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# AN INDUSTRIAL SYMBIOSIS METHOD APPLIED TO WASTE MANAGEMENT

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## Abstract

Sustainability is a subject incorporated in most governments and companies' agendas, as well as in the news and even during casual talks. However, its real meaning and applicability into the society, economy or into the environment itself is not very well known. The aim of this work is to analyze the waste produced by a large agroindustry located at the region of Maringá, under the perspective of Industrial Ecology, and present a method of an alternative destination for the waste generated by the company through Industrial Symbiosis concepts. The purpose of this investigation is to offer a different destination to by-products such as Clarifying Clay, iron scrap, big bags, paper and corrugated cardboard, offering not a final destination, but transforming the waste into raw material of other production processes. This attitude helps the company to consider the waste management as an opportunity for new sources of income and as a mean of gaining competitive advantages in the market. As an outcome of the development process it was possible to verify that the chosen tool is very useful and brings significant financial results, such as the reduction of destination expenses by approximately 40% and the reuse of by-products by the own industry.

*Keywords:* industrial ecology, industrial symbiosis, sustainability

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## 1. Introduction

The corporate competitive pressures elevate the companies' attention about the environmental and social impacts of their own activities in the Value Chain. Undoubtedly, the sustainability integration is one of the most important matters in the modern study of operational management in the industrial scope. The word "sustainability" sustains the concept of maintaining the system, which can be done by both ways: considering it as a closed system and dealing with its internal aspects only or recognize outside connections, based on a network of inputs and outputs (Stindt, 2017; Yedla and Park, 2017).

One of the strategies used to ensure sustainability comprise Industrial Ecology and its leads, which emphasizes the sustainability on industries from energy and material flows. Thus, these flows are transformed and, generated energy and residues are reused by industries' productive system itself (Coelho et al., 2011). Companies' precautions used to focus exclusively in competition and product quality. Nowadays, productive department has been incorporating in its costs, and it is associated to it is necessary to change production, commercialization and consumption patterns, in order to obtain competitive advantages (Daddi et al., 2017).

In this context, interconnecting the conceptions of Industrial Ecosystem and Industrial Ecology, a subfield was created, equivalent to the natural ecosystems, named Industrial Symbiosis, which can be understood as a science that promotes sustainable

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industrial ecosystems through paradigms that supports the interactions between industrial flows and the environment where it is inserted. The keys to this science's success are cooperation and synergistic possibilities offered by geographic approximation (Cecelja et al., 2014; Yu et al., 2015). The economic impact of circular economy principles on companies' costs is rather limited (Bartolacci et al., 2017).

For Jia et al. (2020) to accomplish the circularity of manufacturing, a strong association among partners throughout the Textile and Apparel (T&A) supply chain is needed. Following this recommendation, given by the T&A, the company where this study was applied, in an agro-industrial cooperative, tried to verify the results of the implementation of industrial ecology practices in an organization with habits of association between companies. Thus, it is also intended to fill another gap in the literature raised by Jia et al. (2020).

There is a need to remove barriers to sustainability in food production systems (Galli et al., 2020). Brazil is the second largest food producer (FAO, 2020) and has expanded its agricultural frontiers (IBGE, 2016) and agricultural expansion generates anthropogenic environmental impacts (FAO, 2016) and for its mitigation, management systems that reduce and or control this impact (FAO, 2016) should be implemented. So, studying the implementation of industrial symbiosis in a cooperative in the agricultural sector is important, as there is an expansion of the agricultural frontier in the country and the adoption of sustainable technologies can mitigate the impact of such practices. Cooperatives have a significant participation in the Brazilian agribusiness economy, representing almost 50% of the total agricultural Gros Domestic Product (GDP) (OCB, 2020).

In view of these perspectives, the proposed method, in addition to meeting environmental criteria, also aims to adapt to the characteristics of cooperatives. The work aims at identifying several research gaps, which include the lack of social factors in CE (Circular Economy) measurements and diversity of research methodology and ignore organizational obstacles in the application of the CE model and so on.

Still justifying the study, future research could systematically compare how various contextual factors can favor certain strategies and assess the influence of factors such as industry structure, production technology, culture and political governance. In addition, the case study research can present in-depth analyzes of decision-making processes. This study addresses the cultural issue as a background and is carried out through a case study (Magnusson et al., 2019). Therefore, the purpose of this paper is to present a method to implement Industrial Symbiosis. The method offers an important support to implement the conceptions of Industrial Ecology and, mainly, Industrial Symbiosis, to bring forth higher competition to companies and, in addition, to consolidate a sustainable process.

The proposal is based on the work of Matin et al. (1996), where Eco-industrial Park is the focus. The novelty of this work consists in highlighting of Industrial Symbiosis as the part of Industrial Ecology that can easily be applied to any company not structured enough for Industrial Ecology. Therefore, the method was applied in a real context in an agroindustry, to evaluate its results.

This work is organized as follows: in addition to the introduction, section 2 conceptualizes the subjects that are relevant to the work's discussions, and section 3 specifies research methods. Finally, conclusions along with future work are presented.

## 2. Theoretical framework

### *2.1. Industrial ecology*

Industrial Ecology concerns the interactions between industrial activities and the environment, looking forward to analyze material and energy flows in the industry. These flows affect the environment, and the modality by which the economic, social, political and legal factors interfere on those flows (Fraccascia et al., 2017a).

Industrial ecology is grounded in three pillars based on biological analogies, which are centered in the sustainability analysis of the resources flow, looking to industries, optimistically, as potential agents of environmental improvement, as they possess technological resources that can efficiently execute sustainable management of products and processes (Chertow et al., 2008). Chertow (2007) highlights that some instruments allow a company to reach Industrial Ecology in many operation levels: intern, between companies or in global/regional scale, depending on the companies' size, as showed in Fig. 1.

