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INDUSTRIAL ECOLOGY, INDUSTRIAL SYMBIOSIS AND INDUSTRIAL ECO-PARK: TO KNOW TO APPLY

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ABSTRACT

Among the various ideas and practices related to sustainable development there is the Industrial Ecology (IE). Its emergence is linked to the metaphor between natural and industrial ecosystems. IE provides a holistic view that considers concurrently and broadly, the needs of nature and man. However, in Brazil, IE is still a relatively unknown topic in the academic world and especially in the business world. There is little clarity as to the relationships and distinctions between IE settings, Industrial Symbiosis (IS) and industrial eco-park. To date, no records were found in the literature about the existence of Brazilian industrial ecoparks, although they have been observed initiatives such as Rio de Janeiro, which did not prosper. This objective conceptual theoretical study show the definition, features and performance scales, as well as other aspects relating to IE as well as its natural link with sustainable development. The main results show that the use of IE and IS concepts in the form of an industrial eco-park aims to revitalize urban and rural areasas well as promoting the growth and retention of jobs. Some countries use to alleviate environmental degradation and the amount of waste generated.

Key-words: Industrial Ecology; Sustainable development; Industrial Symbiosis; Industrial Eco-Park.

1. INTRODUCTION

Gradually and slowly, society, represented by customers, suppliers, academics, governments and investors, among others of its members, passes to value initiatives related to sustainable development. The appreciation and concern related to environmental sustainability may be related to the presentation in 2002 by the Organization for Economic Co-operation and Development (Organisation of Coopération et de Développment Economiques, 2002), global trends related to growth in industrial production, consumption and waste. The negative situation is amplified by the improper disposal of waste that can contaminate the water (surface and underground) and soil, causing losses to the nature and human being. Such predictions are guided in various data, including those who realize that, between 1980 and 2000 in the context of the countries of the OECD (Organisation for Economic Co-operation and Development), the municipalities that produced 100 kg waste per capita/year started to produce 150 kg per capita/year, estimating that this number reach 200 kg per capita/year by 2020 (Organisation de Coopération et de Développment Economiques, 2002).

From these predictions simultaneously rises the interest in sustainable development and the inherent challenges linked to it. On the other hand, as a chance to catch up in the period by the 1980s and 1990s (Erkman, 1997), entered into evidence the concept of Industrial Ecology (IE). Although the practices linked to IE can be considered recent, due to the body of knowledge that contemplates, it can be appreciated as a science of sustainability, because the IE comes from the metaphor of nature to analyze and optimize the industrial complexes, logistics and consumer as well as your energy and materials flows (Cohen-Rosenthal, 2000; Costa et al, 2010; Eh-

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renfeld, 2000; Erkman, 1997; Hoffman, 2003; Isenmann, 2003; Jelinski et al, 1992; Korhonen, 2004). Bristow et Wells (2005) argue that sustainable development requires innovative actions based on ecological metaphors of diversity beyond the limits of contemporary economic rationality. Thus, according Deutz (2009, p. 276), the EI "comprises theory and practice to implement sustainable development", inasmuch as "residues are replaced by other possibilities, being understood as raw material for other activities "(Rodrigues et al., 2013, p. 46).

Specifically in Brazil, Industrial Ecology is still a relatively unknown topic in the academic world and especially in the business world (Araujo et al., 2013). So much so that no records were found in the literature about the existence of industrial eco-parks in the country. However, important initiatives have been observed, but did not achieve the expected success, as the Rio de Janeiro (Fragomeni, 2005; Veiga, 2007; Veiga et Magrini, 2009). On the other hand, in terms of Industrial Symbiosis, we are seeing actions like this in the Camaçari Petrochemical Complex in Bahia (Tanimoto, 2004), and by the Brazilian Program of Industrial Symbiosis (PBSI) (Industries Federation of Minas Gerais State, 2013).

In turn, Chertow (2000) and Sakr et al. (2011) state that it is in environments such as industrial eco-parks (IEP) - places in which companies cooperate with each other and with their local communities, sharing various resources and getting returns in economic, environmental and human terms (Chertow, 2007) - that the principles of IS find better implementation conditions.

