30th International Conference Ecological Truth & Environmental Research 2023

Proceedings

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PROCEEDINGS

30th INTERNATIONAL CONFERENCE

ECOLOGICAL TRUTH AND ENVIRONMENTAL RESEARCH – EcoTER'23

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Publisher: University of Belgrade, Technical Faculty in Bor

For the publisher: Prof. Dr Dejan Tanikić, Dean

Printed: University of Belgrade, Technical Faculty in Bor, 100 copies, electronic edition

Year of publication: 2023

ISBN 978-86-6305-137-9

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

502/504(082)(0.034.2)
574(082)(0.034.2)

INTERNATIONAL Conference Ecological Truth & Environmental Research (30 ; 2023)
Proceedings [Elektronski izvor] / 30th International Conference Ecological Truth & Environmental Research - EcoTER'23, 20-23 June 2023, Serbia ; organized by University of Belgrade, Technical faculty in Bor (Serbia) ; co-organizers University of Banja Luka, Faculty of Technology – Banja Luka (B&H) ... [et al.] ; [editor Snežana Šerbula]. - Bor : University of Belgrade, Technical faculty, 2023 (Bor : University of Belgrade, Technical faculty). - 1 elektronski optički disk (CD-ROM) ; 12 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Preface / Snežana Šerbula. - Tiraž 100. - Bibliografija uz svaki rad.

ISBN 978-86-6305-137-9

а) Животна средина -- Зборници б) Екологија – Зборници

COBISS.SR-ID 118723849

30th International Conference
Ecological Truth and Environmental Research – EcoTER'23

is organized by:

UNIVERSITY OF BELGRADE
TECHNICAL FACULTY IN BOR (SERBIA)

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POTENTIAL ENVIRONMENT POLLUTANT – INTERMEDIATE PRODUCT OF THE STEEL PRODUCTION PROCESS

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Abstract

As an intermediate product of the steel production process using an electric arc furnace, electric arc furnace dust (EAF dust) occurs. The resulting intermediate product of steel production is considered hazardous industrial solid waste in many countries of the world, given that it contains a large number of heavy metals that can reach the environment due to the action of atmospheric influences if it is not adequately disposed of. In this paper, the physico-chemical characterization of the EAF dust originating from a steel plant in the Republic of Serbia was performed, and Toxicity Characteristic Leaching Procedure (TCLP test) and Leachability Procedure (LP test) were performed in order to define the impact of this material on the environment and human health. The chemical analysis of the tested sample of the EAF dust showed a zinc content of 32.44%, iron – 18.92%, lead – 1.39%, cadmium – 0.04%, chromium – 0.25% and a lower content of a large number of other elements. The results of the LP test showed an increased chloride content in the leaching eluate, above the permitted limits, even for waste disposal at a hazardous waste landfill. In the TCLP eluate, the content of zinc, cadmium and lead are above the permitted limits, thus the sample shows toxic characteristics and danger to the environment and human health. In order to environmental and human health protection, it is necessary to do the treatment of this type of material before disposal at the landfill.

Keywords: EAF dust, environmental protection, TCLP test, LP test.

INTRODUCTION

During the steel production using electric arc furnaces, at a process temperature of 1600°C, during the melting of a batch of scrap iron, some elements evaporate. Volatile elements, together with a part of solid particles, go as a gas phase to the gas purification system, during which one of the intermediate products of this process – electric arc furnace dust (EAF dust) is formed [1,2].

During the production of 1 ton of raw steel, about 10–20 kg of red-brown EAF dust is generated [1,3–9]. Due to the presence of heavy metals in the EAF dust, it is considered officially hazardous industrial solid waste in many countries [3,6–8,10–13].

In this paper, the physico-chemical characterization of the EAF dust originating from a steel plant in the Republic of Serbia was performed, and its toxicity characteristics and leachability were examined in terms of defining its impact on the environment and human health after disposal in a landfill.

POTENTIAL ENVIRONMENTAL POLLUTION WITH EAF DUST

The potential pollution of this type of waste consists in the possibility of leaching of heavy metals, such as: Zn, Cu, Ni, Cd, Cr, Pb, F and Cl, etc., which are in its composition [14]. Inadequate disposal of the EAF dust has a negative impact on the environment [7]. There is still a large amount of EAF dust in the world, the treatment of which should be carried out as soon as possible, and which is accumulated around steel plants or in landfills of this material. Disposal method of the EAF dust is very important. If the EAF dust is inadequately disposed of, and in inappropriate landfills, due to the action of atmospheric influences, self-leaching of heavy metals from the EAF dust may occur. It is necessary to ensure that when the EAF dust is disposed in hazardous waste landfills, it must be protected from rain, in order to prevent the formation of polluted leachate, which could contaminate the surrounding areas [14].