As Fig. 1 illustrates, industries are one of the focus of this new ecology's approach. There are many ways to apply such conception to reduce environmental impacts and to promote sustainability, standing out in this regard - Industrial Symbiosis (Saraceni et al., 2017).

### *2.2. Industrial symbiosis*

The fundamental objective of Industrial Symbiosis (IS) is to promote a sustainable collective approach with competitive advantage, instead of being disposed; surplus resources generated by an industrial process are captured then are redirected for use as a new input into another process by one or more other companies, providing mutual benefits. Therefore, analyzing the residue management of the value, facilitates, among other things, the supply of important data to the establishment of companies with similar characteristics, facilitates the use of residues to create job opportunities, and improve economic-social stability, as well as sustainable aspects (Bain et al., 2010; Majale et al., 2016; Yedla and Park, 2017).

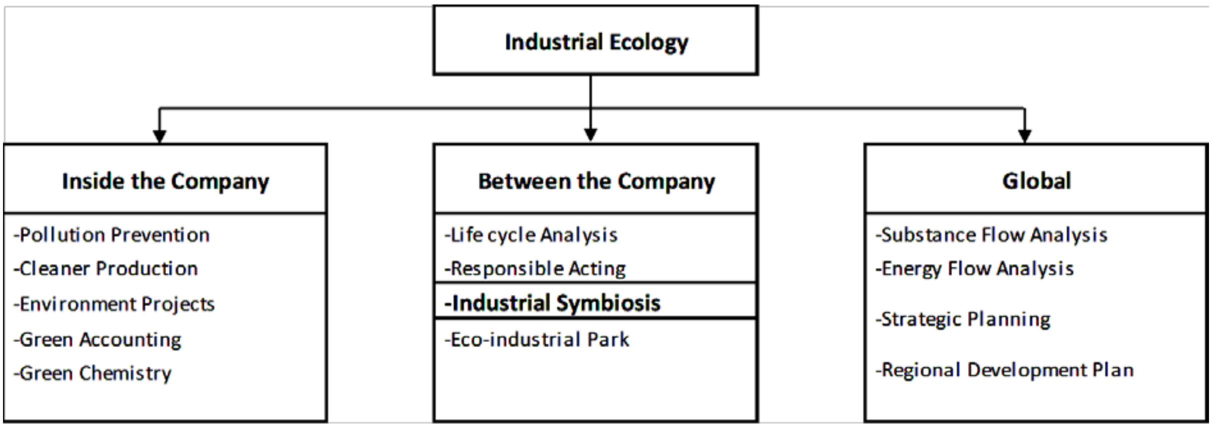


**Fig. 1.** Industrial ecology extent (adapted upon Chertow, 2007)

The goal of a network of Industrial symbiosis is to build collective flow between those that promote the materials interchange to benefit the environment, reduce carbon footprint, and minimize the waste of landfills and save raw resources. This networks exchange resources, byproducts, goods and services through closed and sustainable life cycles. In general, the IS consists of a subfield of industrial ecology, involving "industries traditionally separated in a collective approach of competitive advantage promoting the physical exchange of materials energy, water and byproducts" (Cecelja et al., 2014; Fraccascia et al., 2017b).

The symbiosis bonds between two industrial units, independently, from the exchange of byproducts and residues, are elements of the eco-industrial network, which searches for an ecologically efficient industrial development. Essentially is an important tool of Industrial Ecology, involving the symbiotic relationship formation, the correspondence phase, in which the partners are tracked, and the monitoring phase, in which the performance is evaluated. The proposal is based on changing the industrial energy and material flow into cycles, where residues are not discarded, but reinserted into the productive chain as inputs (Cecelja et al., 2014; Grant et al., 2010).

Sharing material resources, energy, water and byproducts between companies is one of industrial symbiosis main features. Another important aspect of industrial symbiosis can be the establishment of agreements between companies, in order to grant the sustainability of its solid residues (Saraceni et al., 2017).

### *2.3. Solid waste management*

The problem of industrial waste and the difficulty of its movement can limit the thoughts that they can be considered as alternatives to the promotion of sustainability, facilitating its use as raw material, energy source and income generation for other industries in order to minimize its impacts to the environment (Geng et al., 2010). According to Environment Protection Authority (EPA, 2014) waste classification guidelines, residues are all the material generated by human activities (industrial, domestic, hospital, commercial, agricultural, and services), considered by its generators as useless material, undesirable or disposable that can be in solid or liquid state and that is not feasible to conventional treatment. According to EPA (2014), it is possible to classify residues in three categories: Class I - Dangerous, Class II A - Non-inert and Class II B - Inert.

The main problems about Solid Residues involves projects' financial sustainability for its reuse, the short-term planning and the lack of companies' involvement. This way, a series of guidelines to the planning of the future can be developed, in order to make industrial symbiosis possible. Therefore, it is important to consider residues as an alternative of sustainability promotion, and technologies that shall be adopted to its processing. These technologies should be considered by each company, developing, then, an interrelationship between companies (Purser and Cohen, 2014; Santos et al., 2015).

## 3. Research method

The proposed method is guided by phases and activity demanded to implement Industrial Symbiosis, being based on the steps stablished by Martin et al. (1996), known as "end of pipe" practices, Pollution Prevention in synergy with Industrial Symbiosis, accession of new member to Industrial Symbiosis and attraction of new enterprises to the industrial park.

The research study can be classified from the viewpoint of: application, perspectives of objectives and enquiry mode employed (Kumar, 2011). From the viewpoint of objectives, the research is an application study, allowing the evaluation of the methods and tools under the business approach (Sjoberg et al., 2007).

### *3.1. Proposed method*

The proposed method was developed by using a cooperative system, in Brazil, as a pilot for the implementation, however it can be used as a support for symbiosis implementation in any other system that generates recyclable or reusable waste.

