Eco industrial parks: a tool towards the reduction, reuse and recycling (3R's) of by-products and wastes: case study in Paracambi EIP, Rio de Janeiro State

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Abstract

This paper presents the Eco Industrial Park (EIP) concept, an environmental management tool that is being spread in many nations as an industrial model that can reconcile the three "Es" of sustainability – environment, social equity and economic efficiency – as it reorganizes industrial practices and activities in order to meet sustainable development goals. This mutual benefit results in more sustainable communities and environment, in the reduction of pollution, by products and waste discarded in the environment, increasing companies' competitiveness and access to new markets. Although this is an emerging concept, there are many EIP projects being implemented, and many of them already operating in North America, Europe, Asia, Central and South America, including in Rio de Janeiro State (RJS), Brazil.

This paper highlights the problem of waste generation increase from the industrial sector. All over the world, economic growth has increased resource consumption and environmental degradation. Industrialization brought wealth and development; however it has also brought many externalities. One of these externalities is the high level of by products and waste discarded by societies, being disposed in the environment without proper treatment and management.

The objective of this paper is to present how EIPs can contribute to the reduction, reuse and recycling (3R's) of by products and waste from the industrial sector. As a case study, this paper presents the Paracambi EIP, located in RJS, in which the methodology of the software Facility Synergy Tool (FaST), developed by the US-EPA, was a major tool used in order to develop by products and waste synergies among the different industrial typologies suggested for this EIP. Finally this paper presents an analysis and recommendations in the long term, regarding EIP development that may be implemented by the public sector in partnership with the private sector, communities and university.
Keywords: Eco Industrial Park, waste management, reduce, reuse and recycle (3R's), Rio de Janeiro State, Brazil.

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1 Introduction

This paper presents an environmental management tool that that tries to meet sustainable development goals: the Eco Industrial Parks (EIP). The EIP concept is being spread in many nations worldwide as a new industrial model that can reconcile the three dimensions of sustainability - environmental integrity, social equity and economic efficiency, as it reorganizes industrial practices and activities in order to meet sustainable development goals. In recent years, attention to EIP development has grown among governments, academia and industries in many countries. The major force behind the EIP concept is that it yields better economic, environmental and social results for industries cooperating with each other than industries acting independently. Although this is an emerging concept, there are many EIP projects being implemented, and many of them already operating in North America, Europe, Asia, Central and South America, including in Rio de Janeiro State (RJS), Brazil.

This paper first presents the problem of waste generation increase from the industrial sector. All over the world, economic growth has increased resource consumption and environmental degradation. Industrialization brought wealth and development; however it also brought many externalities. One of these externalities is the high level of by products and waste discarded by society's, being disposed in the environment without proper treatment and management.

In Brazil, the state of Rio de Janeiro State is struggling to find alternative ways to realize sustainable development. Facing a negative heritage of unsustainable economic growth experienced in the last twenty years, Rio de Janeiro's development reflects a picture of high urban and industrial concentration, an increasing number of land conflicts and deterioration of major environmental areas. The industrial park settlement in Rio de Janeiro reflects its disorderly development. In addition, the absence of proper integrated waste management practices instead of only end-of-pipe solutions, has contributed to severe environmental damages. More recently, the Rio the Janeiro State Government, looking for possible solutions and for possible ways to minimize by products and waste management problems, inspired by international experiences, launched the EIP program as a means to foster sustainable development, to ameliorate the environmental, economic and social distress caused by industrial development.

This paper aims to present how EIP can contribute to the reduction, reuse and recycling (3R's) of by products' and waste from the industrial sector, presenting as a case study, Paracambi EIP, located in Paracambi municipality, Rio de Janiro Metrpolitan Area (RJMA), in which the software Facility Synergy Tool (FaST) developed by the United States Environmental Protection Agency (US-EPA) was a major tool used on selecting the industrial mix in order to define possible by-product and waste synergies looking for the reduction, reuse and recycling possibilities among the industrial mix selected.

2 Waste management problem

The continuous growth of population, growth in the global demand for materials, urbanization, technological development and consumption pattern changes resulted in an increase in the amounts of byproducts and waste generated and disposed of by the industrial, residential and other sectors. In some countries the conventional waste management policies and technologies alone may not suffice to improve material efficiency and offset the byproduct and waste related environmental impacts of materials production and use [1].

