7

Management of the Salt Cake Generated at Secondary Aluminium Melting Plants

A. Gil and S.A. Korili
Department of Applied Chemistry, Building Los Acebos, Public University of Navarra, Campus of Arrosadia, E-31006 Pamplona Spain

1. Introduction

Aluminium is, due to its properties, the second most used metal after iron. It is used in a wide number of products and sectors, either alone or as an alloy (Kammer, 1999).

The aluminium production is based on an electrolytic process, the Hall-Hérolt process, in which metallic aluminium is obtained from the reduction of aluminium oxide. The metal obtained with this process is called primary aluminium. Aluminium oxide is extracted from natural bauxite in the Bayer process. Since the development of the large-scale production of aluminium oxide, aluminium production has expanded enormously (http://www.worldaluminium. org). It is worth mentioning the important growth in aluminium production in China in recent years, over 12,964 tones of aluminium were produced in 2009 (http://www.world-aluminium.org).

The recycling of aluminium is very important, since the residues of this metal can be reused without any loss of quality. The metal obtained in this way is called secondary aluminium. The aluminium destined for recycling can be divided into two categories: preconsumer byproducts from the production of primary aluminium, and scrap, associated with postconsumer aluminium. By means of melting, in some cases with prior processing, the byproducts and scrap are transformed into ingots, half balls and plates for subsequent commercialization.

Comparing primary and secondary aluminium production, the secondary process causes less environmental impact than the primary process (Drossel et al, 2003). It consumes 17 times less energy; it emits 17 times less pollution to the atmosphere; it generates between five and nine times less solid wastes, and it consumes 35 times less water. For both processes, the greatest problems derive from the generation and management of wastes.

Regarding waste generation, one of the major products of the alkaline extraction of aluminium oxide from bauxite in the Bayer process is red mud. This waste consists of iron, aluminium, silicon, and titanium, with oxides of zinc, phosphorous, nickel, and vanadium in smaller quantities (http://www.world-aluminium.org). The management of this waste is normally carried out by means of controlled landfill disposal. Recently, several studies have been published considering various applications for this type of waste (Altundogan et al., 2002; Cengeloglu et al., 2006; Sushil & Batra, 2008). During the secondary recycling of aluminium, various types of wastes may also be generated. The most important one, in terms of the amount generated, is the named as salt cake (Sreenivasarao et al., 1997), catalogued as hazardous waste (Order MMA/304/2002, BOE 43/2002). It is generated when salt fluxes are used to improve the aluminium recovery. The composition of salt cake is metallic aluminium, several oxides (fraction named as non-metallic products, NMP), flux brines and others components in smaller proportions (Drossel et al., 2003). Based in its composition, salt cake is an important by-product of considerable economic value that is recovering, as long as the process can be economically viable.

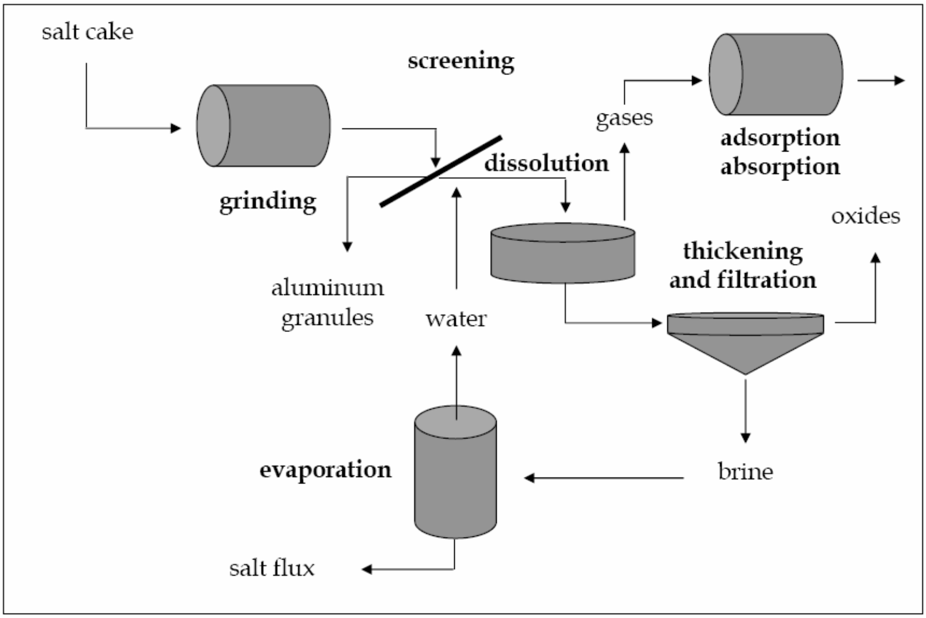
There are two possibilities of management of salt cake, separation of its components for possible recovery and application, or storage in controlled landfills (see schemes 1 and 2). The recovery process consists of an initial separation of the metallic aluminium present in salt cake by means of electromagnetic and mechanical procedures (Hryn et al., 1995). This process is economically viable if the content in metallic aluminium is higher than 4 to 6 wt.%. The remaining waste consists of non-metallic products, and it can be recovered, i.e., by the HANSE process (Drossel et al., 2003). The idea is that the saline fraction must be separated from the oxides. For certain specific applications, the non-metallic fraction should be free of salts. It is considered free of salts when the salt content is lower than 2 wt.%. It should be noted that the recovery of the saline fraction and of non-metallic products is economically viable only if a concentrated flow of salt and a waste that is free of nonmetallic products can be obtained. The main objection, in the case of subsequent applications, is that these two determining factors cannot be ensured simultaneously, meaning that the process is not economically viable.

