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ENVIRONMENTAL PLANNING AND MANAGEMENT

Eco-industrial zones in the context of sustainability development of urban areas

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Abstract

Industry is one of the main activities in the city and in many cities of the world, and the dominant industrial zones are the most significant morphological forms of concentration of industrial facilities in the city and are concentrated industrial and business activity. Industrial parks combine activities related to energy and resource consumption, emissions, waste generation, economic benefits, and regional development. The focus of this work is the path of transformation between the present and the vision of a sustainable city in the future. The problem and the subject of research related to two related objects of research: the city and sustainable development. In this paper, the co-author's industrial symbiosis parks, modern tendencies of the spatial distribution of productive activities, circular economy, to attract leading corporations and open the way for new ventures while preserving the living environment in an urban area.

Keywords Cities · Industrial zones · Industrial parks · Pollutants · Monitoring

Introduction

In the post-modern ambiance, industry is one of the main activities in the city and in many cities of the world and is dominant. Industrial zones are the most significant morphological forms of concentration of industrial facilities in the city and represent concentrated industrial and business activities. A business zone is limited space in which is realized certain businesses or economic activities or actions. According to size and purpose, business zones can be grouped into three:

1. *Specialized zones* that include technology centers, parks, incubators, technology transfer centers, and areas specialized for certain activities
2. *Entrepreneurial-craft zones*, in which we include areas with a high concentration, primarily small businesses and entrepreneurs
3. *Industrial zones*, where we include, above all, larger areas with a high concentration of industry, which is dominated by large companies (Alendar 1994)

Industrial zones represent special organized business units that are in one location, well connected with communications and develop types of production and service activities on the principles of cluster organization (Fig. 1).

Experiment

The industrial zones/parks play a central role in the sustainable development of cities, as they can have large effects on the

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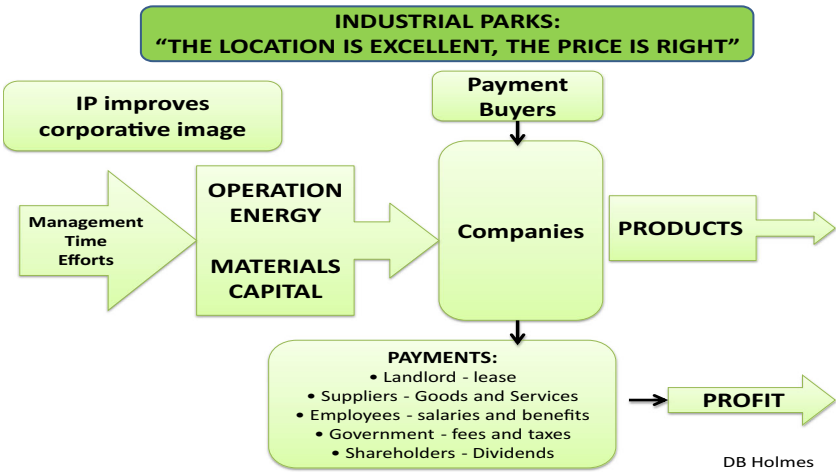

Fig. 1 Industrial parks/zones (specific characteristics)

system as a whole. These parks incorporate activities related to energy and resource consumption, harmful emissions, waste generation, economic benefits, and regional development.

For the development of urban areas, which have industrial zones/parks, particularly is an important issue of optimizing the activities and actions at regional and local level (Andevski 2006). Certain regions in the country provide different conditions for economic development, especially the development of certain industries. Within these regions, certain local communities, such as municipalities and cities, create the differences in terms of the development of the business environment for specific industries, essential for ecological security and sustainable development.

The research objectives are closely related to a predetermined problem research:

- It is wanted to give an overview of all the major problems of the city, with the tracking of generator pollutants in urban and rural parts of the city.
- It is wanted to prove the importance of ecological management efficiency in the city.
- It is wanted to highlight the importance of managing environmental security, risks, and vulnerabilities.
- It is wanted to point out the interaction between the economic development policy of the city and sustainable development, respectively sustainable vision of the future.
- It is wanted to show the importance of innovation in all aspects of life and work.
- It is wanted to emphasize the importance of active participation of all interested parties.
- It is wanted to highlight the importance of education and the development of environmental awareness from an early age.
- The aim is, also, to make use of existing knowledge and the world practice, in order to resolve some of the current environmental problems, for example of the city including 100,000 inhabitants.