The OECD report [1] made some global projections:

- Population: until 2050 it is expected that the world population will increase in 50%. 95% of this increase will happen in developed countries.
- Resource extraction: since 1980, global resource extraction has increased by 36%, and is expected to grow to 80 billion tones in 2020.
- Demand side: consumers will prefer products developed with eco-friendly technologies.
- Industrial Waste: the volume of non-hazardous wastes from industry will increase by about 60% between 2008 and 2020.
- Impact: until 2030, it is expected that the world population will continue to grow by about one-third, while the economy will double, placing increasing strains on the global environment.
- Impact: until 2025 it is expected that the byproducts and waste generated will increase five times.
- Brazil: it is estimated that 60% of all solid waste is disposed of inappropriately.

These remarks raise the question of how to sustain economic growth and welfare in the longer term, while keeping negative environmental impact under control and preserving natural capital. As Lemos [2] points out, more than 400 million tons of dangerous waste are generated worldwide each year. Almost 10% of these cross transnational borders, meaning a serious treat to human health and to the natural ecosystems, resulting in air, superficial and ground water and soil pollution and contamination [2].

In Brazil, a National Waste Management Policy has not been established yet. The Resolution 313/2002 from the National Environmental Council (CONAMA), established the Solid Waste National Inventory and the criteria for managing certain waste before being discarded.

The Brazilian Technical Standards Association (ABNT) established national standards regarding solid waste classification. The ABNT -10.004 classifies solid waste in class 1 – hazardous waste and class II, non hazardous waste. Table 1 gives an overview of the amount of hazardous and non hazardous waste generated in some Brazilian states.

Table 1 reveals that the amount of hazardous waste generated per year in São Paulo, Rio de Janeiro, Rio Grande do Sul, Paraná, Pernambuco, Goiás, Ceará and Minas Gerais represents only 3.8% of the total amount of industrial solid waste. However, in the states of Rio Grande do Sul and Ceará, the participation of hazardous waste in the generation of total industrial solid waste is more

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Table 1: Industrial solid waste generation in Brazilian states [3].

Brazilian States	Industrial Solid Waste		
	Hazardous Waste (I class)	Non Hazardous Waste (II class)	Total amount of industrial solid waste
São Paulo	535.615	26.084.062	26.619.677
Rio de Janeiro	293.953	5.768.562	6.062.515
Rio Grande do Sul	205.326	1.430.364	1.635.690
Paraná	634.543	15.106.393	15.740.936
Pernambuco	2.622	1.39.861	1.342.483
Goiás	4.405	1.486.969	1.491.374
Ceará	115.238	393.831	509.069
Minas Gerais	828.183	14.337.011	15.165.194
Total	2.629.88 (3.8%)	65.937.053 (96.2%)	68.566.938 (100%)

significant: 12.55% and 22.64% of the total amount of industrial solid waste respectively. The Table 1 also reveals that the states of São Paulo, Paraná, Minas Gerais and Rio Janeiro states are responsible for the largest amounts of industrial solid waste generated. This fact is due to the scale of their respective industrial parks. Highlighting Rio de Janeiro state, the total generated amount of industrial hazardous and non hazardous waste has already reached 293.953 million tons per year and 5.768.562 million tons per year [3].

In 2005, the Brazilian Association of Special Wastes (ABRELPE) published the report Panorama of Solid Waste in Brazil. This report highlighted the major problems that Brazil faces [3]:

- The extension of environmental damages and hazards caused by industrial solid waste is alarming.
- The industrial solid waste segment is still suffering from the lack of frequent, consistent and reliable data information with national coverage.
- Most of industrial waste is being stored or disposed off inappropriately.
- For the reuse and recycling activities, the predominance of actions carried out by the informal chain harms the expansion of recycling rates for an expressive amount of materials with such potential, due to the absolute impossibility of managing the process.
- The lack of a specific tax legislation that benefits the utilization of raw material deriving from recycling also inhibits the process by restraining the demand for such materials
- Legislation to support waste management is weak and the waste management infrastructure is still underdeveloped.

Rio de Janeiro State is struggling to find alternative ways to realize sustainable development. Facing a negative heritage of unsustainable economic growth experienced in the last twenty years, Rio de Janeiro's State development reflects a picture of high urban and industrial concentration, an increasing number of land conflicts and deterioration of major environmental areas. The industrial park settlement in Rio de Janeiro state reflects its disorderly development, shown by tightly clustered industries outside industrial zones, as well as the occupation of industrial zones for other purposes, mainly residential [4]. In addition, the absence of proper integrated waste management practices instead of only end-of-pipe solutions, has contributed to severe environmental damage and social distress. In RJMA, the heavy industrial concentration has resulted in an increase in the amount of byproducts and wastes generated. How to better dispose of waste economically without degrading the environment is another problem [4]. The lack of sufficient public funds and waste management and treatment practices, particularly by small and medium sized (SMS) industries, severely limits the range of options.