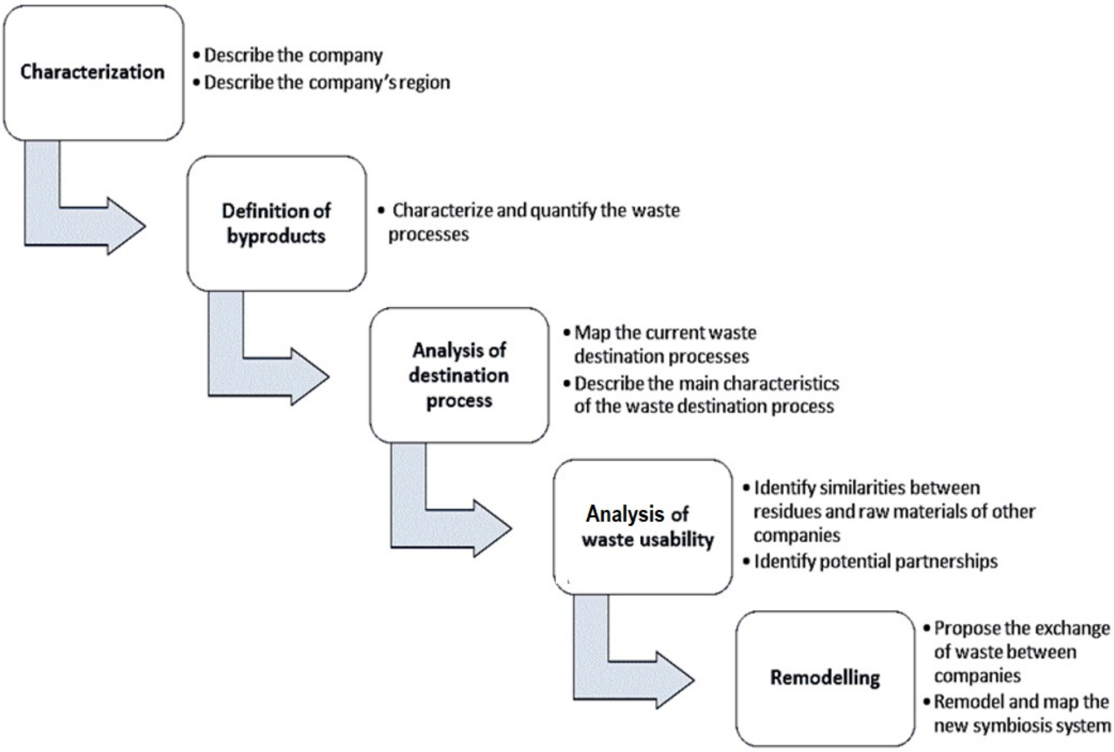


**Fig. 2.** Proposed method for industrial symbiosis in five steps

Based on the work of Martin et al. (1996), the proposed method highlight Industrial Symbiosis and was divided in 5 steps using a sequence of events to be completed before moving forward from step to step. To guarantee that such steps are fully developed, the framework of this study is represented in Fig. 2.

The proposed method is prescriptive; it presents recommendations that guide the execution of the activities, highlighting what should be done. The method of implementation is structured in steps, which are composed of activities along with their instructions. The activities aim at determining what should be achieved. The instructions aim at identifying means of carrying out the activity, and may take the form of guidance, practices and tools. The steps and activities are described as follows:

**1.Step one - Characterization**: the first step of the application is to characterize the environment which will be studied through observation. To accomplish step one, the activities developed describe the companies' features, such as, its location, social-economics aspects, productive process and types of waste generated. It is necessary to describe the companies region, what other industries are around it, if there are urban areas surrounding it, what other companies could probably use the waste generate in it, and what wastes could probably be exchanged.

**2.Step two – Definition of byproducts**: on the second step it is time to define byproducts and produced residues. The activity developed in this step is to analyze the company's reports to characterize and quantify the produced waste by each process.

**3.Step three- Analysis of destination proces**s: involves the collection of information of the destination process through observation and use of company's data. Two main activities are executed in step 3 which are: map the current waste destination processes and describe the main characteristics of the waste destination process.

**4.Step four – Analysis of waste's usability:** After analyzing the destination process it is necessary to verify if the residues fit in the productive processes of other companies as raw material by checking main characteristics of residues. The activities executed in step four are to identify similarities between residues and raw materials of other companies and to identify the potential partnerships.

**5.Step five - Remodeling:** the last step is to remodel the supplying process according to Industrial Symbiosis. The first activity of step five is to propose the exchange of waste between companies; it could be by selling the residues, or even by donation (which is also an advantage when it is necessary to pay for waste discharge). Then, the second activity is to remodel and map the new symbiosis system.

To evaluate the efficiency of the proposed model, a case study is presented. The case was developed in an agro-industrial cooperative. The case is an example, in a real context, of the proposed method.

## 4. Results and discussion

This topic describes the application of the method in a real case. Each topic is related to the steps and activities explained on the methodology topic.

*4.1. Step one - Study environment characterization*

The company, which is the object of this study, has been in the market for 54 years beginning with coffee producers' cooperative in the region of Maringá – Brazil. In 1989, the cooperative already had several industrial units, such as production of oil and soybean meal, cottonseed oil, refining and bottling of vegetable oils, cotton spinning, silk spinning and the company's flagship: roasted coffee and ground. The Cooperative has about 12 thousand members, more than 2.500 employees and it is present in more than 60 grain receiving units spread throughout the interior of the state of São Paulo, Mato Grosso do Sul, and throughout the north and northwest of Paraná state, where its administrative unit is located.

To apply Industrial Symbiosis in the company, it was necessary to understand the residue generation processes and classify them according to EPA (2014). Two departments that were directly involved with the industrial processes and the company's management supported the data stratification of company's generated residues, namely: Environmental Department and Procurement Department.

According to information provided by both departments, it was possible to do a screening of the residues according to its origin process. To such division, it was identified the list of materials that are directly generated by company's productive processes and secondary processes, such as maintenance, effluent treatment process residues and office residues.

