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Review

Management of solid wastes from steelmaking and galvanizing processes: A brief review

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ABSTRACT

Waste generation is inherent to any industrial process. Gaseous and liquid wastes are commonly treated in plants, resulting in clean streams and solid fractions. This solid fraction, along with the solid waste generated during the process itself, requires treatment and/or appropriate disposal in compliance with environmental laws, giving priority to reuse rather than final disposal in landfills. In the steel industry, the possibilities of solid waste disposal are important sources of research to achieve sustainable industrial standards. In this context, this paper presents an updated review of the management of slags, sludges, dusts, and mill scales generated by the steel industry, including precipitating sludges generated by galvanizing processes. Current knowledge and studies on the development of alternative management plans were also examined, bearing in mind the importance of sustainable development and the responsible consumption of natural resources.

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1. Introduction

Any industrial activity breeds pollutants, and the steel industry is no exception. The variety of types, toxicity, and volume of generated wastes by steelmaking and galvanizing processes is considerable. Despite significant efforts carried out by these industrial sectors to minimize their environmental impacts worldwide, the demand for new technologies to reduce gaseous emissions,, increase efficiency in recycling water and solid wastes, and clean gaseous and liquid effluents is continuous. In fact, environment control has become an area of research and implementation of techniques in the metallurgical engineering sector.

Effluents normally pass through treatment plants, resulting in gaseous and liquid treated streams. Unlike the industrial management of such effluents, the management of solid wastes (including those directly generated by the steelmaking process and/or recovered by the effluent treatment plants) involves more complex procedures aimed at reducing the final amount destined to landfills or incineration. It consists of environmentally safe practices to prevent, reuse, and/or recycle generated wastes, including, whenever

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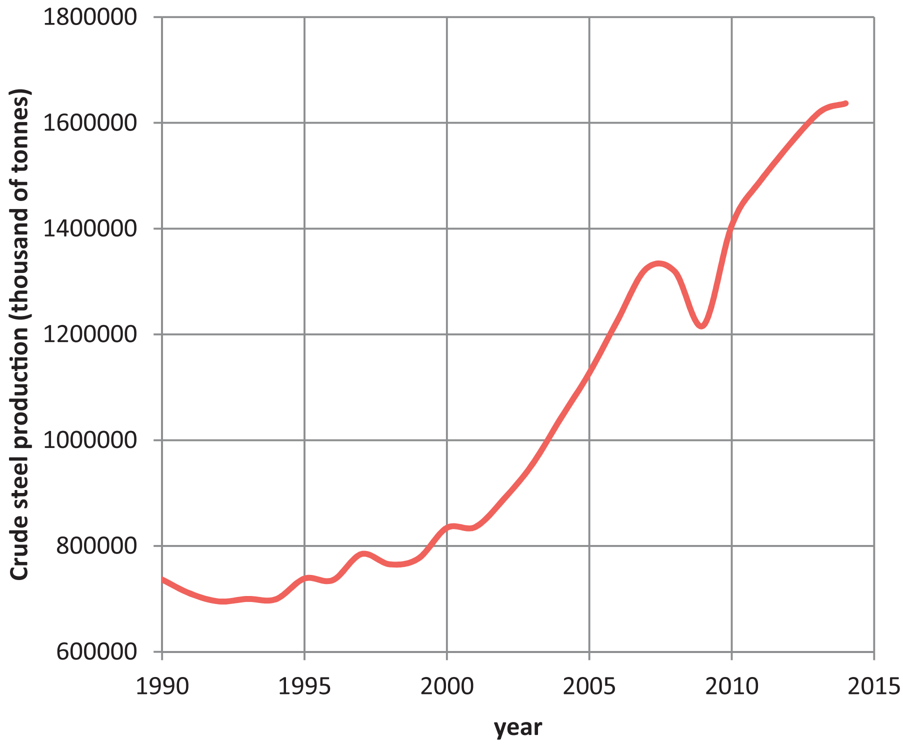

Fig. 1. World's crude steel production (Worldsteel Association, 2015).

possible, the recovery of materials and energy. The incorporation of the solid waste in the steelmaking route itself is preferable, followed by its commercialization as a raw material for other industrial processes. Alternatively this waste could be treated to reduce toxicity and/or recover elements that contain a commercial value. In this case, only a fraction of the material is used, while the remainder is sent for final disposal as tailings and/or for incineration, in accordance with the environmental regulations of each country.

In fact, actions for the recycling and incorporation of steelmaking wastes currently are being carried out by industries with promising results. For example, approximately 80–90% of generated mill scale returns to steelmaking processes by sintering, while around 85–90% of slags are commercialized to other industrial processes (Martín et al., 2012; Remus et al., 2013). On the contrary, the reuse of wastes, such as sludges and dust, are still small due to the need for specific pretreatment steps; consequently, they are commonly disposed of in landfills.

Regardless of the preferred strategy for waste management, specific consequences in terms of environmental impacts must be considered; therefore, it is of utmost importance to assess the destinations of solid waste accurately in order to minimize such consequences. This strategy choice is also associated with shorter processing times, lower amounts of handling, and lower investment costs.

2. The main types of solid waste generated in the steelmaking process

The growth of the estimated production of crude steel in the world from 1990 to 2014 is shown in Fig.1.

Steel production occurs primarily through integrated or semi-integrated routes. In the former route, the reduction of the raw material (iron ore, sinter and/or pellets; mineral coal or charcoal; and fluxing agents) in the blast furnace generates pig iron, which is then refined to produce steel, while in the latter route, steel is directly produced in electric arc furnaces (Fruehan, 1998).

The production process in an integrated steel plant and the main types of solid waste generated in each step are briefly presented as follows. First, the raw material is loaded into the blast furnace to obtain pig iron. The main types of solid waste generated in this step are slag, from the blast furnace, as well as sludge and dust, collected in the reactor gas system treatment. The pig iron goes to a refining step in the Linz-Donawitz (LD) converter to produce steel. Likewise, the main types of solid waste generated in this step include LD slag and LD sludge from the gas handling system. The refined steel then undergoes a secondary refining step, which may occur in the ladle furnace, and is then sent to the continuous casting step for solidification. Subsequently, in the rolling step, the steel achieves the required thickness and mechanical characteristics. During the continuous casting and rolling steps, a solid waste, known as mill scale, is generated by the oxidation of the metal surface.

The steps in the semi-integrated route consist of melting in the electric arc furnaces, continuous casting, and the rolling step. Thus, in the first stage, the raw material, which typically consists of scrap, is added to an electric furnace to generate liquid steel, as well as slag and dust from the gas treatment system. Table 1 shows the various residues considered in this review and the typical amount produced.

Finally, the steel can undergo a surface coating step in order to protect it against corrosion. Hot galvanizing and electroplating are the most commonly used processes for steel coating. In both methods, the obtained solid waste is an unsuitable form of sludge, rich in various metallic compounds, which is commonly obtained after treatment through the precipitation of the metals contained in the spent baths (Kong and White, 2010).

Fig. 2 presents a flow sheet of the steelmaking process, through integrated or semi-integrated routes, including the main solid wastes generated in each step.

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