Municipal Solid Waste Management in the context of Industrial Ecology:

the case study of Athens – Greece

T. Ioannou, K. Abeliotis and K. Lasaridi

School of Environment, Geography and Applied Economics, Harokopio University of Athens, 70, El. Venizelou Str, Athens 17671, GREECE

Keywords: Municipal Solid Waste, industrial ecology, recycling, Athens

Presenting author email: klasaridi@hua.gr, tel.: +30-210-9549164

Abstract

The current state-of-the-art research in Municipal Solid Waste (MSW) management is based on the concept of integrated management, life cycle thinking and de-coupling the waste production from economic growth. The European Union (EU) proposed the so called "waste hierarchy" and tried to guide the member-states to develop legislation and infrastructure towards this direction making it a legal requirement with the latest Framework Directive (2008/98/EU).

Under this prism, MSW management is a very complex issue with several technical, economic and social constraints. In this context MSW facilities can be regarded as any other industrial plant, possibly in a higher complexity context, as the waste will be produced anyway necessitating some type of treatment.

On the other hand, Industrial Ecology (IE), as a concept, adopts a systemic approach and supports the reduction of the environmental impact of any industrial activity by learning from an analogy with natural ecosystems. Moreover, it is considered that the term "industrial" is referred to all human activities of modern society and includes activities such as tourism, manufacturing, household, medical services, transport, agriculture and waste management.

In this context, the first goal of the present study is to highlight the common ground between integrated MSW management, as imposed by Waste Framework Directive-2008/98/EU and IE. The second goal is to present the current state of MSW management in the Greater Area of Athens in terms of the "industrial ecology" concept, hoping that this specific perspective will give the chance to the decision makers and all of us to reassess the non-sustainable way of MSW management we have applied so far.

1. Introduction

In scientific literature on sustainable development several researchers use the analogy between natural ecosystems and industrial infrastructure (or industrial ecosystems as they are known). Of course, the latest ones are affected not only by natural laws but by social interventions, economic interests, legislative measures and operational rules as well. In this context, Municipal Solid Waste (MSW) management consists a clear example of the complex situation that one can face as a decision maker. Nowadays, as is widely accepted, a waste management system forms an industrial complex of facilities, which as a whole is and it will remain sustainable in the future, if it is environmentally effective, economically affordable and socially acceptable [1].

On the other hand, an industrial network designed as proposed by the concept of Industrial Ecology (IE) promises less environmental burdens, increased revenues and social benefits [2]. For those reasons, this paper attempts to bridge the specific needs of a MSW management system along with the features of IE, while respecting the existing institutional framework (e.g. Directive 2008/98/EC).

2. A brief review in the context of Industrial Ecology

2.1. Industrial Ecology: definition and principles

Industrial Ecology was made popular by Frosch and Gallopoulos (1989) [3]. In general terms they proposed: a) industrial systems to mimic biological ecosystems and b) to transform entire industrial production from a linear path to a circular one. Since then several and varied definitions have been given for IE (e.g. [4-8]), but as referred in relative literature, all authors agree more or less on three basic elements of it: a) the systems' view b) the study of the energy and matter flows (except the economic ones) in the industrial system and c) the relation between IE and technological dynamic [9]. Given that IE provides a vision and basis for understanding how improvements can be made to current production processes, its principals and goals (presented in Table 1) are considered idealized and hard to achieved. That's the reason for the existence of the term "implementation gap" that highlights the distance between the theory and implementations of IE [10].

Table 1. The principles of industrial ecology, adapted from [11].

Promote opportunities to establish genuine partnerships and engagement with communities and government in developing a more responsive attitude to sustainable industry practices
Locate industries strategically to optimize the capture and concentration of by-products, waste material flows and energy surplus for use by other industries
Co-locate industries that will benefit economically from the trade or exchange of waste and by-products. Capture and create opportunities to add value by applying waste and energy recovery practices in industrial systems
Provide a catalyst to create synergies and an environment for fostering technological advancement in cleaner production, waste management and sustainable industry development
Provide appropriate ‘smart infrastructure’, to ensure the growth of eco-industries that support sustainable industry practices to maintain high levels of innovation as the basis of their competitive edge
Support industry policies and incentives to encourage innovation, collaboration and commercialization of new and improved product developments using materials, water and energy surplus to production
Demonstrate commitment to the benefit of industries that have strong, sustainable development

Regardless of what any researcher believes on the successful implementation (or not) of IE there are some, at least, promising implementation examples, while the most famous one is the industrial complex of Kalundborg that operates since early ‘80. The small Danish city of Kalundborg is located on the island of Seeland, about 100 km west of Copenhagen, Denmark [12]. For a review on more recent initiatives concerning IE implementation, see [13] (p. 40-42).

