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Evaluation of energy generation potential from residues generated in a footwear industry

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Abstract: - The leather-footwear industry became responsible for the generation of a large amount of solid waste, mostly received in landfills. However, this would be the final option for its disposal, exhausted all possibilities for its reuse. In this scenario, there are alternatives for the treatment or reuse of these wastes such as coprocessing, a non-commercial waste recovery process, which consists of the recovery and recycling of waste for use as partial substitutes for the fuel and raw material in the process of production of cement (clinker). Incineration is a thermal waste treatment process and thermal hydrolysis consisting of the breaking of molecules that results in gelatin, which in the case of leather produces fertilizer. The heat generated allows its use as a form of production of electric energy and steam. This paper will present a study of the possible alternatives of waste disposal, with the objective of studying a way of transforming this waste into electric power generation, in order to be used by the companies of the footwear segment of the Paranhana valley region in RS, since the economy of this region revolves around this segment.

Keywords: - *Electricity, coprocessing, waste, incineration, thermal hydrolysis.*

I.INTRODUCTION

Municipality Solid Waste (MSW) represents one of the most severe environmental problems in the modern world, with a tendency to increase with population and economic activity [1].

The maximization of productivity and competitiveness has become, in an increasingly pronounced way, a central focus of the attention of the productive sector towards the sustained growth of the country's economy and the companies' survival [2]. Innovation has come to play a significant role in the competitiveness of companies, particularly in the sectors of accelerated technical and scientific progress [3].

Currently, this sector is going through a time of intensification of competition, in which companies are forced to rethink their strategy and seek new investments and new technologies to innovate to stand out from competitors and conquer new markets.

With the technological advancements, the shortening of barriers caused by globalization and, consequently, the potential struggle for space in the market, one can perceive the main dynamic character in which the organizations are involved [5]. With the competitiveness in the market is facing, companies tend to look for viable solutions like process improvement with this cost reduction and optimization in their products and services [6].

With the economic growth and the search for improvements in the manufacturing of industrialized products, it is necessary to invest in technologies that minimize the consumption of raw material, with better use, and consequently reducing the solid waste generated [7-8-9].

Footwear companies generate large amounts of solid waste such as leather trimmings, fabrics, foams, synthetic PU and PVC, insole, EVA, rubber, and other wastes [10].

The present work had as objective to discuss the different alternatives, in the research phase and possible future implantation, of a form of energy generation through solid waste generated in the productive process of this industry. Since in the region where the industry operates one of the leading industrial activities are companies in this segment, it is possible to study a potential partnership with other companies in the region that have the same concern on this subject. The study in this article will be a small sized located in the city of Três Coroas/RS in the segment of men's shoe.

II. BIBLIOGRAPHICAL REVIEW

In Brazil, according to industrial waste is the obligation of the generator, most of the industries adopt the outsourcing of this service since it is more economically efficient and that favors more than one industry, in the case of footwear companies of the region under study also adopt this practice. Although the public power specifies the quality standards in waste management, whoever is responsible in practice is the generator itself, as executor or contractor [11].

Waste treatment is any process that changes the characteristics, composition, or property of the waste, to make it less impacting its final disposal in the soil or only its destruction [12].

The waste generated by the footwear associated industries of the city of Três Coroas is disposed of in the Landfill of Hazardous Industrial Waste - ARIP until 2013. This was a quick and economic destination, but it is not a permanent solution since materials are confined, generating a liability environmental. Another difficulty is due to the large quantity of material sent for disposal in ARIP's, the capacity of these ends being exhausted in short periods, leading to the construction of new landfills [13].

There are many ways to recycle the materials used in the manufacture of footwear. One of the already consolidated methods is the manufacture of gelatine, agglomerated leathers, oils, and animal feed products such as dog food. Other methods under development and still under study is the use of cosmetics and hydrolysates of protein for animal feed [14].

As of 2014, companies started adopting other methods of destination, as shown in figure 1, but there were still buried residues for years destined for co-processing [15].