We report in this work the process carried out by the company *Ibérica de Aleaciones Ligeras, Ltd., IDALSA*, a Spanish refinery devoted to the production of special alloys of aluminium coming from the recycling of by-products of this metal, which can be presented as a good case study of best practice. This company has implemented new several technologies in order to minimize the salt cake generation from secondary aluminium fusion process (Gil, 2005). The incorporated treatments have helped *IDALSA* to decrease the salt cake generated per each recycled ton of by-product to less than a half. Finally, the remaining waste is disposed in a controlled landfill (Gil, 2007).

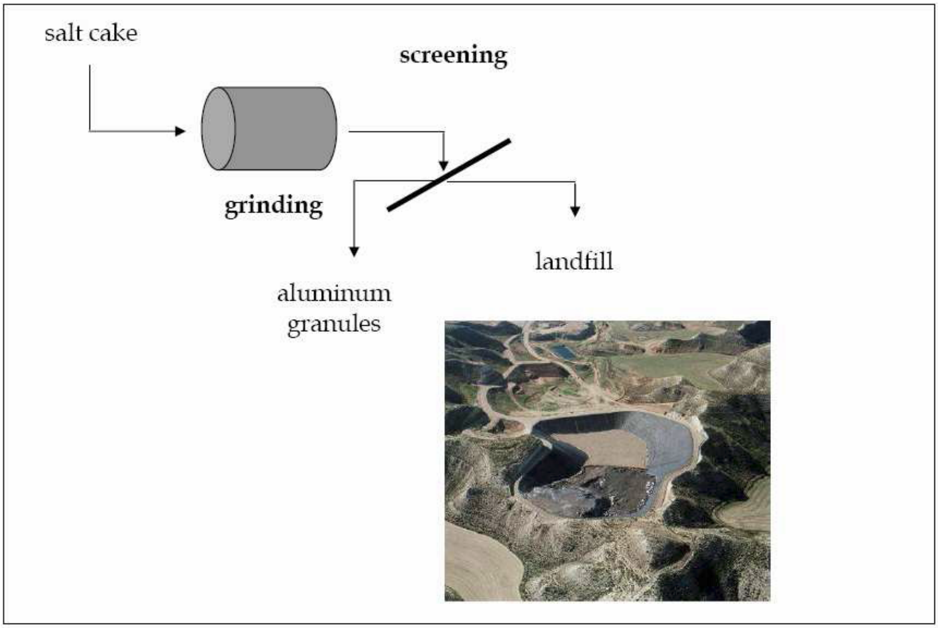
2. A case study of best practice in the recycling and reassessment of salt cake generated in the second melting of aluminium: *Ibérica de Aleaciones Ligeras, Ltd., IDALSA*

Ibérica de Aleaciones Ligeras, Ltd., IDALSA, is a Spanish company located at Pradilla de Ebro, Zaragoza (see Figure 1, http://www.idalsa.com). It has more than 25 years of experience in the production of special aluminium alloys obtained from the recycling of by-products of this metal. It recycles 6,365 Tm of aluminium scrap and by-products monthly, obtaining various formats (See Figures 2 and 3).

