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Cleaner Production in a Steel Industry

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Abstract: This paper focuses on the efficiency of steel production process of a steel industry located in the Northeast of Brazil through the eyes of eco-efficiency that integrates the three aspects of sustainable development which are economic, environmental and social. Aims to analyze the critical inputs and residues from the point of view of industrial eco-efficiency according to the Cleaner Production program on your electric steelworks. It is work based on information obtained directly in the industry. Although steelworks (unit where it becomes pig iron or scrap in liquid steel) is one of the most critical units of the steel plant, where the slag is formed, which represents the largest amount of residue generated and the greatest financial waste, it was observed that the industry in question the use of slag as a co-product for the cement industry was the choice for process improvement. Considering that the scrap, pig iron and lime are the inputs with more expensive costs in steelworks, the process temperature control is a practice that allows the reduction of these inputs, and lower energy consumption. Another practice adopted in the steelworks is the purification of scrap. It follows, therefore, that the application of the Cleaner Production program provides a significant improvement in industrial processes, particularly the steel industry.

Key words: steel industry, steelworks, sustainable development, eco-efficiency, cleaner production

1. Introduction

The development of urban society and industrial occurred in disarray causing increasing levels of pollution and environmental degradation that has entailed negative impacts significant in nature that compromised the quality of air, polluted rivers, reduced soil fertility and contributed to the increase in desert areas on our planet [1].

The technology has shown, then, that it was able to contribute effectively to the improvement of critical situations [1]. The technological advancement has enabled the development of methods of planning and equipment for pollution control. These technological tools both have correct existing problems as estimated effects and impacts of hypothetical situations through physical models and mathematical. Despite these advances in technology, it is not considered that technology will solve all the problems in full. In this field there are several limits, some of which are still unknown to the control of environmental problems.

Among the well-known limitations that prevent the absence of losses in processes that generate environmental degradation are the law of mass conservation, the 1ST law of thermodynamics and the 2ND law of thermodynamics.

The law of conservation of mass states that matter cannot be created, but only transformed. According to this law, to manufacture and dispose of the products, these only change, but its mass is preserved and never ceases to exist.

The 1ST law of thermodynamics, which also focuses on conservation, says that energy is transformed from one form to another, but it is preserved, i.e., cannot be created nor destroyed. This law shows that in order to carry out work in processes only becomes a power in another. For example, the energy potential of hydroelectric power is transformed into electrical energy which, in turn, is transformed into energy that performs work in processes such as, for example, the kinetic energy.

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The 2ND law of thermodynamics says that energy is transformed in a way more noble to another of lower quality [1]. This way, the energy changes always involve efficiency of less than 100%. Therefore, for any process, always occur energy losses so that you never get 100% of useful energy from the inputs of the processes.

The problems manifested in environmental degradation have led scholars to create in 1987, the concept of sustainable development proposed by the World Commission on Development and Environment. Formed in 1984, this commission was coordinated by Norwegian prime minister Gro Harlem Brundtland. On that occasion, the Commission considered that it was technically feasible to provide the minimum needs of the world's population until the following century in a sustainable manner and without continued degradation of global ecosystems. From then passed to understand sustainable development as a model that integrates the economy, society and the environment. Thus, it includes the concept of that in addition to the economical aspect should be considered the social aspect and the environmental aspect.

A few years after the emergence of the concept of sustainable development has emerged more a concept, called eco-efficiency, which arose from the need to synthesize the idea that it is possible to reduce the environmental impact and, at the same time, increase profitability. The term eco-efficiency was introduced in 1992 by the World Business Council for Sustainable Development (WBCSD) — World Council of Business to Sustainable Development and published in the book Changing Course.

In this perspective, it is possible to understand eco-efficiency as much as philosophy, management strategy and as a management tool. The various concepts always seek for linking the environmental performance with the economic performance to create more added value with less impact to the environment. Eco-efficiency is based on three pillars [2]:

• Reduce the consumption of resources;

• Reduce impact on nature;

• Improve the value of the service or product.

