Waste Generation in Primary and Secondary Aluminum Sector in Turkey

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Abstract

Aluminum is the most produced and used metal following steel in the world because of its combination of physical properties. Aluminum is produced in two ways; primary aluminum production and secondary aluminum production. The main objectives of this study are to find out waste generation in aluminum industry, to determine waste generation factors (WGFs) and to suggest best available techniques for the management of wastes from this activity. For determination of waste generation in primary and secondary aluminum sectors in Turkey, aluminum producers were listed and examined, in terms of their production processes, raw materials, production capacities, waste types and waste generation steps. In addition, field studies were carried out for on-site examination of both primary and secondary aluminum producers. After that, wastes were identified based on literature review and field studies using the waste list defined by European Commission as a base (Commission Decision 2000/532/EC). Then, range for WGF*s* for both primary and secondary aluminum sectors in Turkey were determined based on literature review, field studies and declared amount of wastes to the Ministry of Environment and Urbanization. When the waste generation in primary and secondary aluminum production was assessed, it is seen that secondary aluminum production generates high quantities of hazardous wastes whereas generated amount of total wastes is considerably higher in the primary production. Within the scope of this study, best available techniques that can be adopted to the Turkish aluminum industry for a better management of the wastes generated were also investigated.

Keywords

Primary aluminum, secondary aluminum, waste generation factor, best available techniques, waste code.

Introduction

Aluminum has been commonly used in different industrial applications. Construction industry, chemical and food industries, metal industry, transportation, electrical and electronics and manufacture of machinery and equipment sectors can be an example to the most significant areas of usage of aluminum. Table 1 provides percent distribution of aluminum with respect to its usage areas in Turkey. The basic properties of aluminum do not change after being subjected to mechanical and physical processes. Therefore, once it is produced, it can be recycled or reused without any loss in its quality [1, 2, 3, and 4].

Table 1 Percent distribution of aluminum according to usage areas [1]

Usage Area	Distribution (%)
Construction	25
Transportation	24
Package	15
Electrical/Electronics	10
Engineering	9
Furniture/Office Stuff	6
Iron and Steel/Metallurgy	3
Chemical and Agricultural Products Industry	1
Others	7