The model followed by IDALSA is in compliance with European Union legislation in waste Management (Directive 96/61/CE, Law 16/2002, BOE 157/2002). First, processes that involve a reduction in the generation of wastes at the origin are promoted, processes also called Better Available Technologies (Farrell, 2001). When the waste has already been produced, its recovery, recycling, and reuse should be fostered.



Scheme 1. Management of salt cake from separation of its components for recovery and application.



Scheme 2. Management of salt cake for storage in controlled landfills.

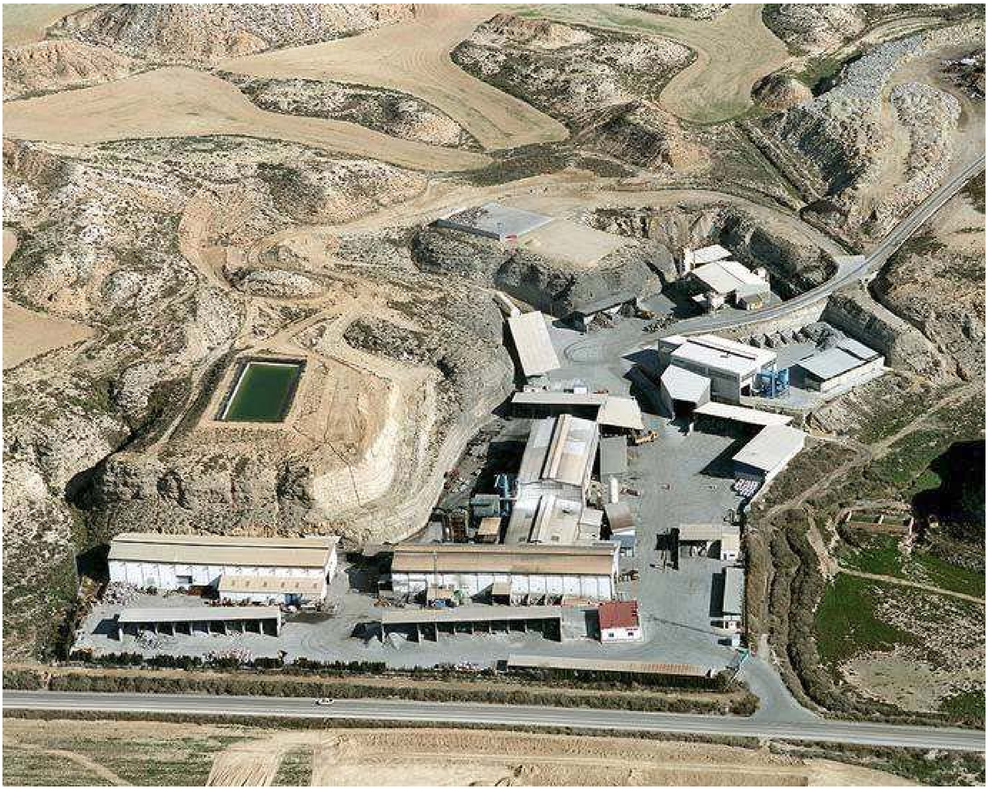


Fig. 1. Localization of *Ibérica de Aleaciones Ligeras, LTD, IDALSA.*

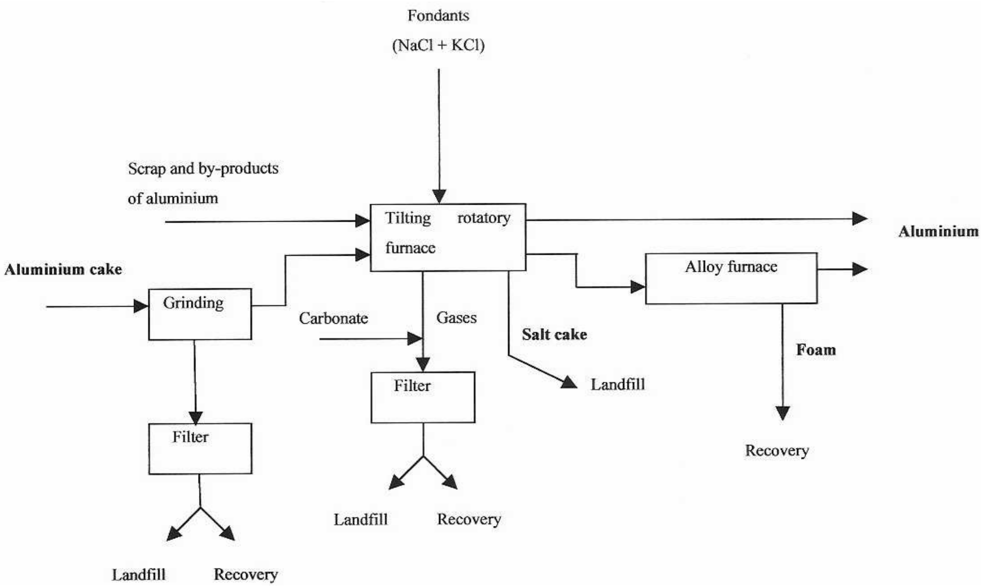
The technological measures adopted by IDALSA in its production process are as follows: oxy-combustion technology, pre-treatment of raw materials, use of a tilting rotatory furnace with a capacity of 18 Tm, and processing of salt cake. The use of a tilting rotatory furnace allows the consumption of fondants and the generation of salt cake can be minimized (Gil, 2005). The metals in the salt cake are separated by means of electromagnetic and mechanical processing of the saline and non-metallic fractions. The production processes carried out at IDALSA are schematically summarized in scheme 3.