These principles are correlated with other seven elements, also recognized by WBCSD, assuming that the business can use them to improve the eco-efficiency [2, 3]:

• Decrease the consumption of material goods and services;

• Reducing the energy consumption of goods and services;

• Reduce the dissipation of toxic substances;

• Intensify the practice of recycling of materials;

•Maximize the sustainable use of renewable resources;

• Increase the durability of the products;

• Enhance the service.

However, the concept of “eco-efficiency” has been undergoing changes in accordance with the organization and its applicability. Several business leaders defined this concept in a general way how to do more with less [2]. People who work in the area consider eco-efficiency as the synthesis of economic efficiency and environmental, in which the prefix eco represents the economy and ecology.

After the understanding of the need for the application of eco-efficiency for the sustainable development, experts and industrial leaders have created a program called for Cleaner Production (CP) that encompasses the sustainability. This program is a method for the prevention of pollution, which is defined as continuous application of a strategy environmental, economical and social preventive and integrated services, processes and products. The CP is designed to increase the efficiency in the use of raw materials, water and energy, thereby providing a non-generation, minimisation or recycling of waste and emissions.

In 1992, the Newsletter of Cleaner Production (Journal of UNEP on Cleaner Production) has published four statements that try to define as Cleaner Production [4]:

• Cleaner Production is the continuous application of an integrated environmental strategy and preventive processes and products to reduce the environmental and social risks;

• The Cleaner Production techniques include the conservation of energy and raw materials, the elimination of toxic materials in the processes and the reduction of the quantity and toxicity of all emissions and wastes;

• The strategy of Cleaner Production for products emphasizes the reduction of environmental impacts throughout the product life cycle (from the extraction of raw materials to the ultimate disposal of the product);

• The Cleaner Production is achieved by the application of evaluation, technological advances and changes in attitude.

Thus, the CP proposes that companies invest in waste reduction since there is methodologies to assist this process. The methodology of CP involves some steps and presents the following way [5]:

(1) Planning and organization: commitment of the board and the staff, and the formation of work teams;

(2) Pre-evaluation and diagnosis: determination of goals for CP and completion of flowcharts, with evaluation of inputs and outputs;

(3) Evaluation of CP: identify the actions that can be implemented immediately and those that need new more detailed analyzes by means of balance sheets of materials and energy and information of the sources and causes of the generation of waste and emissions.

(4) Feasibility study technical, economical and environmental: choose the opportunities viable and document the expected results;

(5) Implementation and continuity plan: implement the selected options and ensure activities that maintain the CP, monitor and assess the opportunities implemented, in addition to plan activities to ensure the continuous improvement of the CP.

The environmental technologies conventional work primarily in the treatment of waste and existing emissions, acting at the end of the production process (techniques for end-of-pipe) and generate new costs for the company as, for example, the deployment of treatment plants.

The Cleaner Production, in turn, integrates the environmental objectives in the process of production, in order to reduce waste and emissions in terms of quantity and toxicity, and implies the reduction of production costs.

Some of the benefits of the program on Cleaner Production in comparison with the conventional technologies for end-of-pipe as are expressed below [6]:

- Occur the decrease the amount of materials and energy used;
- Exploitation of productive process with the minimisation of waste and emissions, providing a process of innovation within the company;
- Production process is observed as a whole, reducing the risks in the disposal of waste and environmental obligations.
- Access to an economic development stronger, provided by minimizing emissions and waste.

In industrial processes, the production of steel in steel plant is one of which promotes greater impact on sustainable development, in view of the high power consumption and large amount of inputs and waste generated in the production.

In the steel mill, in a general way, the production of steel occurs in four stages: preparation of load, reducing, refining and lamination.

In the stage of preparation of the load through the sintering, clumps iron-ore is forming the sinter. This step occurs also processing coal in coking plant forming the coke.