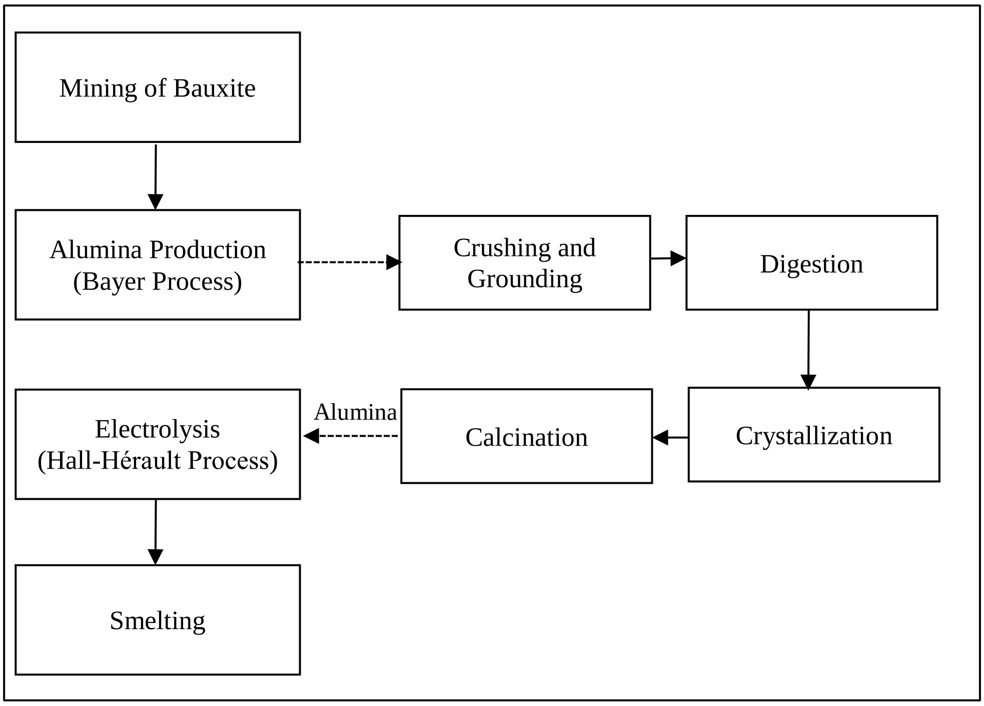
Usage Area	Distribution (%)
Total	100

Aluminum industry includes both primary aluminum production from the bauxite mine and secondary aluminum production from the scrap. The production of primary aluminum begins with the mining of bauxite. Then, alumina is produced by further crushing and grounding the bauxite ore and digesting it with a mixture of sodium hydroxide. The last step is the electrolytic reduction of the alumina to liquid aluminum. In secondary aluminum production; firstly pretreatment is applied to old and/or new scrap or dross to remove undesirable materials. After that, pretreated scrap is melted in melting furnaces. When these processes are applied, 0.9 ton aluminum can be obtained from 1 ton scrap [5]. In other words, secondary aluminum production can achieve 90% recycling efficiency. General flow diagrams for both primary and secondary aluminum production are provided in Fig. 1 and a comparison of the primary and secondary aluminum industries is given in (a)

(b)

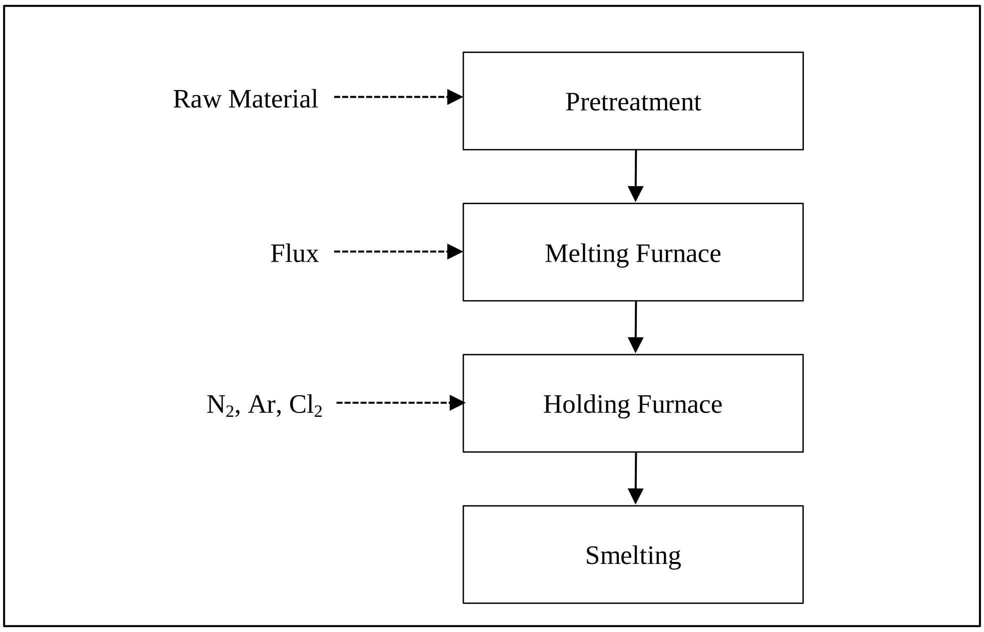
Fig. 1 (a) Primary aluminum production flow diagram (b) Secondary aluminum production flow diagram

Table 2. Primary aluminum production is an energy intensive industry. The share of the energy cost in primary aluminum production is approximately 40%. On the other hand, only 5% of the energy consumed in primary production is needed in secondary aluminum production sector [6, 7]. Energy consumption is also considered as the significant contributor to the environmental impact identified in aluminum production sectors [8]. Therefore, secondary aluminum production can be categorized as more environmentally friendly than primary aluminum production.



Mining of Bauxite
Alumina Production
(Bayer Process)
Crushing and
Grounding
Digestion
Electrolysis
(Hall-Hérault Process)
Alumina
Calcination
Crystallization
Smelting

(a)



Raw Material
Pretreatment
Flux
Melting Furnace
N_2, Ar, Cl_2
Holding Furnace
Smelting

(b)

Fig. 1 (a) Primary aluminum production flow diagram (b) Secondary aluminum production flow diagram

Table 2 Primary versus secondary aluminum production industries [5]

Primary Aluminum Industry	Secondary Aluminum Industry
High investment cost	Low investment cost
High energy consumption	Low energy consumption
Long start-up period	Short start-up period
Consumption of bauxite resources	Preservation of bauxite resources
High level emission	Low level emission