In 2017, 566.53 tons of industrial wastes were received from class I and II.

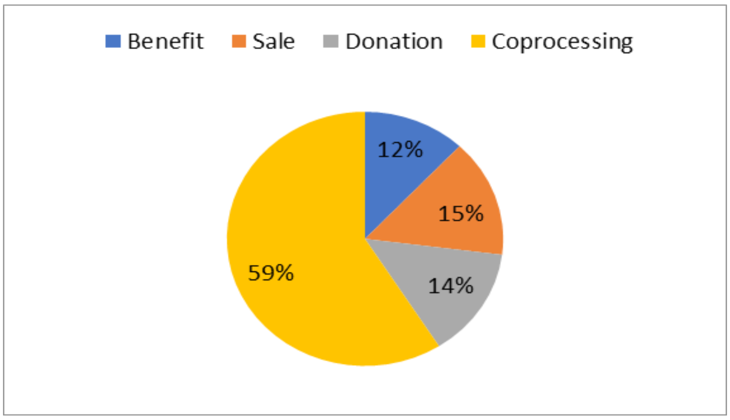

Figure 1 - Destination of waste generated in 2017.
Source: Sindicato das Indústrias de Calçados 2017 [15].

In the graph of figure 1, the companies current concern for the waste generated by it can be observed, firstly if a sustainable alternative is sought for the destination and after all possibilities have been evaluated, the waste is destined for landfills.

Co-incineration, also called co-processing, is the use of waste as raw material and as a source of energy. In this case, it has to replace natural mineral resources and fossil fuels in industrial processes, especially in energy-intensive industries such as cement production and power generation. This method has several benefits such as a reduction, and greater control of pollutant emission levels can replace conventional fuel by up to 30%, there is a reduction in energy consumption, there is also an increase in investment in the environmental area.

The co-processing process takes place inside a rotary kiln which provides a region with a temperature between 1400 ° C and 1500 ° C, with residence time, turbulence and atmosphere capable of achieving a minimum destruction and reduction efficiency (EDR) of at least, 99.99% of the Principal Persistent Organic Compound. As for the inorganic components, which will be present in the ashes, they are incorporated into the clinker (main element for the production of cement), eliminating the residue and the risk of environmental liabilities.

Considering the situation of the cement industry in Brazil, where there are excellent idle capacity and the need to use cheaper fuels, co-incineration has emerged as a great business opportunity for the sector. First, companies reduce operating costs due to reduced fuel and raw material purchases. Second, they increase their billing by collecting, most of the time, waste treatment. In some cases, revenue from co-incineration and fuel economy can reach about 10% of a factory's turnover [16].

The term co-incineration is the correct one to designate the practice adopted in the industry instead of the term coprocessing [17]. Coincineration is the correct term when the residue is the fuel, and the waste is used as a source of heat and raw material, can be incorporated into the clinker and improving the quality of the product, the most appropriate term is coprocessing. Using the word coprocessing is the most suitable for the elimination of waste not only by the generation of energy, but by the focus on collaborating with sustainability [18]. In this article, the term coprocessing will be adopted, since the materials pertinent to the production of footwear after coprocessing are incorporated into the clinker.

The wastes that can be processed are EPIs, rubbers, tires, oily lees, paints and solvents, furnace ash, contaminated soils, station sludge, packaging, pulp, wood, cellulose, among others, materials similar to those used in the manufacturing of footwear.

This coprocessing method is continually evolving and is being increasingly used for environmental and energy reasons. Residues used as alternative fuels reduce the cost of the process by replacing conventional fuels required by the high temperatures of the clinker kiln. However, about the environmental aspect, coprocessing is an alternative to waste disposal that could have a provision of more significant environmental impact [17].

Incineration is a process of reducing the weight, volume, and hazardous characteristics of the waste, with the consequent elimination of organic matter and pathogenicity characteristics, through controlled combustion. Today, this conception is even more relevant, stating that incineration is also a process of recycling the energy released in the burning of the materials, aiming at the production of electric energy and steam, which can be immediately converted into cold / co-generation [19].