Therefore, the absence of an industrial eco-park in Brazil ratified the justification to expose clearly the topics related to this theoretical study. Also assessed to be important to conduct this research in the country, given its emerging economic characteristics (as well as those of other nations that already have industrial eco-parks initiatives) and also the social, political, cultural and environmental similar to other countries in South America - expressionless region in terms of IEP projects.

In this sense, this objective conceptual theoretical study show the definition, features and performance scales, as well as other aspects relating to IE as well as its natural link with sustainable development. In other words, it seeks to clarify the assumptions of IE and its application possibilities.

Therefore, this article is divided into four sections, considering this introduction. The second refers to the Industrial Ecology, exposing a historical context, its definition, its characteristics and its levels or performance scales as well as its natural link with sustainable development. The third section deals with the Industrial Symbiosis (IS), with the expected results of symbiotic relationships, the concept of an industrial eco-park (IEP) and the origin of the pioneering initiative of Kalundborg. It also details the characteristics of spontaneous and planned actions of IS. Finally, are exposed the final considerations.

2. INDUSTRIAL ECOLOGY

A concise assessment of the context of sustainable development and environmental sustainability shows that, as stated Gladwin et al. (1995), these are concepts that arouse various interpretations and still allow room for new proposals, given its multidisciplinary nature (Despeisse et al., 2012), although these definitions are still under construction. Accordingly, Robinson (2004) and Jabbour et al. (2012) emphasized that sustainable development involves the creation of new methods, disciplines and tools that are integrators and actively create synergy, not just the sum of these elements.

It is possible that this involvement is due to the fact that these concepts are in a very subjective level, favoring the spread of many interpretations of the theme. According Avelino et Rotmans (2011), the definition of sustainable development is challenged because of its inherent complexity, to involve ambiguities aspects grounded on multidimensional perceptions and in need of integrated and interdisciplinary approaches. However, on the other hand, there is also some convergent elements in its concept and present in different publications that emphasize, for example, aspects related to the simultaneous maximization of biological, economic and social systems as well as improving the quality of human life, in a bearable ecosystem perspective (Brazil, 2012; Gladwin et al., 1995).

Being composed of multidimensional elements, sustainability causes changes in various fields of research and action of organizations and individuals. "Sustainable development is one of the most important movements of our time, and, judging by the vitality of institutional factors present in almost all the world, you can infer that he will continue spreading for many decades" (Barbieri *et al.*, 2010, p. 153).

However, the organizational guidelines are still focused on the growth and globalization of the economy through of a continual rise in consumption in the currency need to rotate swiftly, and what is produced must be consumed quickly and can generate energy and raw materials waste (Barbieri et al, 2010; Costa et al, 2010; Lang, 2003). These guidelines besides being merely eco-

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nomic, bring harm to the biosphere and the man's own survival, so that, in a short time, it will be able to realize the impossibility of reversing this scenario.

For Banerjee (2003), environmental problems (such as pollution) do not recognize national or regional borders. However, Hopwood et al. (2005) point out that the dominant view in the agenda of major corporations, on the practical level of sustainable development, it is still one in which the economy, society and the environment are considered as separate elements. In contrast, Mauerhofer (2008) argues that achieving environmental goals is a pre-condition for the maintenance of economic and social system.

Some parts of society support reaction of events, others just follow, others are resistant and credited climate change to natural transformations. However, it is clear the increasing importance of environmental issues amongst people, these issues including concerns of social and economic order. International organizations such as Greenpeace and the United Nations are leading movements that seek collective and collaborative solutions within the context of sustainable development. The demands for sustainability involve practices that must include a commitment of several groups, because the collaboration should be institutionalized in actions of organizations and stakeholders as participants in society. Accordingly, Boons et al. (2011) highlighted that sustainable development, including the ideas advocated by Industrial Ecology (IE) involves social processes guided in ecological, institutional and economic factors.

It is clear, therefore, that the organizational acts gradually tend to be guided by this concept of sustainability, which has its origin in the concept of sustainable development (Despeisse et al., 2012), which provides the use of natural resources at the present time but without compromising survivability in the future, so it is defended as a social and institutional value. The very "model of sustainable innovative organizations is an organizational response to these institutional pressures" (Barbieri et al., 2010, p. 150). This makes the executives understand this concept as an inherent cost to business or a necessary evil to obtain the legitimacy and retaining the right of the company to work (Hart et Milstein. 2003; Perez-Batres et al, 2011).