At the stage of reduction, the raw materials are loaded and ready for the blast furnace. In the bottom of the blast furnace oxygen is blown heated to a temperature of approximately 1000 degrees Celsius. The coal comes in contact with oxygen transferring thermal energy that melts the metal load and start the

reduction of the iron ore into pig iron liquid. The pig iron is an alloy of iron-carbon with high carbon content.

In the next step is the refining where the steelworks transform iron liquid or solid and scrap in liquid steel. At this stage, part of the carbon contained in pig iron is removed along with the impurities.

The step of laminating, semi-finished goods, ingots and blocks are processed by rolling mills and processed in different steel products, whose nomenclature depends on the shape and the chemical composition.

One of the most critical units of the steel industry in accordance with the vision of sustainability is the steelworks, which involves a large amount of inputs and waste. In this unit of steel plant occurs the refining phase of steel. In this step, as was said earlier, the machinery and equipment of the unit transform the pig iron (liquid or solid) or scrap in liquid steel.

The steelworks is a unit that is present in any type of steel plant. The steel industries can be classified according to their productive process, such as:

Integrated — that operate the three basic stages: reduction, refining and lamination are involved in the whole production process and produce steel

Semi-integrated — that operating two stages: refining and lamination. These mills departing from pig iron, sponge iron or scrap metal purchased from thirdparties to transform them into steel in the electric steelworks and its subsequent lamination.

In the mills integrated processing of pig iron in steel (refining) is made in oven to oxygen and in the mills semi-integrated the scrap and pig iron solid are refined in electric furnace.

Fig. 1 Image of a Electric Steelworks [7]

Considering the large number of waste produced in the electric steelworks, it is necessary to reduce the inputs and the generation of waste by means of eco-efficiency and industrial, and those that are generated, should be reused in some way.

In this perspective, the aim of this study is to analyze the inputs and critical residues (from the point of view of industrial eco-efficiency in accordance with the program CP) of a electric steelworks of a steel industry in the Northeast region.

2. Method

Basing it on tasks of the methodology of the Guide to the Cleaner Production of Brazilian Business Council for Sustainable Development (CEBDS) [8], in 2014, was analyzed the electric steelworks in a steel plant semi-integrated (which uses electric steelworks) from the Northeast Region of Brazil.

All data were collected in a race (production cycle of the steelmaking plant) and according to the tonne of liquid steel produced.

For the purpose of analysis, the costs were transformed into annual as requires the program CP.

It was analyzed the economic losses, social and environmental caused by solid waste, liquid and gaseous effluents in accordance with the vision of eco-efficiency of the process.

3. Results and Discussion

In the analysis of inputs and critical residues of the electric steelworks, it was decided to carry out the balance of mass and energy of the electric furnace, since there are the inputs and waste more critical the steelworks in the production process, i.e. , those that represent major risks to the environment and higher costs. Thus, through the balance of mass and energy you can identify the inputs and waste which entail greater damage to sustainability. Is shown in Fig. 2 below the mass balance and energy the electric furnace steelworks in analysis.