Due to geographical location, aluminum demand and increase in world trade volume regarding aluminum, Turkey's production capacity has shown an increasing trend. However, rise in energy prices, inadequacy of resources and dependence of raw materials and production technologies on imports has negative impact on the growth in the aluminum sector [6]. When domestic aluminum demand and consumption data are examined, it can be seen that aluminum is the most used metal following steel in Turkey. In addition, more than 50% of the aluminum produced in Turkey is exported [3, 6]. Primary aluminum production capacity of Turkey has not changed with years and Eti Aluminum Seydisehir is the only integrated aluminum industry that produces aluminum from ore. On the other hand, secondary aluminum production has become a growing sector. There are many small-scale facilities operated in the field of secondary aluminum production. Low energy consumption in secondary aluminum production plays a significant role in this growth.

Besides its high production volume and common usage, aluminum production has also a considerable impact on the environment. Although it has an impact on all the environmental compartments, the main objectives of this study are to obtain a solid waste inventory regarding aluminum production, to determine waste generation factors (WGFs, kg waste per ton of production) and to develop and evaluate its management strategies. The results obtained from this study can be considered as guidance for the facilities that produce primary and secondary aluminum.

Methods

In this study, a three phase approach was adopted and implemented both for determination of waste generation factors (WGFs, kg waste per ton of production) and evaluation of best available techniques (BATs) for the management of wastes. Methodology followed through this study is summarized in Fig. 2. As can be seen from Fig. 2, WGFs can be determined by using information obtained from waste declaration system, the literature or field studies. The first step towards the determination of waste generation in primary and secondary aluminum sectors in Turkey is to list and examine aluminum producers. Once the producers were identified, information regarding their production processes, raw materials, production capacities, waste types and waste generation steps was gathered. For that purpose, Hazardous Waste Declaration System (HWDS) which is a web-based information management system developed for declaration of wastes by their generators to the Ministry of Environment and Urbanization was used. HWDS aims to provide record for hazardous waste producing companies in Turkey and to create inventory regarding hazardous wastes. Moreover, field studies were conducted for on-site examination of both primary and secondary aluminum producers. During field studies, production processes were investigated on site in detail. By this way information obtained from HWDS was confirmed. Then, wastes were identified based on HWDS, literature review and field studies and listed by using the waste list defined by European Commission (Commission Decision 2000/532/EC). After that, range for WGFs for both primary and secondary aluminum sectors in Turkey were determined based on information obtained from literature review, field studies and declared amount of wastes to the Ministry of Environment and Urbanization.

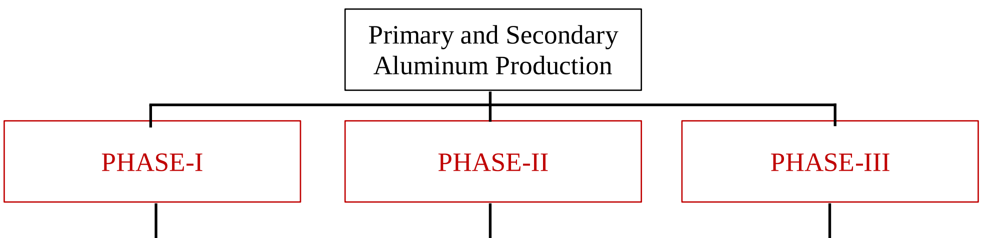


Fig. 2 Three-phase approach followed within the scope of the study

For the second part of the research, waste management hierarchy was considered. According to this hierarchy, firstly generation of waste should be prevented. Therefore, BATs developed under the Integrated Pollution Prevention and Control (IPPC) Directive and the Industrial Emissions Directive (IED) were investigated whether they can be applied to the Turkish aluminum industry for a better management of the wastes or not. Both in-plant and end-of-pipe BAT alternatives were considered. When the waste generated cannot be prevented or reduced, then it should be recovered or disposed with a proper technology that is compatible with its characteristic. Applicable recovery and disposal methods were also examined for the generated waste considering waste properties and legal requirements.