*4.2. Step two - Definition of byproducts*

Once the stratification was complete, tables were elaborated according to the selected classification, also adding the quantity of residue generated by the company and classifying it according to EPA (2014). The results are shown in Table 1 and Table 2. Table 1 shows the main residues generated by the productive process in twelve month for Year 1 and in six month for Year 2.

The time considered for the research was therefore 18 months. Table 2 comprises the products classification as secondary residues generated in the productive process considering that secondary residues are not making part of main products produced in the industry. Through Tables 1 and 2 it is possible to verify a substantial increase of residue generation, and it is also possible to assert that Year 2 residues generation will almost double when compared to Year 2 numbers. This fact can be explained due to company's strategic planning, which has as a goal, to double its size within five years.

Considering this, it is convenient to provide a more detailed analysis of the residues produced by the company, and it can be said that these residues are prevenient of the company's productive processes. According to the data presented in Table 1, the residues are as follows:

- Clarifying Clay: Material used in the process of soybean oil refining, withdrawing impurities presents in the product.
- Cardboard Juice Packaging: Packages composed by several layers that help to condition fruit nectars, company's soy-based juices.
- Wooden Pallets: Usually used in product transportation.
- Paper and Corrugated Board: Materials used to the making of finished products storing boxes.
- Plastic: Residue formed in the packaging process of PET material and stretch film.
- Big Bags: Generated through big bags that transport raw material inside the company.
- Civil Construction Residues: Concrete rubbish, bricks, sand and stones produced by structural maintenance in the company.
- Iron Scrap: Results of machinery maintenance, transportation structures and grain storage.

**Table 1.** Productive processes residues list

| ***Residue*** | ***Year 1 (12 months)*** | ***Year 2 (6 months)*** | ***Classification according to EPA (2014)*** |
|---|---|---|---|
| Clarifying Clay | 2.500.000 kg | 1.700.000 kg | Class I Residue |
| Cardboard Juice Packaging | 41.280 kg | 39.960 kg | Class II A Residue |
| Wooden Pallets | 396.260 kg | 484.194 kg | Class II B Residue |
| Corrugated Board | 459.432 kg | 257.164 kg | Class II B Residue |
| Plastic | 50.780 kg | 66.600 kg | Class II B Residue |
| Big Bags | 26.080 kg | 19.680 kg | Class II A Residue |

**Table 2.** Residues list of secondary productive processes

| ***Residue*** | ***Year 1 (12 Months)*** | ***Year 2 (6 Months)*** | ***Classification according to EPA (2014)*** |
|---|---|---|---|
| Civil Construction Residues | 300 $m^3$ | 75 $m^3$ | Class II B Residue |
| Iron Scrap | 176.964 kg | 262.520 kg | Class II B Residue |
| Informatics | 5.160 kg | 11.360 kg | Class II B Residue |
| Sludge | 150.000 kg | 90.000 kg | Class I Residue |
| Administrative waste | 1.020.000 kg | 560.000 kg | Class II B Residue |
| 30 liters barrels | 4.286 units | 1.092 units | Class I Residue |

- Informatics: Change of technology, company's office equipment malfunctioning.
- Sludge: Generated in effluent treatment stations.
- Administrative Waste: Organic materials or non-recyclable produced in company's office.

60 Liters barrels: Containers that holds chemical products to use in the effluent treatment station.

*4.3. Step 3 - Data collection of destination processes*

Since the company has several types of residue generation, it is necessary to understand how the destination process currently happens, what are the problems associated with the current method and what are the improvement opportunities that new method can offer. The company presents two ways to deal with the generated waste: sale of recyclables components and proper destination of non-recyclable waste. To support these two processes, the Procurement and Environmental departments are directly involved, being responsible for the control, management and improvement of the implemented system.

Figs. 3 and 4 illustrates the system adopted by the company for the waste destination, and, how the sale of recyclable materials is conduced, presenting the values regarding the final disposal and sale of recyclables, transportation expenses and the locations where the residues are sent.

Fig. 3 shows the company's main residues of production processes, and how they currently treat them. It is possible to verify that only one by-product generates expenses for its treatment and transportation. The other five by-products are sold by the cooperative to other companies that reuse this material. It is substantially visible the end of pipe practice that the cooperative currently applies to recycling, generating a certain amount of income.

Fig. 4 represents the by-products that are obtained in secondary processes within the cooperative's productive plant.

It was observed a higher amount of waste in which the cooperative has transportation and treatment expenses. This gives us a perspective that the recycling practice presented in Fig. 2 may be misleading, all the process had financial expenses and gains. However, it is not possible to analyze whether the expenses are paid with the sale of these materials or not. It is noticed that for the sale of recyclable materials the company has no transportation cost. This is explained by the fact that companies buying these materials make the collections with their own trucks, different from the materials that are sent to disposal destination, where the freight of this material is accounted as an expense of the company.

To facilitate the understanding of this discrepancy of values, with the data provided by the company, it was possible to provide Table 3 and Table 4, which show all sales values of recyclable materials in the Year 1 and the amount spent by the company with the disposal destination during the same year.

If the money collected from the sale process were not used to pay the cost of the disposal destination, the company would have a deficit of US$ 43,455.10 per year. This does not show that the sale of the material is wrong, quite the opposite, this type of initiative is very positive; since it shows that the company already has a culture of environmental responsibility implemented, even if the company has no environmental reports and in a certain way. Therefore, it is possible to use these money to mitigate waste disposal costs. The application of Industrial symbiosis would interfere in the process, precisely to make a better evaluation of these materials that are discarded by the company, offering other ways to treat them, other possibilities of how to use them in other productive processes. These actions would generate waste valorization, reducing the deficit between the revenue generated from the sale of recyclables and the expenses of non-recyclable materials.