This process of thermal degradation of the waste occurs within equipment called an incinerator that provides a temperature between 800 ° C and 1000 ° C, providing residence time and turbulence necessary for the thermal degradation of the waste. This degradation provides the volume reduction by turning them into ashes, which still need to be disposed of in controlled landfills. Control and monitoring of ash composition are mandatory, and stabilization or inertization processes may be necessary to avoid contamination of the environment.

Among the wastes that can be incinerated: polychlorinated biphenyls (ascarel), organochlorines, organophosphates, laboratory reagents, health services (autoclave), among others, these materials do not resemble those used in the production of footwear. Most used when it comes to urban waste.

Incineration can be environmentally sound and allied to the protection of the environment, provided that they are operated by qualified and trained teams and are accompanied by the community and the public and private environmental agents. The solutions for the management and disposal of solid waste are increasing because this problem is growing and has been recognized as an immense factor aggravating the environmental crisis [20].

In Brazil, incineration is used to solve the final disposal of hazardous waste and part of hospital waste. However, this technology currently used in the country does not make use of the energy use, for that purpose some technological improvements would be necessary to allow this use in an economically viable and environmentally correct way [21].

The presence of Cr in the ashes of the incineration process has instigated several researchers to investigate alternatives for the use of this mineral, among them, and the benefits for this study in question will be the proposed use of the obtaining of fuel oils and gases for the generation of energy [22].

The costs of waste incineration for waste incineration plants according to the new environmental preservation standards are very high. Vast sums are needed mainly in the construction of the smoke purification sections, so the investment expenditures required to construct an urban waste incineration plant far outweigh the income from the sale of waste heat [23].

Given the technologies currently available and the standards in force, an average investment of 150 million ECU (excluding the land price) is required for the construction of a 100,000 tonnes per year waste incineration with competence to serve 200,000 inhabitants. For technical reasons, building only a large waste incineration plant is less costly than building several small deployments [23]. In areas of lower population density, cooperation between cities in surrounding communities will be necessary. Currently, it is no longer a trend in Europe to build a waste incineration plant of each town, but rather for each regional center with a capacity of up to 400,000 tonnes of waste per year [23].

Thermal hydrolysis pretreatment is widely used as a method of waste disposal as sludge, which consists in dissolving the organic matter using pressure and temperature [24].

The industry has been adopting this method as a solution for all leather residues used in companies, whose material is the basis of the raw material, the leather chips are hydrolyzed in individual reactors, in a controlled environment, with high temperature and high pressure, promoting their transformation into gelatin, by an enzymatic thermal hydrolysis process. The gelatine then undergoes a drying process, at a controlled temperature, where it is stabilized and successively sent to sieving, obtaining organic fertilizers, with different granulometric ready for shipment. The process does not use chemicals and meets all environmental requirements. In cultures where this substitution of mineral fertilizers by leather fertilizers is occurring, greater success in the productive processes is assured [25]. These authors argue that no doubt hydrolyzed leather develops characteristics more accurately than vegetable fertilizers. This fertilizer is classified as nitrogen fertilizer, according to the Italian fertilizer law [26].

According to Germany's government-run Bundesamt recycling agency, where the incineration of domestic and urban waste has a long tradition, in 2016 there were 68 municipal garbage incineration plants. All waste incineration plants use the resulting energy such as electricity, process steam, and district heating [27]. Its recycling operates on a large scale. For example, the rubbish numbers: 66% are already recycled, 34% incinerated, and going to landfill is zero percent.

Recycling and other forms of disposal of industrial waste are the subjects of many studies. Recycling is one of the ways to avoid the release of waste into the environment and generate benefits to the health of the environment, as well as add value to the product [28].