2.2. Eco-Industrial Parks and industrial symbiosis

According to Korhonen there are two paths to IE and consequently two different approaches can be determined, in order to try to achieve a triple win (economic-environmental-social) bottom scenario. The first path is related to product perspective (e.g. life cycle assessment), while the second approach comprises the spatial dimension of IE (local-regional industrial districts) [14], that is widely known as Eco-Industrial Parks (EIP) or industrial recycling networks or industrial ecosystems [15]. Under the light of this latest approach, in this paper we will be dealing with MSW management in Greater area of Athens.

An EIP is defined as “*a community of businesses that co-operate with each other and with the local community to efficiently share resources (information, materials, water, energy, infrastructure and natural habitat), leading to economic gains, gains in environmental quality and equitable enhancement of human resources for business and local community*” [16]. For a review on EIP definitions see [13] (p. 27-28). Obviously, the basic principle of EIP is IE.

Furthermore, the fundamental analogy between natural and industrial ecosystems, on which the edifice of IE and related concepts are relied on, leads inevitably to the adoption of other sub-principles which already exist in biology and ecology and transferred to IE concept. The correspondence between the principles of the natural ecosystem and industrial ecosystem is presented in Table 2.

Table 2. Natural ecosystem principles vs industrial ecosystem principles adapted from [17].

	Natural ecosystem	Industrial ecosystem
Roundput	Recycling of matter, cascading of energy	Recycling of matter, cascading of energy
Diversity	Biodiversity, diversity in species, organisms, diversity in actions, in interdependency and in co-operation, diversity in information	Diversity in actions, in interdependency and in co-operation, diversity in industrial input, output
Locality	Utilising local resources, respecting the local natural limiting factors, local interdependency, co-operation	Utilising local resources, waste, respecting the local natural limiting factors, co-operation between local actors
Gradual change	Evolution using solar energy, evolution through reproduction, cyclical time, seasonal time, ,slow time rates in the development of system diversity	Using waste material and energy, renewable resources, gradual development of the system diversity

The analogy between natural and industrial ecosystems is completed through the mean of “symbiosis”. According to Chertow ‘‘*industrial symbiosis, as part of the emerging field of industrial ecology, demands resolute attention to the flow of materials and energy through local and regional economies. Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity*” [18]. As can be understood EIP consist the implementation of the IE and industrial symbiosis concepts.

Several researchers pay particular attention to the presence of a key-entity within the limits of an EIP, in order to operate properly. This key-entity has named by many different names like: “symbiosis institute”, “support system”, “anchor tenant”, “initiator”, process unit” or “separate co-ordinating unit” [19]. In line with this approach is the following classification: physical anchor tenant (like a regional power company) and institutional anchor tenant (like a university) [20].

Finally, it should be underlined the comparison of the activities of producers, consumers and decomposers in the natural and industrial ecosystems regarding material and energy flows (Figure 1).