The clean technologies considered by IDALSA have enabled reductions to be made in the quantity of waste generated by each Tm recycled to less than a half (see Figure 4), in according with a decrease in the consumption of materials and energy, and a decrease in the amount of wastes generated at the origin (Directive 96/61/CE, Law 16/2002, BOE 157/2002).

Because the management of the waste finally generated is not economically viable, IDALSA removes this through controlled landfill disposal (see scheme 1). With this target, the company has built an authorized landfill of a capacity of 100,000 m^3, at which some of its wastes can be accumulated.

Fig. 2. Examples of aluminium scraps and by-products recycled by *IDALSA*.

Fig. 3. Several formats for the commercialization of recycled aluminium.



Scheme 3. Production processes carried out at IDALSA.

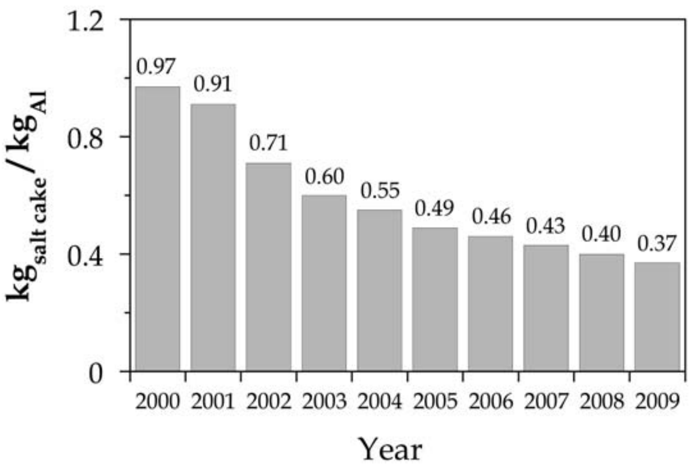


Fig. 4. Evolution of the salt cake generated with respect to the aluminium recovery obtained.

2.1 Nature of the wastes generated by *IDALSA*

The wastes generated by IDALSA in its production process are:

- salt cake from the tilting rotatory furnace. The main waste produced at the installation.
- salt cake from the rotatory furnace. This waste show similar origin and composition that the obtained in the tilting rotatory furnace.
- dust retained in the removal of gases from the furnaces.
- dust from the processing of external salt cake as a raw material.

The chemical compositions of all these wastes are shown in Table 1.

