2002, grass (Festuca rubra) was sown on all treatment plots. Four months later, farmyard manure was applied to half of every plot and grass was re-sown following a poor germination due to exceptionally dry conditions that autumn.

**3.1.2** *Field Experimentation: Results*

The amendment of the soil with bauxite residue had a significant impact on the extractable metals in soil pore water and in a physiological solution. Zn, Cd and Ni concentrations in soil pore water were significantly reduced (Anova, 5% sig. level) with bauxite residue amendment compared to untreated soil while Pb and Cu were not changed. For physiologically extractable metals in soils, a solution of 1M $NH_4NO_3$ was used to measure the soluble and weakly adsorbed metals. In that case, the addition of 5% bauxite residue to the soil gave a significant reduction for all extractable metals measured when compared to untreated soil. Their concentration was lowered by a factor varying between 2 and 7.7, depending on the metal measured.

Figure 1: Application of lime and bauxite residue to experimental plots (April 2002)

Revegetation of the soil was also significantly improved by bauxite residue amendment, giving a healthier grass that contained a lower concentration of metals. A photograph (Figure 2) of the field test is given below to better illustrate the results obtained (McGrath 2003, p. 20). As expected initially, there was no grass growing on untreated plots. Interestingly, lime treated plots only showed marginal growth of unhealthy grass.

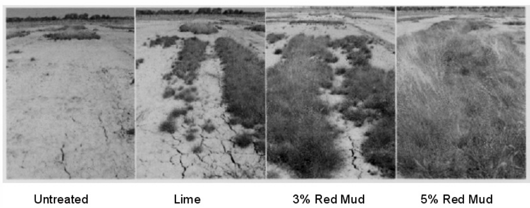


Figure 2: Visual differences on grass growth between different treatments (August 2003)

The expertise of Rothamsted Research in soil remediation as well as its available facilities allowed this work to progress efficiently. Associating with a renown institute added to the credibility of the results obtained. Rothamsted also made the link that led Alcan and the end user to be associated in the project. Overall, this has been a very beneficial experience for ARDC, resulting in identification of a potential application of bauxite residues.

**3.2** *Example 2 – Bauxaline® – Refuse disposal dumps coverage*

Alcan Gardanne invested a lot of energy and effort to identify new applications where bauxite residue could be economically and safely used. To achieve this, different grades of products have been developed and are now commercially available under the name Bauxaline®. Basically, Bauxaline® consists of bauxite residue that has been conditioned to reach a required moisture content and a given granulometry. Bauxaline® can be easily transported and manipulated, as opposed to bauxite residue.

Different uses of Bauxaline® have already been described in the literature (Martinent-Catalot 2002, p.125). In the example given here, the utilization of Bauxaline® to cover refuse disposal dumps is looked at. This application was mentioned, but not detailed, in the previous paper. The experience gained during that study helped to better define the strategy already described in section 2 of this paper. It is a real life example to better illustrate how a partnership may work in a bauxite residue enhancement project and show the results that were obtained in that specific case.

In the late 1990's, Alcan Gardanne and SEMAG (Societe d'Economie Mixte d'Amenagement de Gardanne et sa region) piloted the usage of bauxite residue as a cover in refuse disposal dumps. SEMAG is a public organization active in the municipality of Gardanne and its surroundings; they are involved in environment, urban development and housing, economical development, and transportation. They also own the Malespine refuse disposal dump in Gardanne where the pilot study took place. Previous studies in Marseille had already shown the potential of this valorization of bauxite residues. The pilot phase consisted in using Bauxaline® in a field demonstration under strictly monitored conditions. Illustration of the participants involved and identification of their respective role is given in Figure 3.

