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Aluminum recovery as a product with high added value using aluminum hazardous waste

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HIGHLIGHTS

- Granular and compact aluminum dross were physically and chemically characterized.
- A relationship between density, porosity and metal content from dross was established.
- Chemical reactions involving aluminum in landfill and negative consequences are shown.
- A processing method for aluminum recovering from aluminum dross was developed.
- Aluminum was recovered as an value product with high grade purity such as alumina.

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ABSTRACT

The samples of hazardous aluminum solid waste such as dross were physically and chemically characterized. A relationship between density, porosity and metal content of dross was established. The paper also examines the chemical reactions involving aluminum dross in landfill and the negative consequences. To avoid environmental problems and to recovery the aluminum, a processing method was developed and aluminum was recovered as an added value product such as alumina. This method refers to a process at low temperature, in more stages: acid leaching, purification, precipitation and calcination. At the end of this process aluminum was extracted, first as Al^{3+} soluble ions and final as alumina product. The composition of the aluminum dross and alumina powder obtained were measured by applying the leaching tests, using atomic absorption spectrometry (AAS) and chemical analysis. The mineralogical composition of aluminum dross samples and alumina product were determined by X-ray diffraction (XRD) and the morphological characterization was performed by scanning electron microscopy (SEM). The method presented in this work allows the use of hazardous aluminum solid waste as raw material to recover an important fraction from soluble aluminum content as an added value product, alumina, with high grade purity (99.28%).

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1. Introduction

Aluminum metal is supplied by two distinct aluminum-production sectors: primary aluminum producers and secondary aluminum smelters [1–3]. The primary aluminum industry in the Romania produces aluminum mostly from mined ore (bauxite). Some scrap is also used, which is usually from recycled aluminum beverage cans and industrially generated high-grade aluminum scrap. The continuing growth in aluminum can recycling has increased the value of aluminum, yielded energy savings, and resulted in ecological benefits [4–9]. Recycling 1 kg of aluminum can save about 4 kg of bauxite, 2 kg of chemicals, and 7.5 kWh of electricity [3,10–12]. Worldwide the aluminum industry produces over 4.5 billion kilograms of aluminum waste each year [3,13–15]. Each type of waste has unique chemical and physical characteristics, and the value of the waste is determined by the level of impurities contained and the cost of recovering of the metal [13,14]. Because the process of recovering aluminum from low-grade scrap requires large quantities of salt, furnaces generate large quantities of salt cake. For every kg of low-grade scrap charged into the rotary furnace, 1 kg of salt flux is typically used [12]. More than 100 flux compositions are available to scrap-aluminum smelters, but the most commonly used fluxes are mixtures of NaCl and KC1 in approximately equal amounts, to which 3–5 weight percent (wt.%) cryolite is added [16,17]. The advantages of this chloride mixture (as a fluxing agent) are its low cost ($100/ton) and low melting point

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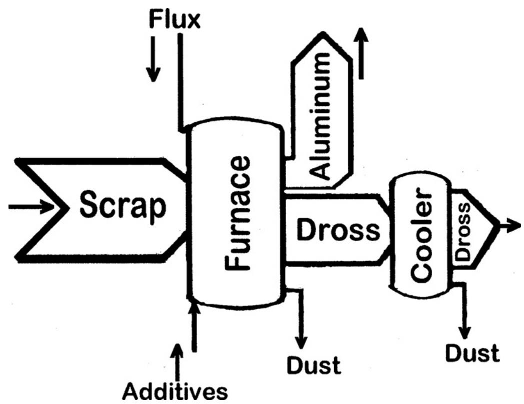

Fig. 1. Aluminum scrap recycling process.

[2,7]. Sodium chloride is lower in cost, but potassium salts have lower viscosity and lower surface tension, qualities that increase fluidity. The melting point of this mixture is just below the melting point of aluminum (660 °C). It is important that the melting point of flux is below the melting point of aluminum, because during heating of the charge, the salt melts first and coats the aluminum before the metal melts, thereby protecting the metal from further oxidation. For dross processing, 1 kg of flux is used for each kg of dross concentrate charged to the rotary furnace [8,12]. The salt flux used in scrap aluminum smelting ends up in the black dross and salt cake, which are commonly disposed of in landfills. Fig. 1 is a diagram of the recycling process for scrap aluminum and the various sources of waste generation. Typically, aluminum black dross (ABD) contains aluminum (12–20%), sodium chloride (20–25%), potassium chloride (20–25%), aluminum oxides (20–50%), and other compounds (2–5%) [12].

Black dross is most often further processed to recover as much as 80% of the remaining aluminum. In order to recover the aluminum and make recycling economically justifiable, the dross must be upgraded (usually by means of milling and screening) at least to 50% aluminum concentrate [14,18]. Because the metal is less brittle than the other dross constituents, it will not break in the milling process, and it will tend to be screened out in coarser fractions. The aluminum "concentrate" is processed in a rotary furnace to recovery of the aluminum (Fig. 2).