Figure 1a shows a "mountain" of the EAF dust generated from steel production in Egypt [1]. The figure represents a typical inadequate way of disposing of this type of waste, given that the waste is exposed to atmospheric influences. Also, considering that the EAF dust is a material with very fine particles that can spread in the air, this kind of exposure to it due to the action of the wind makes it possible [1,14]. A more adequate way of disposal of the EAF dust from steel production in the Republic of Serbia is shown in Figure 1b. The EAF dust is packed in jumbo bags and stored under a canopy at the landfill around of the steel plant, in the production process of which it is generated.

a) *b)*

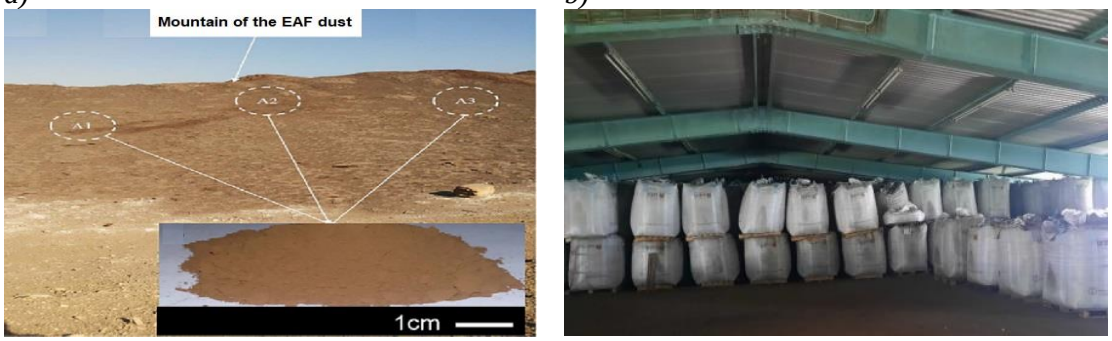

Figure 1 *Method of disposal of the EAF dust in the world and in our country a) landfill in Egypt [1]; b) landfill in the Republic of Serbia*

In order to environmental protection and human health protection from the negative impact of this type of hazardous waste, it is necessary to carry out its treatment in accordance with the legislation of the country where it is located. Before applying any treatment of electric arc furnace dust, it is necessary to carry out its detailed characterization.

Physico-chemical characterization

The results of the physical characterization of the initial representative sample of the EAF dust are as follows: moisture – 0.36%, pH value of the sample – 11.42, density – 4.351 g/cm^3 and bulk mass – 654 kg/m^3.

The chemical composition of a representative EAF dust sample is presented in the Table 1.

Table 1 *Chemical composition of a representative EAF dust sample [15]*

Element	Content, %	Element	Content, %
Zn	32.44	Ca	3.85
Fe	18.92	Co	0.0017
Sn	0.037	Pb	1.39
S	0.51	Ni	0.036
Mo	<0.005	P	0.15
Mn	1.81	Mg	0.93
Si	1.34	Sb	0.022
Cr	0.25	Al	0.73
As	0.0041	K	0.87
Cd	0.04	Na	1.28
Cl	2.85	Hg	0.0001
Bi	0.013	Ag	0.00604
Cu	0.19	Au	0.00004

LABORATORY INVESTIGATIONS OF THE IMPACT ON THE ENVIRONMENT AND HUMAN HEALTH

According to the Rulebook on categories, investigation and classification of waste (Official Gazette of RS 93/2019, 39/2021), with regard to the impact on the environment and human health after its disposal, toxicity and leachability tests of the material were performed on a representative sample of the EAF dust. Laboratory tests were carried out according to accredited standard methods: SRPS EN 12457-2 for testing material leachability, and EPA 1311 for testing material toxicity characteristics.

Leachability Procedure (LP test)

The results of the leachability test (LP test) of a representative EAF dust sample according to the SRPS EN 12457-2:2008 standard are presented in Table 2 [15].

Due to the increased chloride content in the leaching eluate (leaching solution) above the permitted limits, even for waste disposal at a hazardous waste landfill, based on the leachability test results, the EAF dust sample was categorized as hazardous waste in terms of disposal. These results indicate that the EAF dust must undergo pretreatment before final disposal.

