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VALORIZATION OF ZINC FROM THE EAF DUST USING THE HYDROMETALLURGICAL PROCESS

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Abstract

Since the dust from the electric arc furnace (EAF dust) contains a high percentage of zinc in its composition, it can be used as a secondary raw material for zinc valorization. After characterization the original sample of the EAF dust, it was treated using the hydrometallurgical process. After the applied hydrometallurgical treatment of the EAF dust, a pregnant leaching solution, rich in zinc and other impurities, was obtained. To valorize zinc, and obtain the commercial quality $ZnSO_4 \cdot H_2O$ product, the impurities were removed by purification the pregnant leaching solution through the processes of neutralization and cementation. From the purified pregnant leaching solution, using the evaporation and crystallization processes, a product was obtained and its characteristics are in accordance with the characteristics of the $ZnSO_4 \cdot H_2O$ product on the market. The fact that $ZnSO_4 \cdot H_2O$ is the only crystalline phase in the obtained zinc product, it was confirmed by the XRD analysis.
***Keywords**: EAF dust, treatment, zinc valorization*

1. INTRODUCTION

Waste is generated in the production of steel as well as in any industrial production. In the production of steel from the secondary raw materials, using the electric arc furnaces (EAF), a fine dust is produced, called an electric arc furnace dust (EAF dust). For every ton of steel produced, 10-20 kg of the EAF dust is generated [1,2]. Dust has a large number of elements in its composition, such as Fe, Zn, Pb, Cd, Ca, Mn, Cl, etc. Because the generated dust contains heavy metals, it is characterized worldwide as a hazardous solid industrial waste [1,3,4]. To protect the environment and clear out hazardous waste, it is necessary to treat the EAF dust in an appropriate manner.

In addition to the environmental protection, with the application of the EAF dust treatment, the valorization of metals, contained in it, can be achieved. The composition of each EAF dust is individual, as it depends on the steel production process [5,6]. The macro components of the EAF dust include zinc and iron in the form of various compounds. Due to the high content of zinc in the EAF dust, it can also be considered as a secondary raw material for its recovery. To valorize zinc, a study on treatment the EAF dust, carried out by the hydrometallurgical, pyrometallurgical, or combined processes, can be found in the literature [1,3,5,7]. Each of these processes has its advantages and disadvantages.

In this paper, the recovery of zinc from the EAF dust in the form of $ZnSO_4 \cdot H_2O$ was carried out from the pregnant leaching solution, obtained applying the hydrometallurgical process, which includes the leaching processes, process of purifying the pregnant leaching solution and the valorization of zinc from the purified pregnant leaching solution.

2. EXPERIMENTAL

A complete characterization was performed on a representative original sample of the EAF dust, which includes: physico-chemical characterization (device ICP–AES, Spectro CirosVision, Germany), mineralogical characterization (XRD analysis on the device RigakuMiniFlex 600, Japan), as well as the granulometric analysis, determined by the method of sieving on the laboratory sieves from thin mesh, wire and perforated metal plate (SRPS ISO 2591-1:992) for the particle size distribution.

The hydrometallurgical process of the EAF dust treatment includes the four technological stages: 1) pretreatment (water leaching), 2) two-phase acid leaching of the solid residue, obtained after water leaching, 3) purification of the pregnant leaching solution, and 4) evaporation and crystallization of $ZnSO_4 \cdot H_2O$. This paper presents the third and fourth stages of applied hydrometallurgical treatment. The impurities were removed from the pregnant leaching solution ($ZnSO_4$ solution), obtained by two-phase acid leaching of the EAF dust with sulfuric acid solution, neutralization processes (by adding $CaCO_3$ to pH=4 in order to remove Fe and As), and cementation process with zinc powder (removal of Cd and Cu). After the pregnant leaching solution was purified from impurities, it was evaporated for 24 hours in a sand bath, followed by crystallization of the zinc product. An XRD analysis of the obtained product was performed, and to compare the quality of the obtained zinc product with the quality of the commercial product $ZnSO_4 \cdot H_2O$, its chemical characterization was performed.

3. RESULTS AND DISCUSSION

3.1 Characterization of the Original EAF Dust Sample

The physical characteristics of a representative original EAF dust sample are as follows: bulk density: 712 kg/m^3, density: 4.55 g/cm^3, moisture content: 2.90%, and pH value of the sample: 8.05.