The above picture demonstrates that Rio de Janeiro state's "industrial scenario" is eroding not only the physical environment but also the foundation for production and thus the basis for growth. This is emphasized by the realization that the environment is increasingly a competitive factor in location decisions. The question is how to improve natural resource protection, community well being and at the same time maintain economic development. This situation prompted the State government to launch the EIP program as a means to foster sustainable development, to ameliorate the environmental, economic and caused by urban development.

3 Eco Industrial Parks

In recent years, attention to EIP development has grown among governments, academia and industries in many countries, particularly in the United States of America (USA), where the concept was developed in the beginning of the 90's by the United States Environmental Protection Agency (US-EPA) [5]. The major force behind the EIP concept is that it yields better economic, environmental and social results than do industries acting independently.

One of the Industrial Ecology (IE) tools, an EIP mirrors the biological ecosystems: a single organism can exist by itself or it can interact with other organism, in the same way, in an industrial ecosystem, industries can coexist and interact with each other. A major difference between a biological and an industrial ecosystem is the fact that in nature we have a natura process, while in an industrial ecosystem there is intentional action [5]. In sum, IE aims to achieve sustainable production and consumption patterns by minimizing natural resource consumption and waste generation while still satisfying economic demands. This way, an EIP is defined as "a community of manufacturing and service businesses located together on a common property. Member businesses seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues. By working together, the community of businesses seeks a collective benefit that is greater than the sum of individual benefits each company would realize by only optimizing its individual performance. The goal of an EIP is to improve the economic performance of the participating companies while minimizing their environmental impacts. Components of this approach include green design of park infrastructure and plants (new or retrofitted); cleaner production, pollution prevention; energy efficiency; reduction, reuse, recycling of by-products and waste (3 R's) and inter-company partnering. An EIP also seeks benefits for neighboring communities to assure that the net impact of its development is positive." [4]. This definition is broadly accepted by major authors in the eco-industrial development field (see [5–8]).

In North America, more specifically in the USA [9] and in Canada [10] there are many EIPs projects being implemented and many already operating. In Europe,

EIPs are being considered a possible way to overcome environmental damage and to promote a more sustainable development. The classic example of EIP found in the literature is Kalundborg, in Denmark. Initiated in the 70's, Kalundborg was not planned, but gradually evolved over a number of decades when the participants discovered that the establishment of by-products and waste reuse and recycling resulted in economic benefits for all parties involved (see [12] for a detailed history).

In the same way as in developed nations, the EIP concept is being spread in developing and newly industrialized nations (DN/NIN) as a way to foster sustainable development. In some Asian and Latin American nations, the rapid industrialization process has increased resource consumption and environmental degradation [13]. In these nations, particularly in China, South Chorea [13], Thailand, Singapore [14], India [15], Colombia [16], Porto Rico [17] and Brazil, among others, EIPs are being considered a possible way to overcome environmental damage and at the same time to improve industrial and community economic and social welfare and development. Other Asian nations that are implementing EIP initiatives are the Philippines, Indonesia, Malaysia, Japan, Taiwan and Sri Lanka [13].

4 Eco Industrial Park at Paracambi

Located in the northwest part of the RJMA, Paracambi municipality is small, with a population of approximately 41,000 people and an area of 180 km2 (3.7% of RJMA and 0.4% of the whole state area), and is distant 80 km from the city of Rio de Janeiro. The Paracambi EIP is located in a greenfield site, in an area of 2.439 Km2 of land. Site selection was based on possible economic development and strategic land planning possibilities. The site offers excellent transport connections both to the north and south of the country (Rio de Janeiro, Minas Gerais and São Paulo states); water, electricity and natural gas supply are available through the grid. [18].

Based on the international experience (research, initiatives, solutions and mistakes) and on local conditions a methodology was developed for Paracambi EIP planning project (for details see [18]). The project goals would be achieved by a reduction in natural resources consumption, maximum use of natural resources and minimum discharge of waste in the environment due to byproduct and waste synergies, reuse and recycling of materials among EIP industries; energy efficiency maximization; multi-level use of water and shared use of infrastructure and services. In order to define Paracambi EIP industrial mix, a search, looking for possible by products and waste synergies, reuse and recycling was conducted using major databases and the software Facility Synergy Tool (FaST) developed by the United States Environmental Protection Agency (US-EPA). The FaST was a major tool used in this search.

In order to demonstrate possible synergies, a matrix was developed, showing the industries selected byproduct and waste outputs and potential synergies. Table 2 presents the preliminary result of this matrix (for details see [18]).