	Salt cake from rotary furnace	Dust from gases depuration	Dust from the processing of external salt cakes
Al_2O_3	29.60	33.50	70.90
NaCl	49.50	23.40	3.45
KCl	10.40	--	--
SiO_2	2.75	7.00	9.95
Na_2O	2.35	3.78	--
MgO	1.90	6.10	4.65
CaO	1.43	6.95	3.36
Fe_2O_3	1.37	2.50	5.63
N	0.40	2.60	0.10
SO_3	< 0.10	3.25	0.23

Table 1. Chemical composition (%) of the wastes from the production process of *IDALSA*.

Spanish Royal Decree 1481/2001 regulates the management of wastes through landfill disposal and specifies that the wastes destined for disposal in landfills should not be liquid, explosive, corrosive, oxidant, or inflammable. That is the case of the wastes generated at *IDALSA* (Gil, 2007).

2.3 Construction phases of the landfill and characteristics of the location

The construction of hazardous wastes landfills requires measurements of high-security that apart from the construction and exploitation of the site must also consider its closure at the end of its useful life (Royal Decree 1481/2001, BOE 25/2002). The successive phases in the construction of the landfill of *IDALSA* across a surface area of 13.5 Ha were (Gil, 2007):

- conditioning of the land
- waterproofing the landfill
- cover system
- leachate pond
- drainage system

2.4 Study of the environmental impact of the controlled waste landfill

The starting point in such assessments should be the identification of activities that may be harmful to the environment. This identification was an important element in the construction, the exploitation, and closure of the landfill. The actions related to the landfill that might lead to an impact on the environment are as follows:

- in the construction phase: this would be a result of the preparation of the lands where the landfill was located, the construction of the void volume, the alteration of the natural drainage system, and the construction of vehicle accesses.
- in the operation phase: the result of storage, transport, and covering of the wastes.
- in the sealing and closure phase: the physical presence of the landfill.

The environmental components that may be affected are as follows:

- the natural environment: the vegetation and fauna, the geology, water courses, landscape and atmosphere.
- the socioeconomic sector: land use, buildings, and other places of interest.

2.5 Criteria for impact appraisal

The attributes with which the importance of the impacts is established are those established in Royal Decree 1302/1986, and are as follows:

- sign: (+) for a beneficial character and (-) for a damaging character.
- intensity: this refers to how the environment is affected. Between 1 and 4.
- extent: this refers to the area of influence exerted by an impact. Between 1 to 8.
- time: this refers to the time between the appearance of the activity and the beginning of the effect on the factor considered. Between 1 to 4, but as a function of the time.
- persistence: this refers to the period of recovery of initial conditions, either naturally or through the introduction of corrective measures. Between 1 to 4, but as a function of the time.
- reversibility: this refers to the recovery of initial conditions once the action has stopped acting on the environment. Between 1 to 4, but as a function of the time.
- recoverability: this refers to the possibility of a return to initial conditions through the introduction of corrective measures. Between 1 to 8.
- synergy: this occurs when the consequences of two or more effects taking place simultaneously are greater than those observed if each of them had taken place independently. Between 1 to 4.
- accumulation: this refers to the progressive increase in the demonstration of an effect, when it persists in a continued form or when the action that generates it is repeated. Between 1 to 4.
- cause/effect relationship: this refers to whether the action and the appearance of the corresponding effect are related directly or not. Between 1 to 4.
- periodicity: this refers to the repeated demonstration of an effect. Between 1 to 4.
- importance: this refers to the degree of intensity of the alteration produced. This criterion characterizes the environmental impact and is determined as a function of the value adopted by each of the criteria mentioned previously.

Importance = ± (3.intensity + 2.extent + time + persistence + reversibility + recoverability + synergy + accumulation + causality + periodicity)

From the equation, the environmental impact can achieve values between 13 and 84.

2.6 Appraisal of impacts

The values calculated for the impacts identified are summarized in Table 2.

	Importance of the impact
Impact on the vegetation and fauna	40
Impact on the geology	36
Impact on the water courses	53
Impact on the landscape	33
Impact on the atmosphere	27
Impact on the land use	32
Impact on the socioeconomic context	25

Table 2. Importance of the environmental impacts of the controlled waste landfill.

The result of this quantitative evaluation is that the environmental impact of the *IDALSA* controlled hazardous wastes landfill must be considered as compatible-moderate (Royal Decree 1302/1986).