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

Table 1. *Chemical composition of the original EAF dust sample*

Element	Zn	Fe	Ca	Mn	Na	Cr	Mg	Cd	Pb	Si	Cl
Content (%)	32.95	21.92	2.89	2.07	0.91	0.25	0.68	0.06	1.74	1.68	2.23

Based on the results of chemical characterization, it can be seen that zinc and iron have the highest content in the EAF dust and represent the macro components of testedsample.

The minerals magnetite (Fe_3O_4), zincite (ZnO) and simonkolleite ($Zn_5(OH)_8Cl_2 \cdot H_2O$) were identified by the XRD analysis. Magnetite and zincite are more abundant in tested sample, while simonkolleite is less abundant. The obtained results of mineralogical analysis are in agreement with the literature [1,5,7].

Considering the results of the granulometric analysis, it can be concluded that 86% of the investigated EAF dust sample consists of particles smaller than 38 μm indicating a very fine-grained material.

3.2 Valorization of Zinc

Figure 1 schematically shows all the technological stages of applied hydrometallurgical treatment to valorize zinc and obtain the commercial quality product.

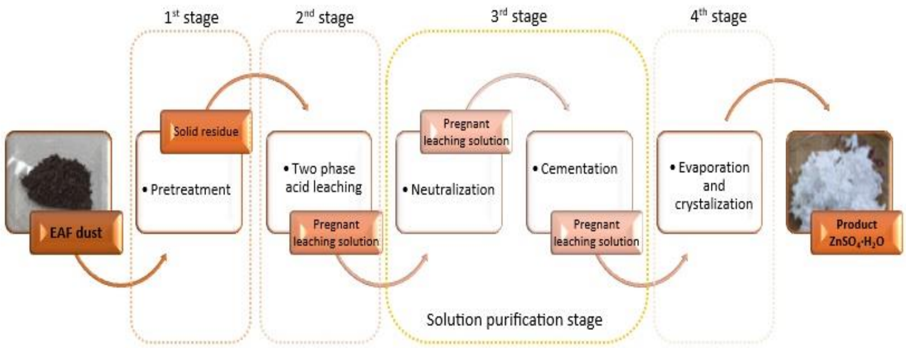

Figure 1. *Schematic representation of the valorization process of zinc from the EAF dust*

Table 2 shows the chemical composition of pregnant leaching solution, obtained after the second and third technological stages of applied hydrometallurgical treatment of the EAF dust, that is, before and after purification the pregnant leaching solution by the neutralization and cementation processes.

Xanthopoulos et al. [2], in their paper, carried out the removal of iron from sulfuric acid solution by the chemical precipitation, that is, by the neutralization process. Ruiz et al. [8] applied the cementation process for purification the carbonate leaching solution, and then recovered zinc by the precipitation in the form of $ZnCO_3$.

Table 2. *Chemical composition of pregnant leaching solution*

	Concentration					
	Zn (g/l)	**Fe (g/l)**	**Pb (mg/l)**	**As (mg/l)**	**Cd (mg/l)**	**Cu (mg/l)**
Pregnant leaching solution before purification	20.79	1.91	4.10	1.70	31.60	77.30
Pregnant leaching solution after purification	20.02	0.031	<0.50	<0.50	1.30	0.83

After the evaporation and crystallization processes, as the final technological stages of the applied hydrometallurgical treatment of the EAF dust, the XRD analysis of the obtained product, presented in Figure 2, has revealed that the mineral zinc-sulfate monohydrate ($ZnSO_4 \cdot H_2O$) was identified as the only crystalline phase.