As organizational activities rely heavily on the social, economic, cultural and political contexts in which they operate, their managers feel "committed" to follow and meet the demands of the community in which they operate. Seek, over time, provide the adoption of the values recognized by the society, following trends, working interdependently, imitating successful actions and yielding to external pressures in a range of values that may be different from today. The result is that organizations tend to establish inter-organizational relations, otherwise they would have difficulties in the acquisition of resources and obtaining the necessary legitimacy to operate in these scenarios.

As Ehrenfeld (2000) explained, are necessary fundamental principles to guide sustainable policies and actions, so that they are not lost in its development and execution, which could bring further damage. It is believed that these principles are the assumptions of Industrial Ecology. The main thing to be considered is not compactuação with unsustainability, which means that any production system can not be easily accepted as a generator of imbalances - environmental, social or economic.

Thus, the Industrial Ecology (IE) is born from human aspiration to integrate their artificial systems to systems belonging to nature. Within this perspective, IE offers a holistic view that considers concurrently and broadly, the needs of nature and men, not only economic, but also social (Isenmann, 2003). IE has its origin linked to the metaphor between natural and industrial ecosystems. Because of this consideration, believed to be valid scoring the origin of the word ecology and how it is perceived by the biological sciences.

According Pinto-Coelho (2002), was the German Ernst Haeckel in 1869, who proposed for the first time, the term ecology. Of Greek origin, its literal meaning is: oikos - house; and logie - study. Modernly, ecology receives definitions such as the study of the interactions that establish the distribution and abundance of living organisms or the study of environment emphasizing the interrelationships between organisms and their surroundings. "Ecology is based on multi, poly and especially transdisciplinary interactions" (Pinto-Coelho, 2002, p. 13), including the social sciences, and thus uses the Systems Theory. Your goal "is to understand the functioning of living systems as a whole and not just break them into their constituent elements to analyze them" (Callenbach, 2001, p. 58). Thus, the ecology would be concerned to understand the relationships between organisms and between them and the environment, allowing the apprehension of the interconnections.

In the opinion of Erkman (1997), when referring to the history of IE, Japan was one of the first countries to address this theme, since the late 1960s, the government hired an independent consulting firm to investigate possibilities for directing the country's economy for activities based on information and knowledge, with lower dependence on consumables. However, the first to use the term "industrial ecosystem" was the American geoche-

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mist Preston Cloud, in a work of 1977. However, the literature recognizes as seminal article about IE the article published in 1989 in the journal Scientific American, entitled "Strategies for Manufacturing", authored by Frosch and Gallopoulos, two researchers from General Motors (Erkman, 1997). Frosch et Gallopoulos (1989) defended the possibility of improving the production methods by integrating processes. The production used the logic of individual transactions whose raw materials, after use, resulted in products and waste. In contrast, the predicted internal use of these waste products, reducing the impact on the environment. Hence the term: industrial ecosystems.

In this sense, according Graedel (2006), although the analogy between the concept of industrial ecosystem and the biological ecosystem not be perfect, it is still valid when considering that the biological ecosystems are the basis of a complex network of processes in which what is produced is consumed by some of its members. Similarly, each industrial process must be viewed as a part dependent and inter-related with a larger whole.

The article of Frosch et Gallopoulos (1989) boosted awareness of the ideas related to IE, but Erkman (1997) had indicated that it was still in the early 1980s in Paris, the researcher Jacques Vigneron launched the notion of Ecology Industrial, even though this is not mentioned much. Other relevant dates of the history of IE and that deserve mention are: in 1991, the National Academy of Sciences (United States) considered the Industrial Ecology a new field of study; in 1992, Braden Allenby is the author of the first doctoral thesis that contains several assumptions related to IE; in 1997, the Journal of Cleaner Production edit a special issue devoted to the subject and in the same year, begins the publication of the Journal of Industrial Ecology (Araujo et al, 2013; Erkman, 1997).

In 1994, Robert White (1994) proposed the definition of Industrial Ecology (Lifset et Graedel, 2002) as the study of flows of materials and energy in industrial activities and of consumption, its effects on the environment and economic influences, political, regulatory and social on the use and transformation of resources. In this concept, you can see, clearly, the multidisciplinary nature that IE has - as well as sustainable development.