Table 2 *Leachability test results for the representative EAF dust sample*

Parameter	Measured value	Reference value for non-hazardous waste[a]	Reference value for hazardous waste[b]
pH	11.31	6–13[c]	-
Conductivity, $\mu S \cdot cm^{-1}$	8288	-	-
Content of dry matter, $mg \cdot kg^{-1}$			

Table 2 *continued*

Elements	Measured value	Reference value for non-hazardous waste[a]	Reference value for hazardous waste[b]
Zn	3.00	50	200
As	<0.20	2	25
Cu	<0.05	50	100
Sb	<0.50	0.7	5
Cd	<0.08	1	5
Mo	4.70	10	30
Ni	<0.07	10	40
Se	<0.33	0.5	7
Pb	10.00	10	50
Cr	<0.05	10	70
V	<0.08	200	-
Hg	<0.005	0.2	2
Ba	2.60	100	300
Ag	<0.05	50	-
Cl^-	**30900**	**15000**	**25000**
F^-	36.30	150	500
SO_4^{2-}	7400	20000	50000
Phenol index	0.24	1000	-

[a,b]Annex 10 of the Rulebook on categories, investigation and classification of waste (Official Gazette of RS 93/2019, 39/2021), Article 2, Parameters for testing waste and leachate from non-hazardous waste landfills[a] and hazardous waste[b]. Ambient temperature 21°C, humidity 52 %, pressure 970 hPa.
[c]Reference value for pH according to the Rulebook 93/2019, 39/2021 Annex 7, H15-Waste that has the property of producing another substance in any way after disposal, e.g. leachate that has any of the following characteristics (H1-H14), is 6–13. The measured pH value is within the allowable range.

Toxicity Characteristic Leaching Procedure (TCLP test)

Table 3 [15] presents the results of the toxic leaching characteristic test (TCLP test) (EPA 1311) of a representative sample of the EAF dust intended for disposal.

The obtained results of the TCLP test show that the EAF dust sample, due to the increased content of zinc, cadmium and lead in the TCLP eluate (leaching solution), which are above the permitted prescribed limits, showed toxic characteristics. This type of hazardous waste requires additional attention and the application of appropriate treatment in order to environmental protection and human health protection.

The treatment of this type of hazardous waste can be performed by hydrometallurgical, pyrometallurgical or combined procedures [1,5,6,10,15]. Considering the highest content of zinc in the EAF dust, compared to all other elements, there is a possibility of its recovery by some of the mentioned procedures, which would also make it possible to make a profit. Apart from the application of the appropriate treatment of the EAF dust, primarily in order to protect the environment from the negative impact of hazardous waste, it is observed that this material can represent a secondary raw material for recovery of zinc.

Table 3 *TCLP test results of a representative EAF dust sample*

Elements	Measured value, mg·dm^{-3}	Reference value for non-hazardous waste[a], mg·dm^{-3}	Elements	Measured value, mg·dm^{-3}	Reference value for non-hazardous waste[a], mg·dm^{-3}
V	<0.008	24	Ag	<0.005	5
Cr	<0.005	5	**Cd**	**13.88**	**1**
Ni	0.068	20	Ba	0.880	100
Cu	0.050	25	Hg	<0.0005	0.20
Zn	**2690.67**	**250**	**Pb**	**61.16**	**5**
Ar	<0.020	5	Mo	<0.007	350
Se	<0.033	1	Sb	<0.050	15

[a]Annex 10 of the Rulebook on categories, investigation and classification of waste (Official Gazette of RS 93/2019, 39/2021), Article 1, Parameters for testing the toxic characteristics of waste intended for disposal.

CONCLUSION

Dust from the electric arc furnace (EAF dust) is generated as an intermediate product of the steel production process by melting secondary raw materials in an electric arc furnace. Due to the fact that the EAF dust contains a large number of heavy metals that can enter the environment due to the action of atmospheric influences, this material is considered hazardous industrial solid waste in many countries of the world. Chemical analysis of a representative EAF dust sample, originating from the Republic of Serbia, determined the content of the following elements: zinc – 32.44%, iron – 18.92%, lead – 1.39%, cadmium – 0.04%, chromium - 0.25% and lower content of a large number of other elements. Laboratory tests of toxicity characteristics (TCLP test) and leachability (LP test) were also performed on a representative EAF dust sample. The results of the TCLP test showed that the content of zinc, cadmium and lead are above the permitted prescribed limits, on the basis of which it can be concluded that the sample shows toxic characteristics and danger to the environment and human health. The results of the LP test showed increased chloride content in the eluate for leaching, above the permitted limits, even for waste disposal at the hazardous waste landfill. In order to protect the environment and human health, it is necessary to do the treatment of this type of material before its disposal in a landfill. The treatment can be performed using hydrometallurgical, pyrometallurgical or combined procedures. Apart from the application of appropriate treatment of the EAF dust, primarily in order to protect the environment from the negative impact of this hazardous waste, this material can also be used as a secondary raw material for zinc recovery, and gaining adequate economic profit.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Ministry of Science, Technological Development and Innovation of the Republic of Serbia for financial support according to the contract with the registration number 451-03-47/2023-01/200052 and number 451-03-47/2023-01/200131.

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