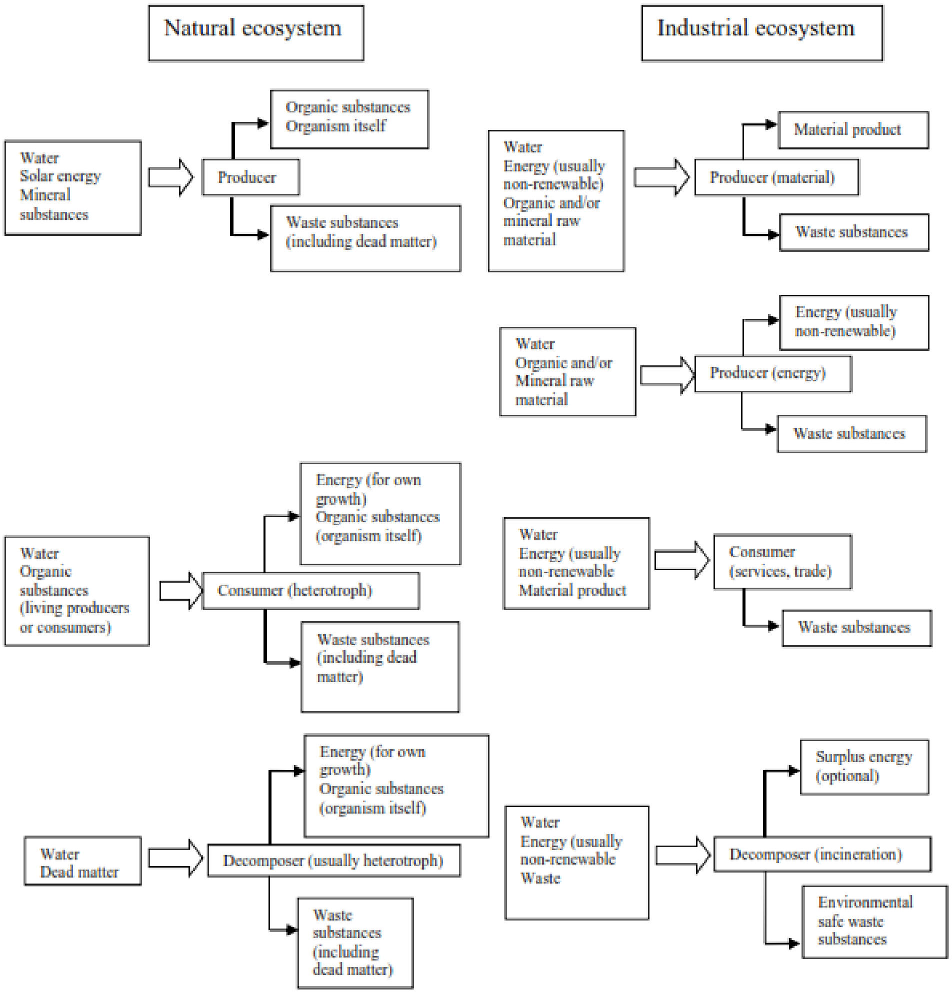

Figure 1. Activities of producers, consumers and decomposers in the natural ecosystems vs industrial ecosystems regarding material and energy flows, adapted from [21].

Following this approach:

- industrial producers include enterprises which accept as input water, energy and mineral raw material and produce material products, water, energy and waste substances as well
- industrial consumers are these entities that need to receive the input materials from industrial producers, as well as they need water and energy and give as output only waste substances and
- industrial decomposers include enterprises aiming at transforming, recycling and neutralizing waste (by-products) derived by industrial producers and consumers, while they produce environmentally safe waste substances.

Moreover, it should be noted the following key point, about the structure and the participants of an EIP: the minimal condition for implementing an EIP is to add in at least one industrial producer or one industrial decomposer [21].

3. Connecting the integrated Municipal Solid Waste management to Industrial Ecology.

3.1. Waste Framework Directive and Industrial Ecology

Nowadays, it is considered that the term “industrial” as part of “industrial ecology”, is referred to all human activities of modern society and includes activities such as tourism, manufacturing, household, medical services, transport, agriculture and waste management [22]. In this context MSW facilities can be regarded as any other industrial plant, possibly in a higher complexity context, as the waste will be produced anyway necessitating some type of treatment.

The current state-of-the-art research in MSW management is based on the concept of integrated management and life cycle thinking. The EU proposed the so called "waste hierarchy" and tried to guide the member-states to develop legislation and infrastructure towards this direction making it a legal requirement with the new Waste Framework Directive [23] that set quantitative targets for the dry recyclable fractions as well.