The metaphor that originated the ideas of Industrial Ecology suggests the systematic reuse of materials and waste as an important contribution to reducing the need for raw materials extraction, mitigating the environmental impacts (Costa et Ferrão, 2010; Graedel, 2006). For Gibbs et Deutz (2007), these actions have a direct relationship with the dimensions of sustainable development, as they tend to reduce input costs and the costs with waste (economic) minimize the use of natural resources and the production of garbage (environmental) and, finally, can also improve the quality of life of the population (social).

Erkman (1997) mentions that the implementation of IE can be a source of competitive advantage, allowing any waste to become marketable by-products, given the need to increase efficiency in the use of energy and materials and the elimination of losses. Thus, it acts as a tool with clear economic, environmental and social properties (Ehrenfeld, 2000). One of the fundamental characteristics of IE is the integration of several components of a system to reduce: a) the input of resources; b) the generation of pollutants; c) waste outputs, and special application in interorganizational level (Despeisse *et al.*, 2012).

According with Isenmann (2003), the IE can be understood in general terms through its five characteristics, namely:

i) fundamental perspective: having nature as a model;

ii) primary objective: to seek harmony, balance, integration between ecological and industrial systems;

iii) definition of work: a science of sustainability;

iv) imain objects of work: products, processes, services and waste;

v) central idea: the search for the interlacing systems.

As the manifestation of Chertow (2000), IE has three different levels or performance scales (Figure 01). The first classification refers to activities developed internally to the organization (intra-organizational) and correspond to actions such as eco-design, pollution prevention and green accounting. At the intermediate level (meso), are initiatives involving inter-organizational relationships such as Industrial Symbiosis, industrial eco-parks (IEP) and analysis of the product life cycle. Finally, at the regional or global level (macro) are the analysis of the flow of materials and energy as well as policies and development plans.

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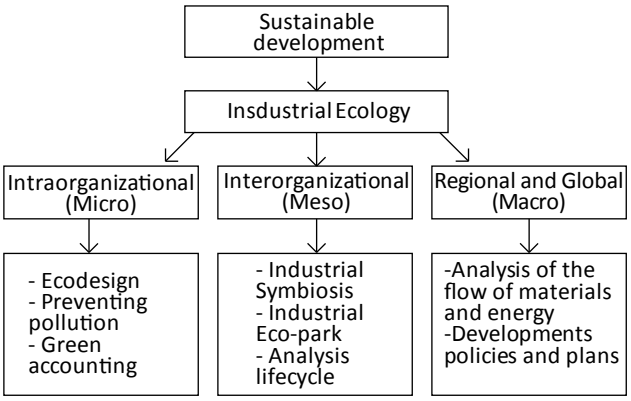

Figure 01 - Performance scales of Industrial Ecology
Source: Elaborated by Chertow (2000, p. 315)

Thus, Giurco et al. (2011) argued that the Industrial Symbiosis (or meso level) may be the most widespread application of IE, whose activity involves not only interorganizational exchanges of materials, products, water, energy and waste, with emphasis the exchange of human resources and technology, and their experience and knowledge (Posch, 2010). Also noteworthy is the rise of thematic IS due to the encouragement of non-governmental organizations, state agencies and the private sector to adopt their practices and to increase the number of studies on the subject in an attempt to soften the impact on the environment (Boons *et al.,* 2011).

Although are necessary periods of medium and long term for the development of the main scales of Industrial Ecology (Boons et al., 2011), it can be considered a potential tool with to add value to organizations (Rodrigues et al., 2013) and to help companies "interested in obtain optimal performance of corporate environmental sustainability, by lead integrated actions between industries, requiring regional planning and policy" (Lima, 2008, p. 91).

In an article whose goal was to provide an analytical framework of Social Sciences to investigate the IE and develop a prescriptive approach, Baas et Boons (2004) proposed three phases for the Regional Industrial Ecology. The first, called regional efficiency, involves decision-making autonomy of each company to coordinate with other local organizations in order to reduce inefficiencies. The second stage is based on mutual recognition and trust between the partners for the exchange of knowledge, and covers community participation (citizens). This provides a regional learning, in that expands the definition of the sustainability to those involved. Finally, in the third stage, the actors move forward on a strategic vision for sustainable development.