The study was completed with an analysis of emissions in the surroundings of the landfill with a view to checking air quality. The quantities of ammonia, aluminium, and particles in suspension were also analyzed. The results obtained do not surpass the maximum limits permitted by current legislation.

3. Conclusions

This work has presented a short summary of the management of hazardous waste generated in the production of secondary aluminium. The production of this waste must be minimized, it should be recycled, either wholly or partially and, if some fraction still remains, it should be disposed in a controlled landfill.

In this context, *Ibérica de Aleaciones Ligeras, Ltd., IDALSA*, has considered in its process of aluminium recycling the best technologies available in this sector in order to minimize the generation of wastes at the origin, to recover it once it has been generated and, to store the remaining fraction in a controlled landfill. The main characteristics of the controlled landfill, in according with the current Spanish legislation that regulate the removal of wastes by disposal in landfills, have been presented.

4. Acknowledgements

This work was supported by the Spanish Ministry of Environment (A554/2007/3-11.1). The author thanks *Ibérica de Aleaciones Ligeras, Ltd., IDALSA*, for the provided information.

5. References

Altundogan, H.S.; Altundogan, S.; Tümen, F. & Bildik, M. (2002) Arsenic adsorption from aqueous solutions by activated red mud, Waste Manag., 22, 357-363.

Cengeloglu, Y.; Tor, A.; Ersoz, M. & Arslan, G. (2006) Removal of nitrate from aqueous solution by using red mud, Sep. Purif. Technol., 51, 374-378.

Directive 96/61/CE of the Council, 24th of Septembre 1996 regarding the prevention and control integrated of the contamination. Law 16/2002 1st of July, BOE 157/2002 2nd of July 2002.

Drossel, G., Friedrich, S., Huppatz, W., Kammer, C., Lehnert, W., Liesenberg, O., Paul, M. & Schemme, K. (Eds.) (2003) Aluminum Handbook, Vol. 2. Forming, Casting, Surface Treatment, Recycling and Ecology. Dusseldorf, Germany: Aluminum-Verlag Marketing & Kommunikation GmbH.

Farrell, F. (2001) The impact of Best Available Techniques (BAT) on the Competitiveness of the European Non-ferreous Metals Industry. Non-ferreous Metals Final Report. Seville: Joint Research Centre. European Commission. Institute for Prospective Technological Studies.

Gil, A. (2005) Management of the salt cake from secondary aluminum fusion processes, Ind. Eng. Chem. Res., 44, 8852-8857.

Gil, A. (2007) Management of salt cake generated at secondary aluminum melting plants by disposal in a controlled landfill: characteristics of the controlled landfill and a study of environmental impacts, Env. Eng. Sci., 24, 1234-1244.

Hryn, J.N., Daniels, J., Gurganus, T.B. & Tomaswick, K.M. (1995) Products from salt cake residue-oxide. In P.B. Queneau and R.D. Peterson, Eds., Third International Symposium on recycling of Metals and Engineering Materials. Warrendale, PA: TMS The Minerals, Metals & Materials Society, p. 905.

Kammer, C. Ed. (1999) Aluminum Handbook, Vol. 1. Fundamentals and Materials. Dusseldorf, Germany: Aluminum-Verlag Marketing & Kommunikation GmbH.

Order MMA/304/2002. (2002) 8th of February 2002, about the recovery processes, waste treatments and european wastes list. BOE 43/2002, 19th of February 2002.

Royal Decree 1302/1986. (1986). 28th of June, of Environmental Impact Assessment. BOE 155/1986, 30th of June 1986.

Royal Decree 1481/2001. (2001). 27th of December, by which the elimination of waste by means of disposal in tips is regulated. BOE 25/2002, 29th of January 2002.

Sreenivasarao, K., Patsiogiannis, F. & Hryn, J.N. (1997) Concentration and precipitation of NaCl and KCl from salt cake leach solutions by electrodialysis. In R. Huglen, Ed., Light Metals, Warrendale, PA: TMS The Minerals, Metals & Materials Society, p. 1153.

Sushil, S. & Batra, V.S. (2008) Catalytic applications of red mud, an aluminium industry waste: A review, Appl. Catal. B, 81, 64-77.