The articles of Waste Framework Directive (2008/98/EU), in line with the conceptual framework of IE are:

- Article 5. Clear distinction between waste and by-products. This distinction is crucial for the transportation and use of materials recovered from waste (e.g. dry recyclables, RDF, compost), as these products can move freely within the EU, while waste are subject to strict regulations.
- Article 6. End of waste status. Certain specified waste shall cease to be waste when it has undergone a recovery, including recycling, operation and complies with specific criteria to be developed in accordance specific conditions.
- Article 8. Extended producer responsibility.
- Article 16. Principles of self-sufficiency and proximity.
- Article 38 (and16). Interpretation and adaptation to technical progress.
- Articles 7, 23, 26, 28, 34, 35 (Indicatively). Requirements for a complete recording system, record keeping and monitoring of the physical flow of waste by establishing specific management plans [23].

Moreover, as is apparent from the grounds of adoption of the Directive, waste management (including MSW management) requires systemic approach of the interactions between producers and traffickers/dealers of waste and natural ecosystems.

3.2. On municipalities, MSW management and Industrial Ecology

Since 1990s, especially after establishing Local Agenda 21, the responsibilities of local authorities have increased in several fields that can affect directly or indirectly, less or more the every-day life of citizens [20]. However, the local authorities in Greece (including Athens) did not sufficiently exercise their powers due to administrative or political reasons, at least in the field of MSW management, resulting delays in planning and project implementation.

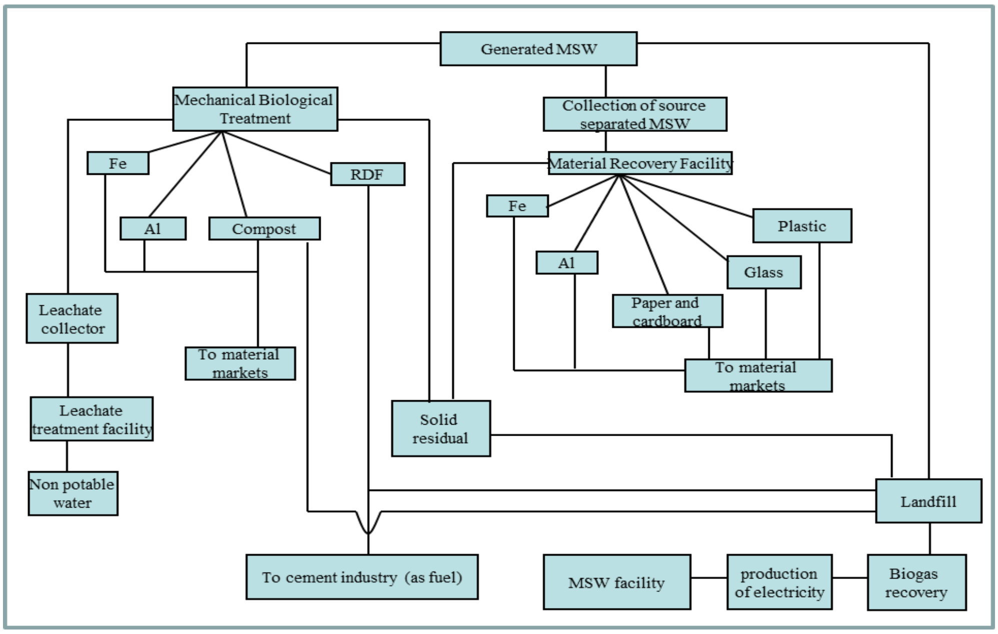

Figure 2. Flow chart of MSW management in Greater Area of Athens – Greece.

In Figure 2 is represented the present situation of Greater Area of Athens concerning MSW management. The Mechanical Biological Treatment facility, Material Recovery Facility and landfilling site, presented in Figure 2, are located in West Attica, (in municipalities of Ano Liossia, Phyli, Aspropyrgos that are close to each other) about 25Km west-northwest of the center of Athens.

As it is concluded, by Figure 2, the initial design and spatial planning of the different subsystems of an integrated MSW management facilities has been partial implemented. However, its current operation is not satisfactory [24, 25]. Specifically, the produced RDF doesn't reach cement industries because of strong opposition of local population, in the area close to cement industries that they should use RDF as fuel. On the other hand, the produced compost is not used for agricultural purposes in the market, because of its poor quality. Thus, is used as coating material in the close landfill site or for the restoration of quarries and other polluted sites. Finally, the electricity generated by biogas only covers the installation needs without connecting households in urban net.