The authors note that before the first phase can be included in a selection stage, in which the actors will be part of the project will be submitted to certain criteria related to the principles of IE and own sustainable development. To Chertow (2007), this inclusion raises the prospect of success, especially initiatives that are planned and run from zero, since there are IS implementations that have arisen naturally, spontaneously (as will be detailed in the next section).

The need to consider the cross and comprehensive perspective of IE was reinforced by Jelinski et al. (1992). According to these authors, and also Cohen-Rosenthal (2000), its application involves engineering processes, of the economic system, of taxation, of government regulation, of consumer standard of living (lifetime of product), of the technological evolution, among other cultural and social factors that extend beyond the boundaries of just one organization, requiring a shared vision.

The multiple and concurrent views that IE provides constitute one of its most important points. To name a few of these views, there is philosophy, ethics, economics, ecology, biophysical and management, which are joined to generate viable sustainable solutions to human systems (Isenmann, 2003). When such elements operate in line, using metaphors and analogies, can provide an encouragement for creativity, for early brainstorming sessions, as well as serving as inspiration for convergence and for the guidance of perspectives and actions before competitors, towards sustainability (Erkman, 1997).

The viability of industrial systems with these characteristics requires at least two attributes: first, the systemic view of all kinds of resources and their relationship with the biosphere; subsequently, recognition of the interdependence between technological progress, economic growth and social change as preconditions to be socio-economic development, considering the respect for the environment. In other words, we must seek that technological progress is in line with the tripod of sustainable development (Isenmann, 2003).

Certainly this coexistence is not perfect. Rather, given the multiplicity of conditions and actors involved in an industrial system, it is possible that the coexistence of their interests continues in some extent, marked by pressures, conflicts, disagreements and contradictions, although probably mitigated by the integrative logic of IE. Even this way, the Industrial Ecology is an important integrative improvement over a pure logic of supply chains, based on resource optimization, or even a significant evolution when compared to the reasoning of the radical environmentalists, desirous of a utopian untouched nature (Hopwood *et al.*; 2005; Marconatto *et al.*, 2013).

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In this sense, Hoffman (2003) calls attention to the fact that, to be discussed and analyzed the levels of Industrial Ecology, it is necessary to recognize that industrial systems are not made only by materials and energy. It should be considered the significant presence of individuals, organizations and their demands for resources, in addition to their structural and institutional aspects. The author states that it is clear the omission of these factors among industrial ecologists, although they are essential factors for business efficiency in competitive markets characterized by scarcity of resources, the pursuit of organizational institutionalization and favorable interorganizational relationships. However, this omission does not prejudice the identified different actions of IE in several countries.

The metaphor proposed by IE in terms of meso level, finds its most illustrious concrete example in the Danish town of Kalundborg. The network of interorganizational exchanges of the location inspired one of his managers to employ, innovatively, the nomenclature Industrial Symbiosis. This is an explicit analogy to mutually beneficial relations existing in nature and called by biologists as symbiotic (Chertow, 2000; Lifset et Graedel, 2002). The next section is devoted to extend this information.

3. INDUSTRIAL SYMBIOSIS

Literally, the term symbiosis means “living together” and is used to describe interactions in which mutualism occurs, i.e., relationships between organisms of different species, engaged in direct exchanges, made for the sake of mutual benefits (Begon et al., 2007; Callenbach, 2001; Pinto-Coelho, 2002). As Begon et al. (2007), mutual relations cover goods or services and result in the acquisition of new capacities by participants.

Similarly, companies seek a collective return greater than the sum of individual benefits they could achieve acting individually. Therefore, according Chertow (2000), the key elements for the Industrial Symbiosis (IS) are collaboration and synergistic possibilities offered by geographical proximity between the organizations. Thus, the IS offers significant contributions to the IE, to the extent that adopts and implements features of natural ecosystems such as connectivity, community and cooperation (Costa *et* Ferrão, 2010).

In a recent study, Lombardi et Laybourn (2012) expose the definition of Industrial Symbiosis as a network of several companies to promote eco-innovation and culture change in long term. Thus, the IS is defined in order to represent a complex of interactions that make it possible to develop and share knowledge, generating mutually profitable transactions and more efficient business processes. For the authors, due to the current technological potential, even if geographical proximity is often associated with the IS, it should not be considered a determining factor of its operationalization.