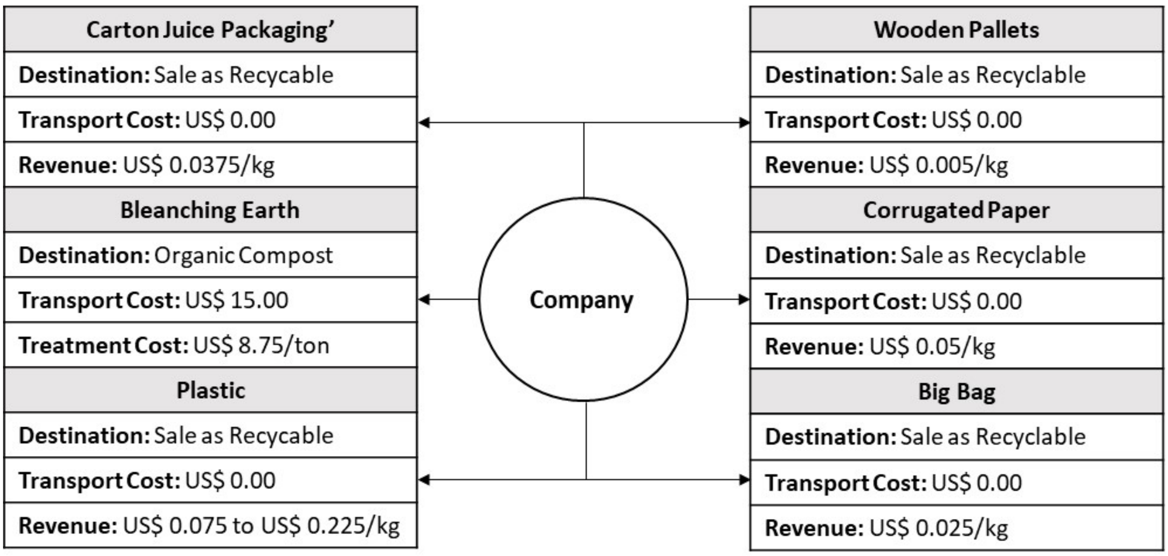


**Fig. 3.** Costs and quantities of main productive processes residues

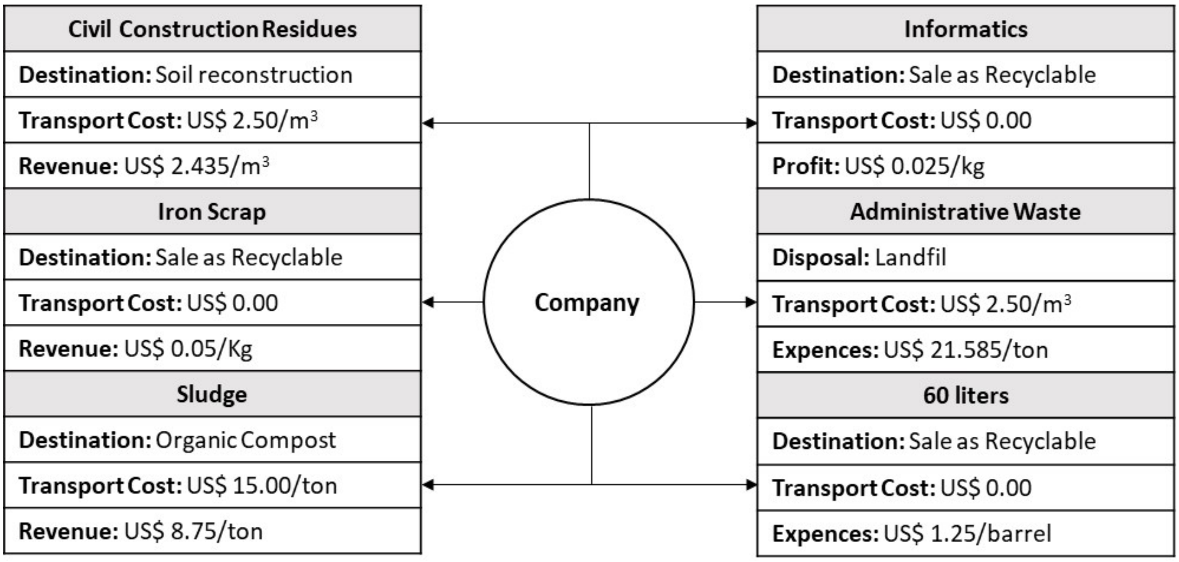


**Fig. 4.** Costs and quantities of secondary processes residues

**Table 3.** Gains with the sale of recyclable material during Year 1

| *Material* | *Amount (kg)* | *Value (US$/kg)* | *Total (US$/kg)* |
|---|---|---|---|
| Cardboard juice packaging | 41,280 | 0.0375 | 1,548.00 |
| Iron scrap | 179,964 | 0.040 | 8,848.20 |
| Informatics | 5,160 | 0.025 | 129.00 |
| Wooden pallets | 396,260 | 0.005 | 1,981.30 |
| Corrugated board | 459,432 | 0.040 | 22,971.60 |
| Plastic | 50,780 | 0.150 | 7,617.00 |
| Big bag | 26,080 | 0.025 | 652.00 |
| 60 liters barrels | 4,286 | 1.25 | 5,357.50 |
| **Total revenue during Year 1** | | | **49,104.60** |

**Table 4.** Gains with residues disposal destination during Year 1

| *Material* | *Amount* | *Transport value* | *Destination value* | *Total* (US$/ton, US$/m$^3$) |
|---|---|---|---|---|
| Clarifying clay | 2,500,000 kg | 12.50 US$/ton | 8.75 US$/ton | 53,125.00 |
| Civil construction residues | 300 m$^3$ | 2.50 US$/m$^3$ | 2.43 US$/m$^3$ | 1,480.50 |
| Sludge | 150,000 kg | 12.50 US$/ton | 8.75 US$/ton | 3,187.50 |
| Administrative waste | 1,020,000 kg | 12.50 US$/ton | 25.58 US$/ton | 34,766.70 |
| **Total expenses of residues during Year 1** | | | | **92,559.70** |

*4.4. Step four – Analysis of waste's usability*

To verify which materials would compose the study of insertion in other industrial processes, the following aspects were considered: i) Materials with a high waste disposal cost; ii) Materials generated in significant quantities; iii) Materials with ease insertion in other productive processes; iv) Materials that do not require complex processes to be inserted in other production processes. Thus, the materials selected for Industrial Symbiosis were Clarifying Clay, Iron Waste, Paper, Corrugated Board and Big Bags. To facilitate a better understanding, the materials selected for treatment by Industrial Symbiosis methods for each material will be explained separately.