There are many benefits of burning garbage to the environment, but technological advances are still poorly understood in Brazil, not to mention that legislation is still timid because it has regulated landfills, whose activity causes damage to the environment in terms of emission of methane gas. Waste incineration technology has advanced a lot and has active control of the emissions of gases, but the perception in Brazil is still that of the old incinerators, already deactivated and that was not very efficient in terms of technology and emissions [29].

For the generation of energy from the burning of the garbage to become a reality in Brazil, it is essential that some bills in progress in Congress regulate the operation of the plant. Prospects begin to improve depending on the possibility of the Solid Waste bill. There is also the expectation of the creation of a special tax regime for alternative sources of energy and the inclusion of the burning of garbage in this proposal.

According to Germany's energy comparison website, waste incineration plants have been in operation since the late 19th century. These plants must meet several requirements for their service. The combustion gases produced during the process contain pollutants that must not exceed stipulated limits.

Currently, most waste incineration plants operated, have a structure that can be comparable [30]. The Brazilian legislation (Resolução 264 Conselho Nacional de Meio Ambiente – CONAMA, 1999) establishes two classes of waste that can be co-processed in industrial processes: the residues that can partially replace the raw material, if they have characteristics similar to this one and the residues with high energetic power that can be used as secondary fuels [31].

Environmental protection legislation establishes that an environmental impact study should be carried out before the construction of a waste disposal site [23]. The documentation to be delivered in order to obtain the authorization must include an environmental impact assessment with the purpose of informing the competent administrative authority to approve the project, to illustrate the data and environmental problems identified during the design of the project, which should be taken into account and, where appropriate, provision should be made for measures to eliminate, reduce or compensate for adverse effects on the environment.

The values of upper and lower calorific values were respectively 5170 kcal/kg and 4,835 kcal/kg. Fuels having a calorific value exceeding 2150 kcal/kg and 3000 kcal/kg allow self-sustaining combustion, and there is no need for an auxiliary fuel, provided that the humidity does not exceed 50% [32]. Several authors have studied the calorific power of materials used in the manufacture of footwear, characterized leather chips and reached a result of 4,406 kcal/kg of higher calorific value and 3959 kcal/kg of lower calorific value [33]. The calorific value in the values of 4,500 kcal/kg or 18,840 J/g, approximately 45% Cr_2O_3, less than 2% of sulfur, considered a low cost [34]. In addition to that, the leather has salts, sulphites, and mainly heavy metals [35]. Several authors confirm the possibility of using leather in heat treatment processes and biofuels [36-22]. The possibility of recovering the heat produced in the heat treatment is the production of saturated steam, which can be used in the footwear industries [33].

These characteristics make this material suitable as a fuel in a controlled incineration process, which can recover thermal energy or electric energy since they have adequate characteristics for combustion and high calorific value fundamental parameter for combustion processes [37].

The uncontrolled combustion process can cause damage to health and the environment, ranging from the formation of acidic compounds to the creation of carcinogenic compounds, the release of compounds such as NOx and SOx, cause atmospheric pollution and can generate acid rain [38- 39].

III. MATERIALS AND METHODS

The methodology used in this article was an applied research of the existing alternatives of a generation of energy through other options of renewable sources.

First: Bibliographic research on methods currently used, coprocessing, Incineration, and Thermal hydrolysis.

Second: A research and contact with Union of the industries to know if already something has based on this subject. Analysis of the industry, monthly costs in the disposal of solid waste, and measurement of the amount of waste that this industry generates monthly, after that an analysis of possible partnerships in the region if the proposed method is implemented.

Third: Analysis of the most appropriate form of energy for the waste generated, based on its calorific value.

The waste generated by the industry under study is destined to a collection center of the city, which is responsible for the correct destination of the materials according to table 1 below, the types of waste produced in the industry studied according to its classification, followed by the value paid by kg to the collection center.

Table 1 - Classification of waste and amount paid in kg.

