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ENVIRONMENT-FRIENDLY MANAGEMENT OF IRON-BEARING METALLURGICAL WASTE

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The main purpose of waste management should be reclamation of valuable raw materials and, consequently, protection of natural environment by reducing consumption of deposits and energy. The metallurgical industry generates considerable quantities of waste containing iron. This article addresses environment-friendly solutions for utilisation of such waste in the form of slime, sludge and dust. What has been discussed is the impact of the technologies proposed on natural environment.

Key words: metallurgical industry, iron, ecology, waste management

INTRODUCTION

Substances referred to as *waste* are subject to rigorous legal regulations the purpose of which is to protect human health and natural environment. Restricting waste generation is the most fundamental principle of rational use of natural and anthropogenic resources, whereas the main goal of waste utilisation is recovery of valuable components (e.g. energy or metal). Decisive for the choice of the waste utilisation technology, not only the economic but also the environmental protection aspects are taken into consideration.

Next to mining and power engineering, the metallurgical industry generates large quantities of waste. In accordance with the applicable legal regulations in force, a waste owner is obliged to prevent the waste generation in the first instance, and secondly to recycle or neutralise waste the generation of which could not be successfully prevented.

IRON-BEARING METALLURGICAL WASTE

The metallurgical industry is one of the largest sources of wastes such as slime, sludge and dust from waste gas purification processes conducted in sintering plants, blast furnaces and steelmaking shops, featuring both converters and electric furnaces, cooling systems for the machinery operating at high temperatures as well as rolling mills. The general principles of managing this waste have been laid down in Council Directive 75/442/EEC on waste, as amended by Council Directive 91/156/EEC. A separate set of regulations applies to the requirements concerning hazardous waste. This subject is provided for in Council Directive 94/31/EC, defining the manner of handling hazardous waste. A list of these types of waste, officially referred to as the List of Hazardous Waste, was published as Council Decision 94/904/EEC.

Sludge and residue produced while iron and steel is manufactured and processed can be divided into the following groups [1,2]:

- pure iron-bearing sludge with the iron content exceeding 60 wt%,
- contaminated iron-bearing sludge,
- oily residue,
- sludge produced in working of metal components,
- sludge from cleaning of cooling systems for steelmaking machinery.

Electric Arc Furnace Dusts (EAFDs) are waste materials from the steel manufacturing process. What is referred to as dust is a collection of solid particles of various sizes and different origin which remain suspended in gas for some time [3]. In accordance with the applicable EU regulations, the solutions recommended for EAF mainly include environmentally friendly activities aimed at reduction of quantities of dust being generated and ensuring its reclamation through various forms of recycling and utilisation.

Waste materials, such as sludge and residue, require removal of the water excess prior to further stages of their processing. Complete separation of sludge and residue lumps can be obtained on the moisture content corresponding to ca. 20 wt % of H_2O, whereas on the moisture content of 10-15 wt % of H_2O, sludge and residue become loose which facilitates their batching in further technological operations [1].

A part of sludge and residue from the metallurgical industry is oily. Oily sludge and residue are currently utilised in small quantities, usually in production of Portland cement clinker or as colouring additives in concrete production. It is indeed for their oiling that wider application of those waste materials is rather difficult. What the oil content precludes is, among others,

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their utilisation in sintering plants equipped with electrostatic precipitators due to the hazard of self-ignition and heat fires. Therefore the development of the oil removal methods for iron-bearing sludge extends the capacity to utilise this iron-bearing metallurgical waste type. Oil may be removed from oily sludge by spraying it with organic acid at the temperature of 60-80 ^{o}C [4]. The products thus obtained are deoiled scale and effluents in need of treatment [5,6].

Electric arc furnace dusts are among the most troublesome products of steelmaking processes being particularly difficult to store and transport as well as posing a serious environmental threat [7]. They constitute production waste which can be utilised in various ways primarily depending on the dust's content of zinc. The utilisation options are as follows:

– furnace recycling by introducing dust with zinc content up to 4 % together with other charge materials (feeding of blast furnaces, converters or EAFs),
– zinc recovery from dust with the zinc content exceeding 20 %, e.g. in a rolldown furnace or by application hydro-metallurgical methods,
– recycling of dust with the zinc content from 4 % to 20 % in other non-metallurgical industries.

EAFDs can be utilised in non-metallurgical industries for a number of purposes, e.g. in production of cement clinker, ceramic construction materials as well as domestic and decorative glassware.

The physical and chemical tests of EAFDs confirmed their applicability in cement clinker production, particularly due to the iron content of more than 33 % and the zinc content below 10 % [8,9].