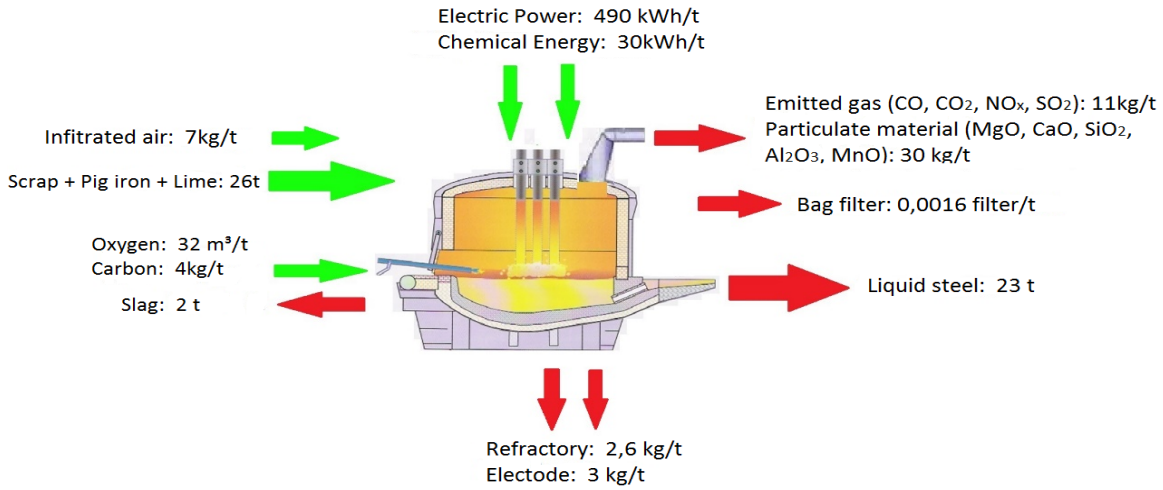

Fig. 2 Mass Balance and Energy of the Electric Furnace in the Electric Steelworks

Through the analysis of the mass balance performed at work it was found that the scrap, pig iron and lime are the inputs that represent the highest cost in the process because they are the raw materials that will be processed into liquid steel, i.e., are used in greater mass. To reduce the quantity of inputs as asks the program CP, the industry in reference performs procedures in order to increase the efficiency of the process, such as the processing and purification of scrap, which provides a greater quantity of steel generated with less scrap. This procedure is performed through the crushing and pinching of the scrap and magnetic separation.

According the ABNT norms, the Brazilian Association of Companies of treatments of Services (ABETRE) says that the solid industrial wastes are all those who are in the solid state or semisolid resulting from industrial activities [9]. If they are played to the environment may cause diseases in the population, destroying forests, damaging soils, etc. therefore, the industry must seek to reuse and recycle waste in some way.

In the steelworks analyzed, in each production cycle, the slag, in kg, represents approximately twice the amount of other waste and carries the largest financial waste as seen in Fig. 3.

In this case, the alternative of this industry is to sell the slag for companies that make asphalt and, thus

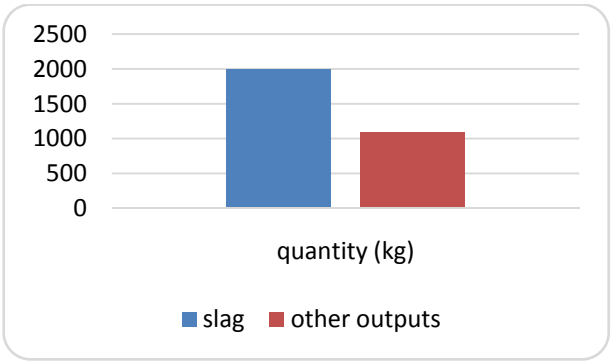

Fig. 3 Comparison Chart between the Quantity of Slag and Other Waste Generated by Race of Production

reuse this residue as a co-product of the process. Among other possibilities to reuse the slag are their sale to the construction industry, the cement industry, glass, among others.

The electrical energy is another input that can be saved in the steel industry. The lack of electricity generates a social impact in the everyday life of the population, limiting the work, transportation, etc. The industry investigated reduces the use of this feature. For this, adopts in its steelworks a programming that regulates the power supplied by the oven at different stages of the process so that they do not have a temperature or too high or too low. The cost of electrical consumption represents only about 2.5% of the purchase cost of the main raw materials of the process which are the scrap, pig iron and the lime, as is illustrated in the Fig. 4.