The matrix above demonstrates that the industrial mix suggested would have potential for developing byproduct and waste synergies, reuse and recycling as most of the byproducts and wastes generated would potentially be reusable by the industries suggested. It should be noted however that the byproduct and wastes generated were potentially considered, as their selection were done based on international sources and databases. As Magrini and Montez [19] explained, in order to have an effective byproduct and waste matrix, an inventory of each industry by product and waste generated should have been done and the viability of using them in natura or after some treatment or recuperation process should be considered.

If the Paracambi planning project evolves as expected, it will help the local community to make progress toward more sustainable development, as it aims to achieve economies of scale, reduce industrial costs, increase industries competitiveness, minimize environmental impacts, waste discharge and natural resource consumption and depletion resulting from the industrial activities, and finally improve community life quality. Therefore, it is expected that the EIP tenants would be guided by a common vision of sustainable development, being committed to ongoing economic, social and environmental improvement.

5 Conclusions

Inspired by experiences in Europe, North America and Asia, EIPs were launched in Rio de Janeiro as a potential environmental planning tool to foster sustainable development and to improve the degraded urban and environmental condition existing in the RJMA. Based on studies, projects and initiatives developed worldwide a methodology containing the initial steps for Paracambi EIP, located in RJMA, was developed. The software Facility Synergy Tool (FaST) was a major tool used on selecting this EIP industrial mix in order to define possible by-product and waste synergies looking for the reduction, reuse and recycling possibilities among the industrial mix selected.

Based on our findings, this paper suggests that the following points should be considered regarding EIP continuity in Rio de Janeiro State, in order to contribute to the reduction, reuse and recycling (3R's) of by products' and waste from the industrial sector:

- Environmental and social development must be done jointly with economic development, following the same path.
- Community and industry education is needed to support EIP development.
- All byproducts and waste should be managed in an environmentally sound manner to protect human health and the environment.

Table 2: Paracambi EIP byproduct and waste matrix.

Industrial Mix	Byproduct and Waste																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Textile Mills	GR	GR	GR	GR	G				GR						G		
Wire Manufacturing		G			G	G	G	G	GR						G		
Marble Processing									G					G			
Paint Manufacturing		G		G	G		G		GR	GR	R				G		
Plastic Recycling					R						G						
Electroplating		GR	G	GR	G				GR	R		G					
Steel Slab Manufacturing		GR	R		G	GR	G	G	GR			R			G		
Plastic Manufacturing					R				G								
Co-processing	R	R	R	R	R	R	R		R		R		R		R		G
Cement Manufacturing		R						GR	R				GR	R		R	R
Recycling Facylity	R					R	R				R				R		

Legend:
G – byproduct and waste generator;
R – possible byproduct and waste receiver;
G/R –generator and receiver of by product and waste.

Main By-products and Waste:
1.Textile scrap, cotton fibers ; 2. Solvents; 3. Acids; 4. Inks and pigments sludge; 5. Plastic bags, unidentified plastic scraps, polypropylene, polyethylene, pellets, film scrap; 6. Metal scrap; 7. Used iron, aluminum, lead, zinc, copper, steel and other non ferrous metals; 8. Ash containing metals; 9. Oil and wax; 10. Chemicals (ammonia, sodium hydroxide, chloride); 11. Plastic resin, acrylic, vinyl; 12. Exotic and Precious Metals (cobalt, nickel, mercury, gold, silver); 13. Cement kiln dust; 14. Marble dust and scrap; 15. Paper, loose paper waste, baled paper waste, paperboard, corrugated cardboard; 16. Sludge containing metals, solvents, ink pigments, acids, oils, chemicals; 17. Co-processed by products and dust.

- It is important that the Brazilian Federal Government institutes measures to oblige the generating sources of industrial byproducts waste to reveal the amounts produced each year, as well as the destination given to it.
- Public sector incentives and policies are needed to encourage the development of byproducts and waste reuse and recycling programs.
- Waste management policies should be supported by reliable information on waste and materials flows, and on resources productivity.
- It is urgent that public policies that institute formal recyclables collection and recycling programs are implemented, mainly by the municipalities.
- It is necessary that the legislators responsible for the definition and approval of new legal instruments pay attention to all the aspects and reach that byproducts and waste management policies should have to become stimulators of sustainable solutions, feasible to apply both by the public and private sectors.
- Rio de Janeiro has different political, social, economic, cultural and environmental constraints compared to other regions of the world

From what has been accomplished so far we concluded that Rio de Janeiro State has the potential for developing a sustainable industrial system through EIP implementation. Just as in many other regions around the world, EIP development in RJMA still has many challenges to overcome. However, the continuity of EIPs in the RJMA will only be successful if we have a convergence of the actors' interests, to build a cooperative network to achieve sustainable development.

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