Results and Discussion

Determination of WGFs and Responsible Processes for Waste Generation

Although aluminum production imposes a significant burden on all the environmental compartments, the main purposes of this study are to reveal the solid waste generated when producing primary and secondary aluminum and to determine a range for its generation factor. WGFs were calculated by dividing amount of waste generated into production capacities of the facility. They were tried to be determined for each waste code. However, for some waste codes WGFs cannot be determined. Table 3 lists waste codes, their definitions and their WGFs for the waste generated from primary aluminum production sector. For the three waste codes (01 03 07*, 01 03 10* and 10 10 03), WGFs cannot be determined because 01 03 07* and 01 03 10* waste codes are not included into the legal legislation published in Turkey. They were taken from the waste list defined by European Commission (Commission Decision 2000/532/EC). Therefore, facilities do not have to declare it to the Ministry of Environment and Urbanization yet. The reason why WGF for 10 10 03 cannot be determined is that up to now there has been a necessity for declaration of only hazardous wastes. Thus, solid information regarding generation of this waste code cannot be obtained. Fig. 3 shows the responsible processes for waste generation in primary aluminum production. 01 03 09 waste code (red mud) which can be categorized as the most problematic waste in terms of environment due to its alkaline nature and quantity has the highest WGF when compared to the other waste codes and it is generated during alumina production. Typically, each ton of alumina production generates two ton of red mud [9].

Table 3 Wastes and waste generation factors originating from primary aluminum production

Code	Wastes from primary aluminum production	WGF (kg t^{-1})
01 03	**wastes from physical and chemical processing of metalliferous minerals**	
01 03 07*	other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals	nd
01 03 09	red mud from alumina production other than the wastes mentioned in 01 03 10	300-2500
01 03 10*	red mud from alumina production containing hazardous substances other than the wastes mentioned in 01 03 07	nd
10 03	**wastes from aluminum thermal metallurgy**	
10 03 02	anode scraps	10-450
10 03 04*	primary production slags	0.20-20
10 10	**wastes from casting of non-ferrous pieces**	
10 10 03	furnace slag	nd
	TOTAL	**310.2-2970**

*Any waste marked with an asterisk is considered as a hazardous waste
nd: not determined