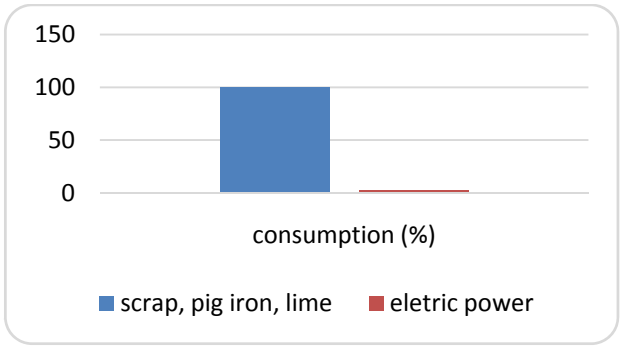

Fig. 4 Chart Comparing the Cost of the Consumption of Electricity and of the Main Raw Materials of the Electric Furnace

Also was analyzed through the balance of mass and energy, the consumption of water in industry investigated. It was found that approximately 95% of this input is recirculated in the industry reference, which provides a spent considerably less than that from other raw materials and certainly less than the agricultural activity as shown in Fig. 5.

The water that does not have direct contact, such as is used in cooling the steelworks can be recirculated continuously [11]. The industry must not recircurlate water that has direct contact with the substances of the production process. Liquid effluents released by the steel industry may generate environmental problems such as water contamination that affects the health of people and animals, as well as to contribute to the contamination of reservoirs.

The industry has also concern facing the atmospheric effluents that should be filtered to prevent damage to health and the environment. The steelworks

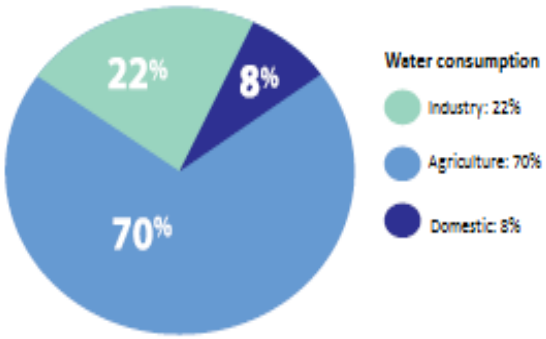

Fig. 5 Water Consumption from Different Sectors [10]

of industry in analysis uses bag filters that allow the significant decrease of atmospheric waste released to the environment. In this way it complies with environmental legislation and prevents social damage as lung diseases, asthma, eye irritation, aggravation of cardiovascular problems, among others, and environmental damage such as losses in vegetation and in the soil, acid rain etc [12].

It was observed that in the steel thermal control of the furnace of the steelmaking plant increases the efficiency of the reactions, which leads the industry in need of less raw materials in their production process and a lower power consumption which also contributes to environmental preservation. This practice meets the vision of eco-efficiency, guaranteeing a reduction of impacts on sustainable development, and is also an option that meets the program on Cleaner Production.

4. Last Remarks

As can be seen the implementation of the program CP provides a significant improvement in industrial processes, with emphasis on the steel industry.

It is understood that in the industrial process is necessary to reduce the generation of waste. The laws of thermodynamics say that it is impossible to exist an industrial process without losses and, therefore, it is important to seek reclaim them in all possible ways.

The slag is the main residue generated in the meltshop, generated in an amount well above the other waste and represents the largest financial waste in the production cost of the steel industry in analysis. In addition, it generates environmental problems, reality that reinforces the need for reuse of this residue by industries, the example of the steel industry analysis that sells its slag to companies responsible for the construction of the asphalt and, this way, reused as a co-product.

The scrap, pig iron and lime are the inputs with cost more expensive in the industry analyzed. The steel industry needs continuously a more efficient process, aiming to eco-efficiency, as suggested by the program

CP, so that always reduce losses and require fewer raw materials for the same amount of steel produced. Reduce the quantity of inputs is a measure that provides less of an impact on sustainability. Measures such as temperature control to reduce the power consumption and the purification of the scrap are very important to increase the efficiency of the process.

Through a continuous improvement of the efficiency of the process, which meets in an integrated manner with the economical, social and environmental aspects, in accordance with the concepts of sustainability, the industry acts in accordance with the eco-efficiency as suggests the program CP.

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