Class	Product	Value R$/kg
Class I / Coprocessing	Chrome leather	0.67
	Leather dust	0.67
	Cracked	0.67
Recyclable / Sale	Buttress	0.30
	Cans II	0.30
	Reel	0.30
Recyclable / Donation	Adaflex/Serraflex	0.30
	Doubts	0.67
	EVA	0.30
Class II / Coprocessing	Leather Strapped	0.67
	PU Lining	0.67
	Thread Tools	0.67
	Cloth	0.67
	Class 2 powder	0.67
	Other Leather parts	0.67
	Shoe Parts	0.67
	Factory Sweeping	0.67

In table 1, the wastes classified by class I and class II are the materials with a larger volume in the manufacture of shoes of this industry since it works with shoes in leather, whose value paid is higher than the materials in synthetic or fabrics. It should be noted that materials destined to recyclable / donated are also paid to the waste collection center.

This topic is the data collected from the shoe industry in the year 2017, the amount of waste generated, the use of power paid during that year. According to the graph in figure 2, the result of the collection of waste volumes produced during the year 2017.

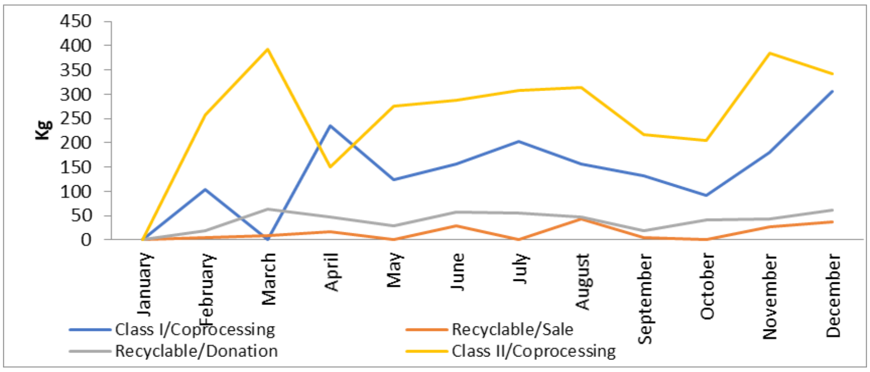

Figure 2 - Quantity of waste generated in 2017 by the industry.

The graph of figure 2 shows the presence of a higher generation of class II waste, material used to manufacture most of the footwear, followed by class I waste, after the waste destined for recyclability or donation, and finally the waste recyclable/sale. The sum of the amount of waste generated in 2017 was 5475.6 kilograms. In the graph of figure 3, the sum of the amount that the industry pays in R$ for the amount of waste generated in 2017 follows.

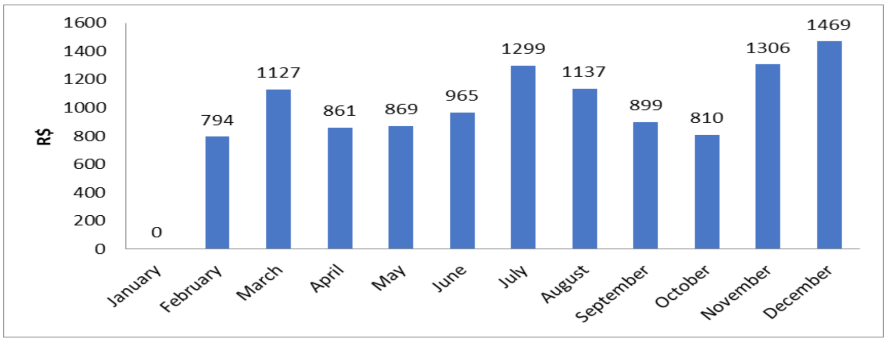

Figure 3 - Amounts paid in 2017.

With the sum of the amounts paid for the destination of waste generated in 2017 it had a cost of R$ 11,535.64 in this period.

The graph of figure 4 details the electric energy consumed during a year, had a total of 39.953 kWh in this period. The total amount paid during this period was R$ 27,625.94, assuming that the industry had a total cost of R$ 39,163.64 per year in electric energy plus the price paid for waste disposal.