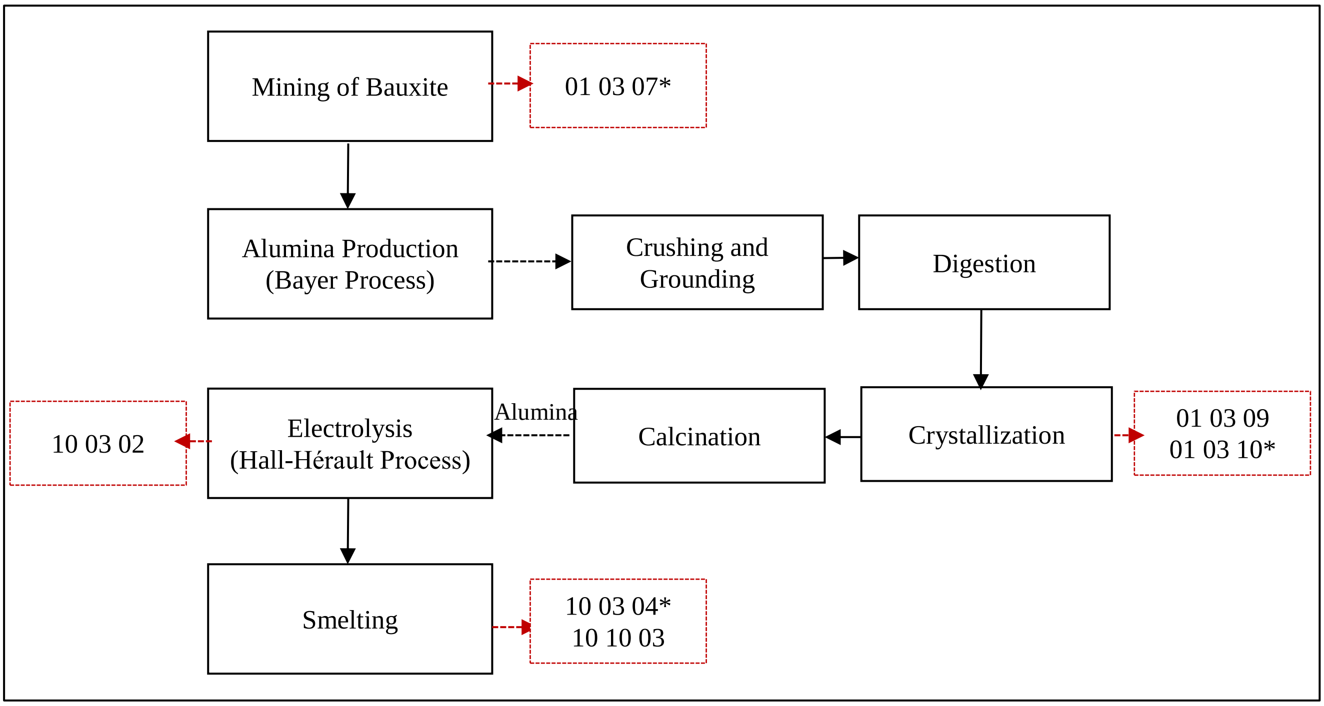


Fig. 3 Sources of waste generated in primary aluminum production

Because of getting involved in different production processes, wastes generated during primary and secondary aluminum production are different from each other. Red mud (01 03 09 and 01 03 10) that is generated during alumina production is the most expected type of waste from primary aluminum production (Table 3). Primary production slag (10 03 04) is a waste which is produced during melting and casting processes of primary aluminum production. On the other hand, salt slags (10 03 08) and black drosses (10 03 09) are the main wastes generated during secondary aluminum production (Table 4). In order to increase the aluminum ratio and accelerate the process, salt can be added as slag maker. Under these circumstances, salt slags are generated. Otherwise, black drosses are generated. Fig. 4 shows the sources of waste generated in secondary aluminum production. The share of salt slags and black drosses (10 03 08 and 10 03 09) in wastes generated in secondary aluminum production is relatively higher. In some cases, salt fluxes are used to reduce oxidation, to prevent pollution and to increase thermal efficiency during melting of pretreated scrap in melting furnaces. They pose a risk for environment because of its chlorine content. When the waste generation in primary and secondary aluminum production was assessed by considering available data, it is seen that the secondary aluminum production generates high quantities of hazardous wastes whereas generated amount of total wastes is considerably higher in the primary production.

Table 4 Wastes and waste generation factors originating from secondary aluminum production
*Any waste marked with an asterisk is considered as a hazardous waste

Code	Wastes from secondary aluminum production	WGF (kg t^{-1})
10 03	**wastes from aluminum thermal metallurgy**	
10 03 05	waste alumina	nd
10 03 08*	salt slags from secondary production	0.20-500
10 03 09*	black drosses from secondary production	5-676
10 03 15*	skimmings that are flammable or emit, upon contact with water, flammable gases in dangerous quantities	80-120
10 03 16	skimmings other than those mentioned in 10 03 15	
10 03 19*	flue-gas dust containing dangerous substances	0.1-80
10 03 20	flue-gas dust other than those mentioned in 10 03 19	
10 03 21*	other particulates and dust (including ball-mill dust) containing dangerous substances	0.2-1130
10 03 22	other particulates and dust (including ball-mill dust) other than those mentioned in 10 03 21	
	TOTAL	**85.5-2506**