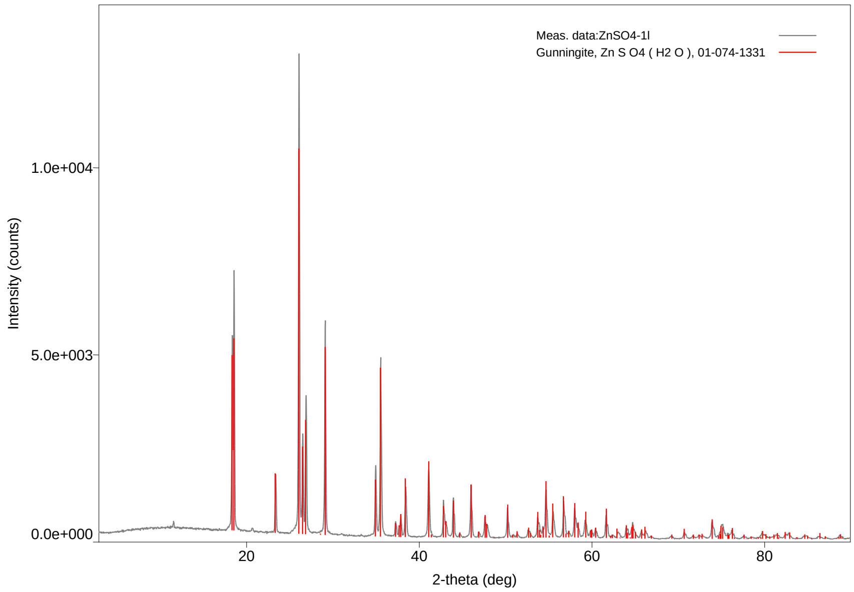

Figure 2. *XRD analysis of the obtained zinc product*

Table 3 gives a comparative view of the chemical composition of the obtained $ZnSO_4 \cdot H_2O$ and limit values for the quality of commercial product $ZnSO_4 \cdot H_2O$ on the market, intended for animal nutrition or use in the production of artificial fertilizers.

Table 3. *Chemical characterization of the obtained product $ZnSO_4 \cdot H_2O$*

	Content					
	Zn (%)	Fe (ppm)	Pb (ppm)	As (ppm)	Cd (ppm)	Cu (ppm)
Obtained $ZnSO_4 \cdot H_2O$	35.85	20	<10	<10	8	41
Limit values*	35.50	<200	<20	<10	<20	-
Limit values**	21.00	-	<20	<10	<20	-

* The quality of commercial $ZnSO_4 \cdot H_2O$ on the market intended for animal nutrition

** The quality of commercial $ZnSO_4 \cdot 7H_2O$ on the market for application in the production of artificial fertilizers

By comparison the results of chemical composition of the product $ZnSO_4 \cdot H_2O$, obtained by the EAF dust treatment with the limit values of impurities in the product $ZnSO_4 \cdot H_2O$ that can be found on the market, it can be concluded that by the use of hydrometallurgical treatment, it is possible to obtain the required quality of $ZnSO_4 \cdot H_2O$ zinc valorization from the EAF dust.

4. CONCLUSION

After characterization the original sample of the EAF dust, it was treated using a hydrometallurgical process to valorize the zinc contained in it. In the second technological phase of the applied process, a sulfuric acid pregnant leaching solution rich in zinc was obtained from which zinc valorization was carried out. This solution also contains the other impurities that have been removed by solution purification with the neutralization and cementation processes. Fe and As were removed in the neutralization process, while Cd and Cu were removed in the cementation process. After purification the pregnant leaching solution, its further evaporation and crystallization have been done to obtain the product $ZnSO_4 \cdot H_2O$ with the characteristics in accordance with the characteristics of product that can be found on the market. It can be concluded that applying the hydrometallurgical treatment, it is possible to valorize zinc from the EAF dust in the form of $ZnSO_4 \cdot H_2O$, as well as that the obtained product has the required quality and appropriate application.

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REFERENCES

[1] F. Kukurugya, T. Vindt, T. Havlík., Hydrometallurgy 154, 2015, 20–32.

[2] P. Xanthopoulos, S. Agatzini-Leonardou, P. Oustadakis, P. E. Tsakiridis., J. Environ. Chem. Eng. 5, 2017, 3550–3559.

[3] J. M. Terrones-Saeta, J. Suárez-Macías, E. R. Moreno-López, F. A. Corpas-Iglesias., Metals 11, 2021,1603.

[4] Commission of the European Communities, Guidance on Classification of Waste According to EWC-Stat Categories, Supplement to the Manual for the Implementation of the Regulation (EC) No 2150/2002 on Waste Statistics, version 2, December 2010.

[5] J. Wang, Y. Zhang, K. Cui, T. Fu, J. Gao, S. Hussain, T. S. AlGarni., J. Cleaner Prod. 298, 2021, 126788.

[6] M. Kamali, S. Sheibani, A. Ataie, Mater. Res. Bull. 148, 2022, 111688.
[7] P. Oustadakis, P. E. Tsakiridis, A. Katsiapi, S. Agatzini-Leonardou., J. Hazard. Mater. 179, 2010, 1–7.
[8] O. Ruiz, C. Clemente, M. Alonso, F. J. Alguacil., J. Hazard. Mater. 2007, 141, 33–36.