In the opinion of Chertow et Ehrenfeld (2012), economic growth and social, as well as their technological opportunities, are propagated by the cooperation that can be identified in the Industrial Symbiosis. Furthermore, Wang et al. (2013) state that it is feasible to reduce waste and pollution through sharing: materials, water, energy, information and experiences.

However, Posch (2010) argues that, to enable these features of the IS, it is necessary to go beyond the restricted connections and intended for water, energy and materials reuse, which the author describes as the first generation Industrial Symbiosis. Thus, the central role of the IS passes to the interorganizational relationships that promote the interaction of skills and knowledge of people who work in partner companies as well as the technologies that each participating actor has to obtain competitive advantages, social and environmental point of view. This new role of IS is called by the author as the second generation (Posch, 2010).

Sustainable development requires more than repurpose energy, water and recycle materials or manufacture by-products. The need to move forward in the relations provided by the IS is justified by Posch (2010), by the fact that these actions are the second best option. By not avoiding or reducing the negative impacts of production processes in the origin, they do not devote (or dedicate very little) attention to interactions during the stages of research and development (R & D) of products and services innovations. In addition, the focus is not on synergies between individuals and their skills.

However, the author recognizes that these symbiotic relationships require, in addition to long-term, the creation of a conscious culture of cooperation not only between companies, but also including other local social actors (such as educational institutions and sectors public and private). In addition, efforts are also mentioned which can bring some important results: a) energy recycling; b) material recycling; c) development and integration of productive processes; d) development of sustainable products; e) collective learning; f) enhancement of joint projects to achieve common goals.

Develop high-performance products, high reliability, low cost, attractive appearance, security and undoubtedly less environmental impact is a challenge on the second generation of Industrial Symbiosis, as proposed

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by Posch (2010), and present in the competitive environment business. Regardless of the size of the organization acting in technology-based markets, these challenges are significant. However, in small enterprises receive an even larger. Thus, an alternative to face these difficulties seems to be working synergistically with other companies, universities, research centers, government agencies and their development agencies, and other stakeholders of society. This can occur more effectively in environments such as technology parks, industrial eco-parks (IEP), incubators, associations and consortiums (Barros *et* Rosa, 2011).

As an example, Graedel (2006) states that, during the sharing of experiences, knowledge and R & D activities, there may be ideas and relevant solutions regarding the choice of inputs to the project for energetic efficiency, the mitigation of air emissions (both at the time of production and in use of the product), the minimization of liquid and solid waste (the production process and the product itself), and also as recycling (reverse logistics). The author points out that excess waste from packaging is a simple demonstration of how much is still necessary to consider some environmental aspects for the development of new products and processes.

Ferrer et Guide Jr. (2002), and also Van Hoof (2009) warn that the professionals themselves (as designers and engineers) need to be prepared to design, develop, manufacture and optimize products and processes aimed at sustainable development. In the literature, it is quite common to find articles that discuss the introduction of courses on Industrial Ecology for graduate students and post-graduate (Cervantes, 2007; Eckelman *et al.*, 2011; Jung *et al.*, 2013; Ramaswami *et al.*, 2012).

For Chertow (2000) and Sakr et al. (2011), they are in environments such as industrial eco-parks (IEP) that the principles of IS find better conditions to be concretely implemented. Chertow (2000) uses the definition IEP developed by the US government when, during the administration of President Bill Clinton, was drawn up a public policy to support the creation of industrial eco-parks. Therefore, IEP is composed of a group of companies that cooperate with each other and with the local community to share information, energy, water, materials, infrastructure and natural resources efficiently, achieving returns in economic, environmental and human terms (Chertow, 2007).

Although there are similarities, some characteristics distinguish a IEP from other areas that congregate ventures. Initially, the identification of symbiotic exchanges is receiving special attention. Subsequently, the internal structure is organized from the assumptions of environmental management and ideas of IE and IS (Chertow *et* Ehrenfeld, 2012; Wang *et al.*, 2013).

The most famous case of Industrial eco-park is the Danish city Kalundborg. This project emerged in the early 1970s and is based in industries interactions in areas as energy, water, material and information flows. With the participation of local government and with companies in the energy sector (oil refinery and power plant), pharmaceutical, plaster manufacturing, among others (Lifset et Graedel, 2002). Its origin is linked to the need for better use of water and energy, comply with environmental legislation, reduce operating costs and also properly manage waste (Chertow, 2007).