Theoretically speaking, these installations could act as a core of an EIP that operates exchanging by-products (waste), coming by urban metabolism or by a waste facility that is located in a close distance. In case that, in this particular MSW management complex are established interconnecting material and energy "pipelines" between neighboring facilities, enterprises and urban web, we could claim that we get an active EIP for MSW management.

The theoretical context of IE includes this kind of EIP. In fact, Lowe, in his attempt to describe their characteristic and operation had adopted the term "Integrated Resources Recovery Parks", since 2001. Within the park "*the resource recovery industry includes recovery industry includes reuse, recycling, remanufacturing and composting, as well as the marketing and end-use of reclaimed discarded materials… The unifying concept is that discarded materials, goods, and by-products are turned into salable materials and products.*" [26]. Moreover, the construction of an EIP of any kind, relatively close to a city, represents a positive development because it helps to improve urban energy efficiency and sustainability [27].

But there is still a crucial question to be investigated: which key factor will take the responsibility to inform stakeholder about the establishment and operation of an EIP, the possible co-operations and possible mutual benefits? Local authorities (municipalities or association of municipalities) could fulfill this role. Ideally, they can: a) provide institutional, political and decision-making support b) educate the stakeholders c) establish and coordinate a database concerning material, energy and information flows and d) act in a sustainable way thinking in terms of environmental protection, economic profit and social acceptance, like a true institutional anchor tenant that every stakeholder or firm will be able to trust. This is a task that is difficult to be accomplished by a private company which usually focuses on profit besides the fact the competitors will not trust it [20].

Concluding this section, concerning MSW management in light of IE, is essential to imprint all the proportions given (see Table 3).

Table 3. Proportions between MSW management and Industrial Ecology concept

Municipal Solid Waste management	**Industrial Ecology concept**
urban area, municipal organizations that are responsible for collection, treatment e.t.c.	Industrial consumer, according to Liwarska-Bizukojc et al. (2009) Physical anchor tenant, according to Burstrom and Korhonen, (2001)
Municipality, association of municipalities	Institutional anchor tenant
Mechanical Biological Treatment + Material Recovery Facility + landfill site + products of treatment	Eco-Industrial Park
Municipal Solid Waste	waste

4. Conclusions

The combination of approaches to IE and integrated management of MSW presents significant advantages. The redefinition of the waste and their classification as secondary materials, exploitable by productive units, lends economic value, while until now were viewed as worthless and burdened the companies with the disposal costs. Reducing the waste stream means (for businesses) reducing their environmental impact, reducing management costs and reduction of cost of compliance of the company to the strict legislative framework. The cooperating enterprises can create new jobs to support the symbiosis (like MRF) and to promote their pro-environmental image [28]. Finally, if the industrial symbiosis within the EIP for MSW management proved successful and socially accepted, would reduce the need for strict separation of integrated MSW management facilities and urban areas and the fuel consumption associated with transport of MSW management system.

References

1) Morrisey, A.J. and Browne, J.: Waste management models and their application to sustainable waste management. Waste Management 24, 297-308 (2004).
2) Mirata, M. and Emtairah, T.: Industrial symbiosis networks and the contribution to environmental innovation: The case of the Landskrona industrial symbiosis programme. Journal of Cleaner Production 13, 993-1002 (2005).
3) Frosch, R. and Gallopoulos, N.: Strategies for Manufacturing. Scientific American, 261, 94-102 (1989).
4) Tibbs, B.C.: Industrial Ecology: an Environmental Agenda for industry. Whole Earth Review, Winter, 4-19 (1992).
5) Frosch, R.A.,: Industrial ecology: adapting technology for a sustainable world. Environment 37(1), 16-24, 34-37 (1995).