ENVIRONMENTAL PERSPECTIVE FOR ASSESSMENT OF THE METALLURGICAL WASTE UTILISATION SOLUTIONS

Waste utilisation is a pro-ecological activity, therefore, from the perspective of the project discussed in the paper, also the benefits related to protection of natural environment and human health should be of relevance. In order to assess the potential environmental hazard connected with utilisation of steelmaking dust and sludge, the waste types studied were classified, their chemical composition analysed, leachability of the contaminants they contain examined, and they were also tested for radioactive properties. In accordance with the applicable Polish legal regulations [10], the dust and sludge studied have been qualified as hazardous waste.

Based on the chemical composition analyses conducted for steelmaking waste, it has been found that the main components of the waste types examined, i.e.:

– EAFDs, are: iron (ca. 34 %), zinc (ca. 9 %), calcium (ca. 4 %), manganese (ca. 2 %) and lead (ca. 1.5 %),
– steelmaking sludge, are: iron (ca. 41 %), zinc (ca. 7 %), calcium (ca. 5 %) and lead (ca. 1.0 %).

Results of the analysis of water extracts prepared from EAFD and sludge were compared with maximum values of permissible contaminant contents for treated industrial waste discharged into water or soil, and then it was established that pH of the dust and sludge types studied indicated their alkalinity. With regard to EAFDs, excessive leaching of sulphides, fluorides, chlorides and zinc was found. The steelmaking sludge examined showed no exceedance of the indices studied compared to the highest permissible values for the waste discharged into water and soil.

The radioactivity tests conducted proved that both EAFDs and steelmaking sludges met the conformity criteria in the scope of values of qualification factors $f_1 \leq 1$ and $f_2 \geq 185$ Bq/kg [8]. On account of their radioactivity, the waste tested may be utilised in production of construction materials.

The physical and chemical tests of EAFDs confirmed their applicability in cement clinker production. The basic measure applied in the assessment of the extent to which adding steelmaking dust to furnace charge affects the scope of environmental impact of the cement clinker burning process is an analysis of the heavy metal balance in a cement kiln. The metal circulation balance developed has implied that the amount of metals released from a kiln smokestack along with dust (zinc, lead, cadmium, copper, chromium and nickel) is smaller than 3 %, with the highest value for cadmium being 2.98 % [8]. The test results evidence the incorporation of heavy metals in the mineralogical structure of the clinker.

In order to determine the environmental impact of the clinker manufactured using EAFD additives, leachability of the contaminants examined, and heavy metals primarily, was tested. The water extract was analysed and the results obtained compared with the highest permissible contaminant contents for effluents discharged into water and soil based on the mandatory values imposed by the Polish regulations. An analysis of the leachability test results for clinker contaminants implies that values of heavy metal concentrations in water extracts are lower than the highest permissible values for effluents discharged into water and soil. Results of leachability tests for contaminants present in the clinker obtained by adding EAFDs imply the incorporation of heavy metals with the clinker's crystallographic lattice, and hence the capacity to apply the technology in question for utilisation of EAFDs.

An environmental impact assessment for the bricks obtained in the course of the industrial test was based on the study of leachability of contaminants. For all the parameters determined, the respective water extracts conformed with the requirements applicable to effluents discharged into water and soil. The only indicator to have exceeded the permissible limits was pH, however, the same was found for both the bricks prepared with the EAFD additive and without one [9]. Results of the leachability test for the contaminants present in the trial brick batch imply full immobilisation of heavy metals in the ceramic process, and hence the capacity to apply the technology in question for the sake of the waste (steelmaking dust) utilisation.

The industrial tests undertaken in order to examine the options of using EAFD in domestic glassware production proved its usefulness as a molten glass dye in manufacturing of coloured domestic glassware as well as semi-finished glass products for artistic purposes. While preparing the molten glass, EAFD is subject to full vitrification and the heavy metals it contains are incorporated with the glass structure, and therefore it causes no pollutants to be released into the environment.

CONCLUSIONS

Metallurgical waste management is a difficult activity, primarily due to the deleterious impact of most such waste types on natural environment as well as human life and health. The solutions proposed in this paper are environmentally safe, constituting a proposal for innovative utilisation of a part of the EAFD as well as oily metallurgical sludge.

Metallurgical waste utilisation based on substitution of primary raw materials with the secondary ones will lead to reduction of the natural environment degradation, by both limiting depletion of natural resources, including energy resources, and decreasing the quantities of waste stored at dumps, and hence reducing the number and size of the dump sites themselves.

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