Barros *et* Rosa (2011, p. 180) states that the IEP of Kalundborg:

> [...]it developed from the scarcity of water for the various activities of the municipality, such that around a thermoelectric mated a myriad of connections; from the production of fertilizers to the energy supply in local housing, including through the supply of plaster.

However, the recognition of the environmental implications arising from exchanges that have evolved over time occurred only in 1989 (Chertow, 2000). It is interesting to note that the word “evolved” is not used by chance. As Heeres et al. (2004), the Kalundborg initiative was not intended as a IEP, but progressed to such a structure gradually through the years. For this to happen, Chertow (2000) notes that a coordination team, responsible for internal and external communications, as well as increase the number of exchanges, has played a major role in the Danish city. And this is a structure that is not found in other similar initiative in Austria, which hindered the process of developing its eco-park (Chertow, 2000). The use of the concept of Industrial Symbiosis in the form of IEP aims to: a) revitalize urban and rural areas; b) promote the growth and retention of jobs; c) encourage sustainable development.

Thus, in some countries, these projects are being used in order to minimize environmental degradation and the amount of waste generated (Chertow, 2007). Veiga et Magrini (2009) extend this data, stating that some nations, such as China, Singapore, Thailand, South Korea, India, Colombia and Puerto Rico comprise a IEP as the opportunity to generate economic development and social welfare, and reducing environmental damage simultaneously.

Besides Denmark, are found industrial eco-parks in several countries, such as United States, Canada, Germany,

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Austria, Australia, UK, Sweden, Netherlands, Japan, the Philippines, Indonesia, Italy, Finland and France (Barros *et* Rosa, 2011; Chertow, 2000; Heeres *et al.,* 2004; Jung *et al.*, 2013; Mirata, 2004; Sakr *et al.*, 2011).

Initiatives that apply the IS principles can emerge and develop in a spontaneously or planned manner. In the first case, also known as self-organized, exchanges start through individual actions of some companies motivated by the need for cost reduction, increase revenue or expand their businesses. Ie there is no awareness of the conditions of an industrial ecosystem. This ends up happening, naturally and spontaneously, over time, when they are "discovered". This is what happened in Kalundborg, nearly two decades after the start of their interorganizational relationships. Furthermore, the existence of a coordinating staff to identify and organize the symbiotic connections, represents a significant incentive for the development (Chertow, 2007).

Already planned projects are the result of a conscious effort to select and approach (including geographically) companies that have potential for sharing various resources. Generally involve the formation of a group of representatives people of different social actors - such as universities, business entities and different levels of government - that will guide the organization and coordination necessary for the idea to be realized in long term (Chertow, 2007). May be from implementation of public policies (Heeres et al., 2004) or community leaders who have credibility, trust, access to different sectors of the local society and are committed to the values of sustainable development (Ferrer et al., 2012). It is noteworthy that affinities and pre-existing trade add facilities to that effort (Chertow, 2000; Gibbs *et* Deutz, 2007).

The literature shows that the planned projects tend to get lower performance before the self-organized. The most negative results are associated with those promoted by the government, due to lack of active participation of companies and because their motivations and their interests were not adequately considered (Chertow, 2007; Costa *et* Ferrão, 2010; Heeres *et al.,* 2004).

As a result, Costa et Ferrão (2010) propose a so-called middle-out approach, which corresponds to employment conjugate of spontaneous and planned ways. It is to carry out "successive, interactive and targeted (planned) interventions of interest groups, which converge in a dynamic process context modification, so that it can come to motivate/support the natural development (spontaneous) of industrial symbioses" (Costa, 2013, p. 13).

According to the authors, the approach makes it possible to integrate the contributions of managers (top-down) and workers (bottom-up) to improve and develop the project. Thus, the proposal adopts the following steps: a) assessment of the context; b) identification of actors who must participate in the initiative; c) interventions and coordination activities, according to the context and the objectives of the project; d) monitoring of actions and their impacts; e) feedback to coordinators to assist them in further interventions (Costa *et* Ferrão, 2010).

It can be observed that the implementation of IS projects and IEP is both beneficial and desired as complex and challenging. In this sense, extrapolates

[...]simple creation of connections between companies for the reuse of materials and energy, as it is to build organizations that are sustainable not only the economic and financial point of view, but also show satisfactory results in relation to environmental and social impacts of its productive activities. Therefore, the entire local community must be involved in the construction, organization and operation (Barros *et* Rosa, 2011, p. 181).