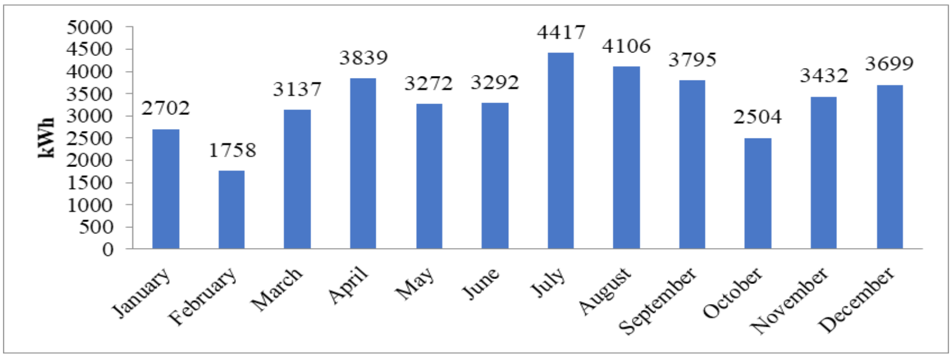

Figure 4 - Electric energy consumed during 2017.

Currently, the waste collected by the waste center by the Três Coroas union has the following destinations:

Leather scrap residues intended for thermal hydrolysis.

Waste of scraps of dubbed leather, chopped shoes (leather), fabric (solvent dubbed), foam (dubbed solution), dirty clothes, leather dust, contaminated plastics, cardboard with adhesive intended for Coprocessing (Class I).

PU-lined waste, chopped shoes (PU), fabric (dubbed water), some foam (dubbed water based), Class II powders, latex rubber, SBR rubber, non-recyclable plastics and paper, destination: Coprocessing (Class II).

Waste of cardboard timbó and cardboard of insole, the destination is the reutilization.

Residues: EVA chips (recyclable), recycling is the destination. This residue returns to the manufacturers of soles where they are incorporated back to the raw material.

Residues of dubbed (water-based) foam and pure foam are intended for reuse by mattress manufacturing companies.

To measure the energy capacity of the waste generated by the industry under study, the calorific value was around 4000 kcal/kg, since their role is around this value. For this calculation, only the values of class I and class II waste will be considered, since they are the ones with the most significant volume in this industry, which is 2017 generated 4821.80 kilograms of these wastes, the remaining materials are with a smaller amount and these already have a destination, not attacking the environment, because they are reused.

Total calorific value (kcal / kg) = Average calorific value of materials (kcal / kg) x Amount of waste generated (kg):

Total calorific value = 4,000 X 4,821.80;

Total calorific value = 19,287.200 kcal/kg.

IV. CONCLUSION

The small industries in this region surveyed spend around R$ 11,000.00 annually in waste disposal. Even with materials destined for donation, collection costs occur because they are responsible for the disposal of this waste. As a result, the industry pays for the union of the region's industries to collect and donate to registered entities.

Co-processing is the most common since the ash generated by it produces the clinker. However, a better use would be through co-incineration, because in addition to taking advantage of the ashes for clinker, the heat generated for the transformation of this waste could be used as fuel for energy generation and thus reduce the amount paid in electric energy.

Since the cost of installing/building a plant for power generation is very high, one of the best solutions would be to partner with the industry union since it already collects waste. The partnership can occur not only for the construction of the plant to generate all partner companies could use energy, but also the energy produced. This proposed method is new and never tested by companies in this segment.

Considering the calorific power of leather, they are similar to those found in other biomasses, and this confirms the possibility of using these residues as biofuels or in heat treatment processes.

From the evaluation of the results obtained in this study, of the opportunities for recycling and recovery, there was significant calorific potential in these wastes. The large volumes generated by the companies, is not only the industry studied since it produces a low amount of waste, which would not be possible the implantation of thermal treatment, but with the partnership the volume is considerable. The best way to solve this problem would be the heat treatment process, the result of which would be the reversal of these residues incombustible material for the generation of thermal energy destined for boilers, or even transformed into electric energy.

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