6) Graedel, T.E. and Allenby, B.R.,: Industrial Ecology, Prentice Hall International, London (1995).
7) Deutz, P. and Gibbs, D.: Eco-industrial development and economic development: industrial ecology or place promotion? Business Strategy and the Environment 13, 347–362 (2004).
8) Yang, P. and Lay, O.,: Applying ecosystem concepts to the planning of industrial areas: a case study of Singapore's Jurong Island. Journal of Cleaner Production 12, 1011–1023 (2004).
9) Korhonen, J., Savolainen, I., Ohlstrom, M.: Applications of the industrial ecology concept in a research project: Technology and Climate Change (CLIMTECH) Research in Finland. Journal of Cleaner Production 12, 1087-1097 (2004).
10) Gibbs, D. and Deutz, P.: Reflections on implementing industrial ecology through eco-industrial park development. Journal of Cleaner Production 15, 1683-1695 (2007).
11) Roberts, B.H.,: The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: an Australian case study. Journal of Cleaner Production 12, 997–1010 (2004).
12) Desrocher, P.: Regional development and inter- industry recycling linkages: some historical perspectives. Entrepreneurship & regional development 14, 49-65 (2002).
13) Ioannou, A.: Applying the principles of industrial ecology to municipal solid waste management: the case study of packaging waste. PhD thesis http://estia.hua.gr:8080/dspace/bitstream/123456789/2327/1/%CE%99%CF%89%CE%AC%CE%BD%CE%BD%CE%BF%CF%85%2c%20%CE%91%CE%B8%CE%B1%CE%BD%CE%AC%CF%83%CE%B9%CE%BF%CF%82.pdf, (in Greek) (2013). Accessed 17 May 2014.
14) Korhonen, J.: Two Paths to Industrial Ecology: Applying the Product-based and Geographical Approaches. Journal of Environmental Planning and Management 45(1), 39–57 (2002).
15) Korhonen, J.: On the Ethics of Corporate Social Responsibility-Considering the Paradigm of Industrial Metabolism. Journal of Business Ethics 48, 301-315 (2003).
16) President's Council for Sustainable Development : Eco-Industrial Park Workshop Proceedings, October 17-18, 1996, Cape Charles, Virginia, USA, http://clinton2.nara.gov/PCSD/Publications/Eco_Workshop.html#iv. (1997). Accessed 17 May 2014.
17) Korhonen, J.: Four ecosystem principles for an industrial ecosystem. Journal of Cleaner Production 9, 253–259 (2001).
18) Chertow, M.R.: Industrial symbiosis: literature and taxonomy. Annual Review of Energy and Environment, 25, 313–337 (2000).
19) Korhonen, J.: Co-production of heat and power: an anchor tenant of a regional industrial ecosystem. Journal of Cleaner Production 9, 509–517 (2001).
20) Burstrom, F. and Korhonen, J.: Municipalities and industrial ecology: reconsidering municipal environmental management. Sustainable Development 9, 36–46 (2001).
21) Liwarska-Bizukojc, E., Bizukojc, M., Marcinkowski, A., Doniec, A.: The conceptual model of an eco-industrial park based upon ecological relationships. Journal of Cleaner Production 17, 732–741 (2009).
22) Graedel, T.E and Allenby, B.R.: Βιομηχανική οικολογία. Δεύτερη αμερικανική έκδοση. Μετάφραση: Κατσαντώνης Γιάννης, Αθήνα: εκδόσεις Κλειδάριθμος (2009)(in Greek).
23) Directive 2008/98/EC. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:en:PDF. Accessed 18 May 2014.
24) Hadjibiros, K., Dermatas, D. Laspidou, C.S.: Municipal solid waste management and landfill site selection in Greece: irrationality versus efficiency, Global NEST Journal, 13 (2), 150-161 (2011).
25) Hadjibiros, K. and Laspidou, C.: A criticism of municipal solid waste management and landfill site selection in Greece. Proceedings of the 11th International Conference on Environmental Science and Technology, Crete 2009, Chania, Crete-Greece, 3/9-5/9/2009, 404-410 (2009).
26) Lowe, E.: Eco-industrial Park Handbook for Asian Developing Countries, A Report to Asian Development Bank, Environment Department, RPP International, Emeryville, CA., http://indigodev.com/ADBHBdownloads.html. (2001). Accessed 17 May 2014.
27) Zhong, P., Xia, W., Xu, B.: Study on energy efficiency model in Xi'an High-tech eco-industrial park. 978-1-4244-4813-5/10/IEEE. (2010).
28) Gibbs, D. and Deutz, P.: Implementing industrial ecology? Planning for eco-industrial parks in the USA. Geoforum 36, 452–464 (2005).