An important reservation, brought by Chertow (2000), highlights the fact that the principles of Industrial Symbiosis not need to occur in the narrow limits of a so-called environment as a IEP. It is also enough to designate a location as an eco-park that this is associated with real symbiotic inter-organizational relationships. In fact, the name is irrelevant, given the possible outcomes that the initiative could bring in economic, social and environmental terms. What matters is the coordination team be aware that, to achieve them, (yet) there is no either exclusively or modeling. In addition, the challenges are wrapped in long-term issues, the necessary investments in their legislation and in the different associated risks, in line with the social, institutional, political and cultural peculiar to each locality.

Specifically in Brazil, no records were found in the literature about the existence of industrial eco-parks. Already initiatives were seen as the Rio de Janeiro, which did not prosper (Fragomeni, 2005; Veiga, 2007; Veiga et Magrini, 2009). On the other hand, in terms of Industrial Symbiosis, actions of this kind are identified in the Camaçari Petrochemical Complex in Bahia (Tanimoto, 2004), and through the Brazilian Program of Industrial Symbiosis (BPIS) (Federation of Industries of the State of Minas Gerais, 2013).

The BPIS is presented as a version of the National Industrial Symbiosis Programme (NISP), originating in the United Kingdom and organized by the Federation of Industries of the State of Minas Gerais (FIEMG), the Federation of Industries of the State of Alagoas (FIEA) and

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the Federation of Industry of the Rio Grande do Sul State (FIERGS). It is intended for companies from various sectors and sizes and aims to establish profitable interactions through resources (human, material waste, water, energy, logistics, asset sharing, technology and expertise) that are available, but are still underutilized. The BPIS is disclosed as being able to reduce costs, to provide new businesses with alternative markets and also to build an environmentally responsible brand, "which, today, can be a great competitive advantage" (Federation of Industries of the State of Minas Gerais, 2013, p. 1).

Given the above, it is clear the dependence of Industrial Symbiosis has the relationships between the various actors, in particular those involving organizations interested in symbiotic exchanges. In this aspect, realized some similarities between the ideas advocated by the Industrial Symbiosis and the reasons for the effectiveness of interactions between organizations, although Van Bommel (2011) suggests the existence of even low levels of experience and knowledge necessary to implement the different aspects sustainable development in the current global network of industrial supply.

Another observation refers to the fact that companies are organized to meet collective interests and interorganizational relationships occur between macroenvironmental and microenvironmental spheres, i.e., the meso level, where a group of organizations act together. Thus, the resources of the interorganizational relationship, "as opposed to the resources of an individual company, are located in the set of relationships between companies, and not within the companies themselves" (Alves *et al.,* 2010, p. 3).

4. FINAL CONSIDERATIONS

Although there was no intention to exhaust the possibilities for discussions and links between the topics discussed, it is believed that it was possible to cause the emergence of other studies to further investigate the relationship between the issues encountered in the application of the ideas of Industrial Ecology. Notes the existence of spaces for research on these issues, as we tried to show in the introductory section of this article.

In this sense, it is believed that it was possible to meet the objective of this conceptual theoretical study, i.e., to show the definition, characteristics and performance scales of IE, as well as its natural link with sustainable development. In other words, aspiredto clarify the assumptions of IE and its application possibilities, which involve both interorganizational exchanges of materials, products, water, energy and waste as the exchange of human and technological resources, and their experiences and knowledge. Your job is interdependent of engineering processes, of the economic system, of taxation, of government regulation, of consumer living standards and technological developments, and other cultural and social factors that extend beyond of the border of just an organization.

The Industrial Ecology processes implementations and its three levels of operation can be successful. However, it is essential to understand their interactions and consider the social and cultural elements of each region. Thus, it is suggested the development of new investigations respecting the size of organizational interdependence and contemplating systemic approaches. It is recommended also the empirical disclosure of the ideas expressed here in the sense of seek to confirm the assumptions discussed and assess the possibility of expansion of the examples. It is noteworthy that the authors of this conceptual theoretical study are finalizing the development of a research aimed at empirically enlarge aspects exposed.

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