- **Clarifying clay:** For this residue, there are washing processes which enable its reuse. However, the recycled material brings to the oil is not the same as the virgin material, that is, the quality presented by the final product is not what is expected at the end of the production process, harming its reuse in the oil refining process. Therefore, it is necessary to investigate other possibilities of using this material in other productive processes. Clay is widely used in the production of bricks, tiles, etc., thus creating the possibility for this material to be used as raw material in pottery of the region in the manufacturing of these types of ceramics. Clarifying Clay does not completely replace the clay used in the production of bricks; it enters as a complement that increases the strength of ceramics by using the material in its composition. Therefore, if the company provide this type of material with no charge to potteries in the region, it would only have transportation expenses; this would represent a saving of 21,875.00 per year.
- **Iron scrap:** An alternative for the company to be able to apply Industrial Symbiosis would be making the negotiations directly with steel mills and

deliver this material as exchange base for the purchase of new material.

- **Paper and corrugated board:** In its majority consists of corrugated cardboard boxes with capacity of about 1000 liters, which are very resistant and practically new. According to the company's information, the company was consulted about this by-product and sold some of those used boxes for a value of 5.00 per unit, that is, a hundred times more than the value that this material is sold per kilogram. If this first strategy cannot be implemented, the second strategy is to offer this material to producers of recyclable paper coil in the region.

In the same way as described to iron scrap, companies that work with the recycling of this type of material will buy it to sell the cardboard shavings to recyclable board processing industries. The direct sale generates a gain of approximately 0.10 per kilogram, besides the gain from direct sales; the company still gets some benefits in the purchase of corrugated board boxes. Another strategy is to resend the boxes, so that the supplier reuses those boxes to fill in with the demanded products. As the company pays 8.00, every 500 boxes reused per month, represents a saving of 4,000.00.

- **Big bags:** the Big Bags are composed by a very strong material, which is used to transport minerals to produce salt in the company. This type of material is not reused in the manufacturing process and is discarded as soon as it is used. An alternative to reuse this material would be within the company itself, using it in the transportation of bulk materials such as clay that can be send to pottery.

### *4.5. Step five - Remodeling*

The current process of disposal of the four selected wastes are illustrated side by side with Improved Process Proposed as it can be seen on the flowcharts of Fig. 5. The Clarifying Clay process with the Industrial Symbiosis would have the modifications shown in Fig. 5. Instead of being transported to disposal landfill, the clay would be stored in the yard of the cooperative itself and then transported to Company partners to be inserted in the production of bricks and tiles. With this hypothesis, the company would only have the expense of transportation and would eliminate the expense of handling such material. This does not prevent the cooperative from making other partnerships to sell this material, reducing even more its transportation expenses.

Corrugated board is the by-product that presents more opportunities of its destination by the cooperative, as it is possible to verify in Fig. 6. It has three ways to apply Industrial Symbiosis. The cooperative can return the boxes to the supplier who can repackage the materials in the used boxes. Another alternative is to sell these boxes not as scrap, but rather as cardboard boxes, this is possible because the cardboard used is very resistant, besides, the lid and bottom of the boxes facilitate its handling and storage. Another way is recycling. The cooperative returns these used boxes to the suppliers of this new material so they can benefit or subsidize the purchase of new material. Fig. 7 presents the big bags destination process.

Big Bags can help the cooperative with the transportation of materials within its area, such as transporting grains, materials from yard cleaning, transporting debris, which can help to move Clarifying Clay in its process of Industrial Symbiosis and so on. After its use, or after the material is no longer useful due to damage, it can be sold for recycling, as shown in Fig. 7. The process of maintenance waste management can be seen in Fig. 8. The by-product of the maintenances that take place in the cooperative is iron scrap. This type of material has a high recycling rate due to the characteristics of the material itself. Fig. 8 illustrates the Symbiosis occurring in this material in partnerships with its suppliers for the cooperative to provide the scrap back to its suppliers and so the company can benefit in the purchase of new materials.