nd: not determined

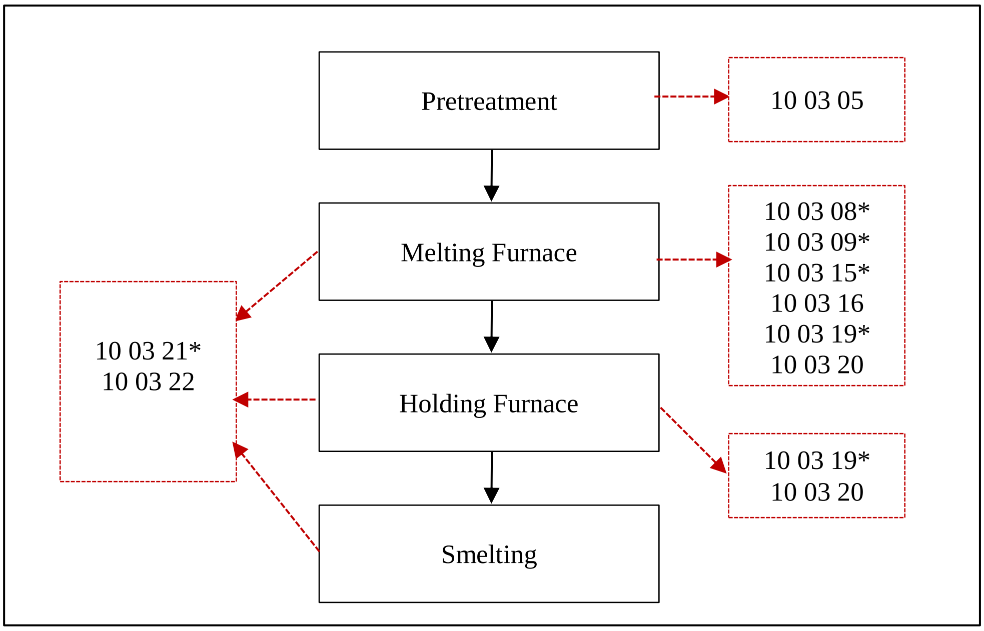


Fig. 4 Sources of waste generated in secondary aluminum production

Development and Evaluation of Management Strategies

The second part of the research was carried out to investigate the best available techniques (BATs) that can be adopted to the Turkish aluminum industry for a better management of the wastes generated (Table 3 and Table 4). Both in-plant and end-of-pipe BAT alternatives were considered. For primary production, to reduce environmental burdens, the use or red mud should be maximized. For wastes entitled “other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals”, “red mud from alumina production other than the wastes mentioned in 01 03 10” and “red mud from alumina production containing hazardous substances other than the wastes mentioned in 01 03 07”, end-of-pipe BAT appeared as the use as an alternative raw material in ceramic industry, building material, packing material, catalyst in chemical industry and for the purpose of pollution control [10, 11]. In-plant BAT for “anode scraps” is using inert anodes instead of anodes that include carbon [12]. “Primary production slag” and “furnace slag” wastes can be used in secondary alumina production, cement industry as additive material and in iron and steel industry as synthetic slag maker [12]. BATs for reducing wastes originating from secondary production were also determined. Slag generated in melting and holding furnaces during production of secondary aluminum contains 4-10 % aluminum, 35-75% alumina and 20-55% salt depending on the fluxes used [12]. Because of its high aluminum content, it can be considered as semi-finished product having an economic value. The BAT for “salt slags from secondary production” is the use in secondary alumina production, in cement industry as additive material and in iron and steel industry as synthetic slag maker, as salt flux in aluminum industry, and in catalyst production in chemical industry [10]. Use of metal pumping or a stirring system to improve efficiency and reduce salt usage and use of a tilting rotary furnace to improve efficiency and minimize the use of salt cover are also suggested to reduce the amount of salt slag generated [12]. “Waste alumina”, “black drosses from secondary production”, “skimmings that are flammable or emit, upon contact with water, flammable gases in dangerous quantities”, “other particulates and dust (including ball-mill dust) containing dangerous substances”, “other particulates and dust (including ball-mill dust) other than those mentioned in 10 03 21” can be used in secondary alumina production, cement industry as additive material and in iron and steel industry as synthetic slag maker, in aluminum industry as salt fluxes and in chemical industry for catalyst production [10]. In-plant BAT for “flue-gas dust containing dangerous substances” is the use of bag filters [12]. In cases where abovementioned prevention techniques cannot be applied, recovery and disposal methods were examined. Metal recovery can be considered as the best option since many of the wastes listed in Table 3 and Table 4 contain aluminum.

Conclusions

This study revealed the situation of both primary and secondary aluminum production sector in Turkey providing a summary for their production processes and generated wastes from each process. Within the scope of this study, range for the amount of waste generated per unit aluminum production, WGFs, was also identified. For that purpose, three phase approach which considers literature review, field studies and waste declaration system was followed. While information obtained from the literature provided only basic understanding of production processes and waste generation trends, field studies and HWDS enabled to obtain detailed information regarding production processes and country specific waste generation amounts. Therefore, contribution of the field studies to the determination of WGFs is considerable. When WGFs were assessed, it was realized that although total amount of waste generated is substantially higher in primary production, secondary production is dominant sector in terms of hazardous waste generation.

Management alternatives for waste generated in the production of primary and secondary aluminum were examined in detail. The results of the examination show that some in-plant and end-of-pipe BAT alternatives can be applied to the aluminum production wastes. In cases where BATs cannot be applicable, metals can be recovered from waste because of its aluminum content. In this way, environmental burden imposed by aluminum production can be minimized.

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