The finer-sized fractions, less than about 1 mm, can represent up to 85% of the milled black dross and can contain as much as 10 wt.% metallic aluminum. A general dross-processing flow diagram is shown in Fig. 3. The salt cake generated from the rotary furnaces ranges up to 75% of the melt charge in rotary furnace.

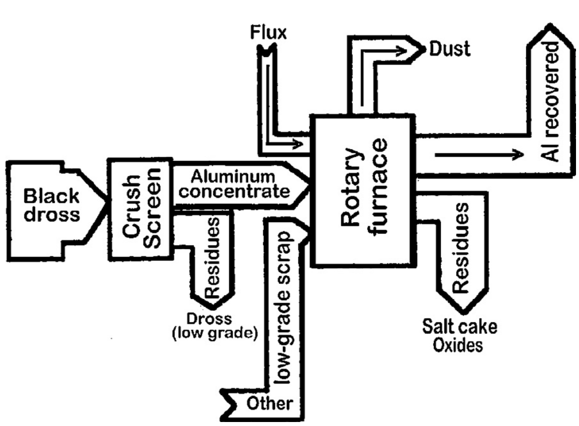

Fig. 2. Aluminum dross recycling process.

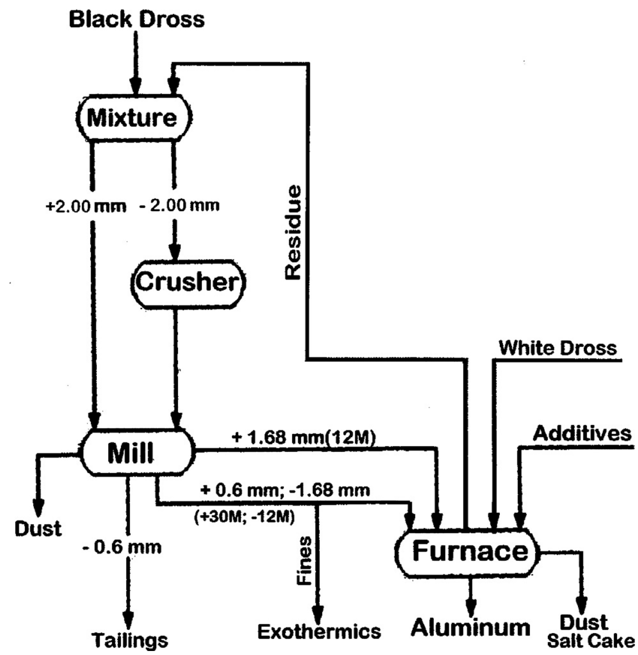

Fig. 3. Aluminum dross processing flow diagram.

Table 1 lists the estimated total amount of solid residues generated by the secondary aluminum industry from secondary aluminum production operations.

Huge quantities of dross and salt cake are generated, of which very little, if any, are recycled, most of them are disposed of in landfills. The salt cake consists of aluminum (1–5%), aluminum oxide (15–30%), sodium chloride (30–55%), potassium chloride (15–30%), and inert compounds (1–4%) [19]. It is very known that due to its properties, the ABD is classified as toxic and hazardous waste (100309), according to the European Catalog for Hazardous Wastes. It is considered as "highly flammable" (H3-A), "irritant" (H4), "harmfull" (H5) and "leachable" (H13). It is also very know that the main problem is its leachability (H13) and its high reactivity with water or even humidity in air (H3-A), leading to the formation of toxic, harmful, explosive, poisonous and unpleasant odorous gases, such as NH_3, CH_4, PH_3, H_2, and H_2S. As a result, when ABD is disposed in hazardous waste landfills, pollution of ground water (e.g., F, Cl, NH_4^+, CN, high pH) and ambient air (e.g., CH_4, H_2, NH_3) can be observed [3,8].

Worldwide are different ways of recycling of this hazardous waste. Mukhopadhyay et al., shown that the recycling of aluminum dross is very important due to economic and environmental benefits, it is saved raw materials and the waste is not sent to landfill [20]. As show Das et al. [1], Dash et al. [16] the disposal of salt slag and dross is a worldwide problem. In the case of improper disposal, leaching of toxic metal ions into ground water would determine serious problems of pollution. They showed that the processing of these wastes and obtaining useful products is a viable way. A series of convincing experimental results tend to prove that sulfuric

Table 1
Major residues from secondary aluminum processing industry.

No.	Solid residues	Estimated quantities (wt.%)
1.	Metal produced	75–76
2.	Black dross	7–8
3.	Black dross residues[a]	6–7
4.	Salt cake	7–8
5.	Baghouse dust	0.6–0.7

[a] Dross – milling residues.

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