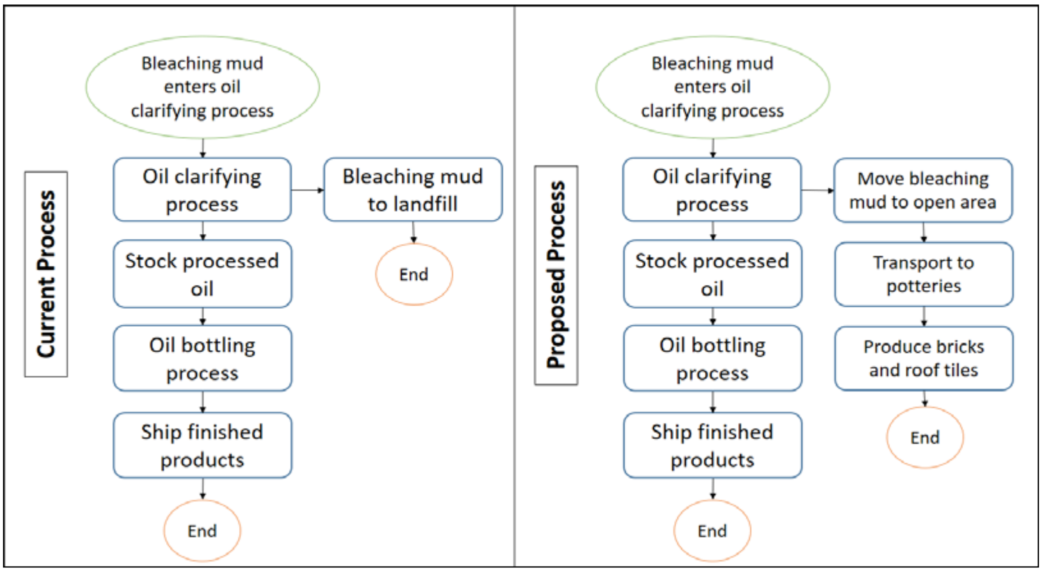


**Fig. 5.** Before and after clarifying clay disposal destination process

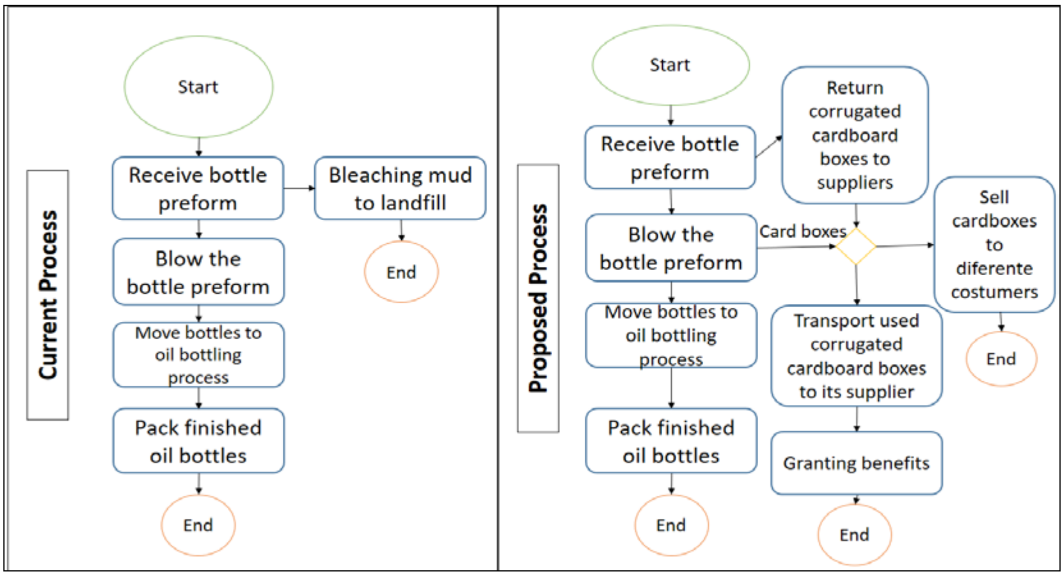


**Fig. 6.** Before and after corrugated board destination process

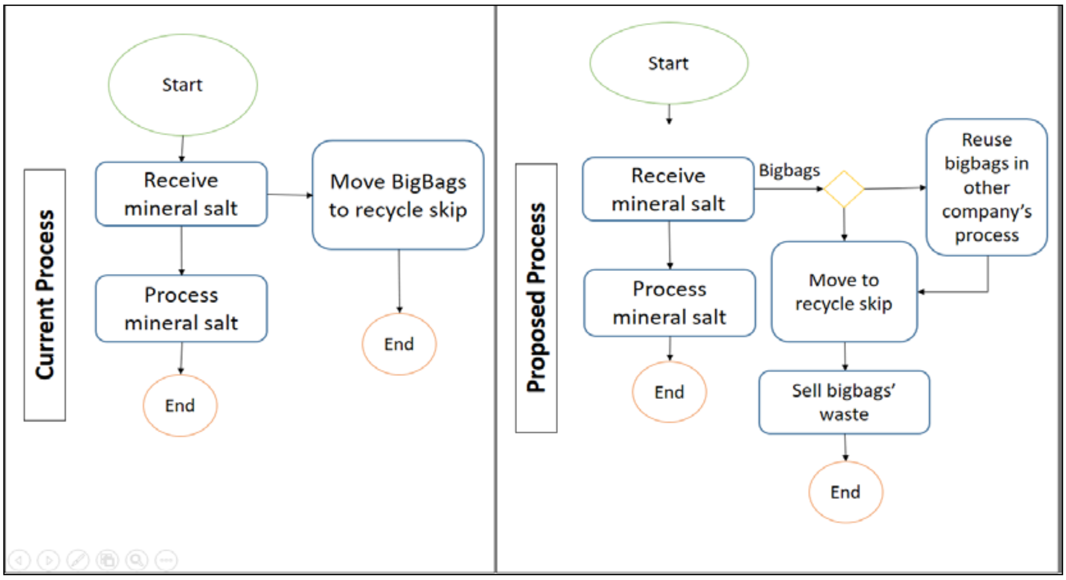


**Fig. 7.** Before and after Big Bags destination process

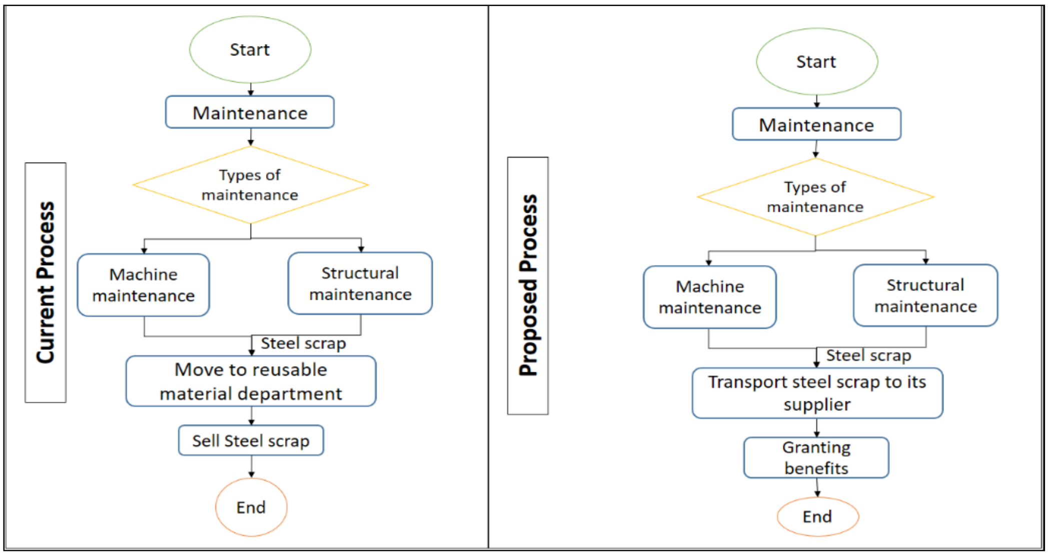


**Fig. 8.** Before and after iron scrap destination process

**Table 5.** Scenarios analysis

| ***Residues*** | ***Before*** | ***After*** |
|---|---|---|
| Clarifying clay | Outsourced disposal representing an expense of 53,125.00 per year | Reduction of expenses by 21,875.00 with partnerships with potteries |
| Iron scrap | Sail of Iron Scrap generating a revenue of 8,848.20 | Reduction of Iron purchase price using Iron Scrap in the negotiation |
| Corrugated board | Sail of Corrugated Board generating a revenue of 22,971.60 per year | Partnerships and reuse reducing expenses by 24,000.00 |
| Big bags | Revenue of 652.00 | Intern transportation reuse |

### *4.6. Analysis and discussion*

For a better visualization in the proposals of Industrial Symbiosis, Table 5 was elaborated to present the scenario practiced by the company and the proposals present in this work. It is possible to verify that among the four residues used to bring proposals, the highest economic impact was a result in changes of Clarifying Clay disposal process. This can be explained by the fact that clay has a high expenditure for its destination, besides being able to use it as raw material in another manufacturing process, adding value to this residue and making it possible to be sold.

Materials such as iron have a high recycling rate, so the company can establish a trade deal of this type of material. However, the value that this sale generates cannot pay the costs of disposal of the other materials in the company and cannot afford to incur the purchase of the new material. This way, agreements with iron makers is very profitable, as the company achieves a significant reduction in the value of the purchase of new material, in addition to discarding the material that is no longer used in the company.

Corrugated Board and Big Bags can create deals similar to the ones of Iron Scrap, but with some differences in the support that these materials would give in the transportation of the company. As previously, stated, cardboard boxes are used to hold PET preforms that are used to carry out the blowing process of oil bottles and, after emptying them, these boxes are discarded. These boxes are charged to the company at the time it makes the purchase of them with a value of approximately 8.00. The cardboard that is used in these boxes is a very resistant material, even after emptying them; they are still in conditions of use. Therefore, the partnership with the company producing PET preforms consists of returning those boxes to be filled again with PET preforms.

With the results of the application of the method for industrial symbiosis in five steps, it was possible to verify the reduction in the total waste generated by a Brazilian agro-industrial cooperative, so if implemented it can reduce the gap presented by FAO (2016), as it reduces the anthropic environmental impact and generates economic results. It is also necessary to involve people linked to the organization to consolidate the method, a fact that narrows the gap presented by Jia et al. (2020). Thus, the method for industrial symbiosis composed in five steps has success in financial aspects and in the reduction, destination and reuse of residues corroborating the factors pointed out by Purser and Cohen (2014) and Santos et al. (2015). Another important aspect verified is the possibility of forming an organizational culture focused on sustainability.