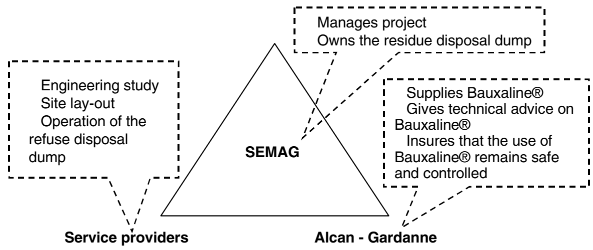


Figure 3: Roles of the participants involved in the application of Bauxaline® as a refuse disposal dump coverage pilot test in Gardanne

The aim of the study was two-fold: 1) to ensure that the use of Bauxaline® would still allow to meet the regulation in place and 2) to ensure that there was no new risk to the environment, particularly in leachate and run-off waters. The methodology used was designed to be reproducible in Malespine or elsewhere in the future.

**3.2.1** *Pilot Test: Methodology*

Bauxaline® was applied in layer of a thickness ranging from 0.5 to 1 m on top of the refuse that had been pre-covered by 0.3-0.6 m of silt. The Bauxaline® was compacted to the Proctor optimum so that its permeability would be lower than 1 x 10-6 m/s. A geotextile membrane, gravel (15 cm) and topsoil or Bauxaline® amended with minerals (30-60cm) would complete the coverage. Overall, 10,000 tonnes of Bauxaline® were required to cover an area of 8,000 m². The covered area was sowed thereafter to study the revegetation potential of the site with the methodology used.

[1]Within the French legislative context [Decret no 89.3 du 3 janvier 1989 (JO du 4 janvier 1989); Arrete ministeriel du 2 fevrier 1998 (JO du 3 mars 1998)]

#### 3.2.2 *Pilot Test: Results*

The results obtained were conclusive. After a follow-up of two years on the run-off waters, it was generally observed that the values obtained were stable and below the reference values established[1]. The only exceptions occurred with Pb, Fe, and Al, in specific events after the first rains following the coverage. During the two-year period, pH of the run-off waters remained high, varying between 9 and 11. The leachate showed high values of COD and pH (avg.=12.5) due to the residual caustic in Bauxaline®. It should be noted that all leachate were already collected and treated prior to being discharged. Geomechanical follow-up has shown that the coverage is stable and compatible to the maximum slope considered (22°). Permeability of the Bauxaline® layer remained between 1 x 10-8 and 8 x 10-8 m/s. Fifteen different species of plants and trees were transplanted out of which 92% survived where a layer of 0.3-0.6m of topsoil was added, and 85-87% survived when the top layer was made of Bauxaline® amended with minerals. Seeding revealed that topsoil was required to allow grass to grow although results obtained elsewhere indicate that amendment of Bauxaline® with organic material (wastewater sludge, coffee grounds, …) could possibly allow grass to grow (not tested in the pilot). Overall, these results confirmed that Bauxaline® is a suitable material for this application.

Based on the results obtained in that pilot test, Bauxaline® was recognized, by the authorities in place, as a material that can now be used for coverage at Gardanne. Since then, other refuse disposal dumps have also shown interest in using Bauxaline® for rehabilitation. On the whole, the partnership between SEMAG and Alcan Gardanne met all the technical, environmental and economical objectives set for the pilot test. Bauxaline® is now commercially available for that application.

## 4 Conclusions

At ARDC, a strategy for selection of bauxite residue enhancement partnerships was set-up. The strategy aims to increase the probability of success in these projects. Sharing the experience gained from previous R&D projects throughout the company was very helpful in designing this strategy. With many potential R&D partnerships being examined year after year, it is believed that having set criteria allows keeping the project portfolio more logical and focussed.

Associating with knowledgeable organizations when the targeted applications are outside the alumina business is found to be more efficient. These organizations already possess the know-how and expertise to manage the project. Nevertheless, implication of the end user is paramount to succeed in developing a viable product in terms of quality and cost.

The need to find safe and sustainable alternatives to the current disposal of bauxite residue is recognized and supported by the organization. Already, some viable alternatives are possible but R&D must continue as the quantities of valorized bauxite residue remain low to this day.

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