## 5. Conclusions

Industrial Ecology concepts, tools and methods of Industrial Symbiosis were discussed over the construction of this work. Counting on the partnership accorded with the studied Agroindustry, it was possible to better understand how the disposal processes happens when the focus is not Industrial Symbiosis, but in the elimination of residues according to its own characteristics. The proposed method is generic enough to be applied in other industrial sectors. The case presented serves as an example for the application of the method in other scenarios.

The method for industrial symbiosis in five steps proposed in this article proved to be feasible through its application in the case study of an agro-industrial cooperative. The main results achieved were allied to the company's provided data, the disposal processes where deeply analyzed, such as generation processes, quantities of residues produced by each one of them, its characteristics, transport cost, generated quantities and sale prices.

After performing the study of the agroindustry residues processes, they were characterized according to Environmental Protection Agency. Then, the residues stratification was provided respecting the insertion possibilities of them on other production processes as raw materials to new products. It was evident that some residues sold as recyclable material generate revenue allowing the destination process of other ones. It is important to highlight that these propositions were constructed following Industrial Symbiosis principles, and represented an economy of 37,500.00 per year if only the changes on the destination processes of Clarifying Clay and Corrugated Board were applied. Another important point is that the insertion of these byproducts implies in a reduction of 40% on the costs of the residue's elimination.

When only two byproducts are responsible by such impact, we reinsure the importance that Industrial Symbiosis brings to destination processes of companies that adopt such principles. Besides that, reinsures that the three sustainability pillars are incorporated within the companies. The preset objectives to this work where achieved as the study of the company's byproducts was complete.

Although all the fulfilled objectives, it was not possible to offer concrete alliances, due to the necessity of realizing a feasibility study to the propositions constructed during the development of the study. This work enables the future implementation of the developed propositions in the disposal processes of the studied agroindustry; furthermore, there is still a possibility of new studies of the byproducts that were not reintegrated into other productive cycles. It is also possible the development of a better way to reuse iron scrap, considering that it is sold by  0.05 per kilogram and bought by  4.06 per kilogram, and finally realize better alliance analysis in order to enforce better integration of acting companies in Industrial symbiosis. There is also the possibility of adding other environmental indicators, such as $CO_2$ emission and the use of water, in addition to adding environmental practices to reduce the environmental impact generated.

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