Methods

Industrial zones—situation and perspectives of development

Industrial zones have two characteristics in common: a shared location of companies that are oriented to mutual business cooperation and joint management structure. These vary from each other in terms of type and size. Considering the area they occupy, they can be divided into:

(1) Micro zones—cover an area up to 10 ha
(2) Small zones—an area from 10 to 50 ha
(3) Median zones—cover an area from 50 to 100 ha
(4) Large zones—areas over 100 ha

According to the purpose/activities that are represented in certain zones, they can be divided into:

(1) Processing—manufacturing
(2) Business—mixed service

The most common divisions of industrial zones/parks on the basis of the type of investments (Fig. 1), i.e., readiness to invest in the:

(1) *Green field*—investment "from wasteland," "from the beginning"
(2) *Brown field*—investment to purchase of already existing buildings

In the case of green field investments, we are talking about creating business zones on completely new locations, while in the case of brown field investments, in the business zone of the same is already created a micro location of previously used land and buildings in urban/industrial centers (Jugovic et al. 2013).

A brown field may include locations that were previously used for industrial production, manufacturing, electricity, gas, petrol stations, railway sidings, cleaners, landfills, storage facilities, landfills, and toxic substances such as riverbanks, the waterfront, and all other locations where there was some industrial or commercial activity. In cases where reconstruction of existing facilities is more expensive than building new ones, priority is given to the first option. There are numerous benefits of investing in these zones (Fig. 2).

Modern tendencies of spatial distribution of the business and manufacturing activities

parks, important issue is optimizing the activities and actions at regional and local levels/parks, important issue is optimizing the activities and actions at regional and local levels (Andevski 2006). Certain regions of the country provide different conditions for economic development, especially the development of certain industries. Within these regions, particular local communities, such as municipalities and cities, create the differences in terms of the development of the business environment for individual industries. Industry is one of the important factors of development in states, regions, and cities. Therefore, particular attention should be paid to the criteria of its accommodation (Fig. 3).

Today, the area represents one of the key factors of economic development of each country. Particularly, legal protection

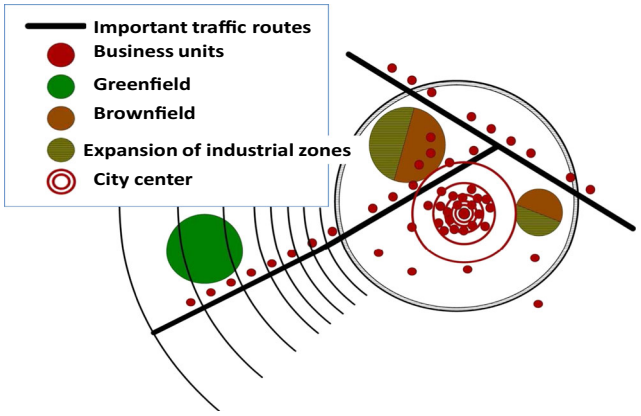

Fig. 3 Modern tendencies of spatial distribution of the business and manufacturing activities

plays an important role in the creation and development of industrial zones. If it is rigid and inflexible and too complex, and acts as a brake, zones are formed slowly and their development does not follow the requirements and needs of the environment and the economy. Then, the effects of industrial zones are limited, and the zones themselves have difficulty developing spontaneously (Deppe & Cohen-Rosenthal 1999).

Infrastructure equipment of zones The development of industrial and eco-industrial parks is a complex process because it requires integration between information technology, innovation, responsibility of producers, design for environment, and decision-making. Zones should be equipped with:

Fig. 2 Benefits of green field and brown field investments

Economic benefits	Increased taxes on income communities Using existing structures Increased Employment Opportunities Opportunities for strategic development locations and facilities The increased value of property in the region Reduction obligations of property owners Profit opportunities for the developer
Social benefits	Revitalization of the environment and the ability to pre-existing areas Improve health and safety in the community Opportunities for development in key areas nearby services Restoration of historic buildings Improvements in the quality of life in the region Better Sustainable Communities
Benefits for the environment (especially from brownfield)	less pressure on greenfield projects and urban expansion improving environmental quality cross removing contaminants reduced the risk of transmission of contamination outside the contaminated area improve air quality through the renewal in developed areas and reducing the need for transportation to and reduces harmful emissions reducing pressure on the environment through restoration of brownfields in relation to greenfield

(1) Energy infrastructure (substations, public lighting, electrical and other connections)
(2) Utility infrastructure (water supply and waterstorm installations, water and sewerage, connection to outdoor installations, etc.)
(3) Transport infrastructure (access roads—roads in the zone, telephone and other terminals, etc.). *Green areas.* Particular attention should be paid to green areas (Fig. 4). The main functions of greenery in an eco-industrial park/zone are:

(a) Creation of a favorable microclimate:

- Temperature control of radiation
- Protection from the dominant winds and aeration

(b) Protection from harmful impacts and pollution:

- Dust, gases, smoke, and the like

(c) Creation of fire-fighting barriers
(d) Mentally and emotionally beneficial effect on the user zone:

- Creation of places for short vacations, recreation, etc.

(e) Aesthetic significance

The choice of plant species that are envisaged for industrial areas are determined by:

(1) Characteristics of production
(2) Concentration of harmful substances emitted by industry
(3) Fire-fighting requirements
(4) Ecological, functional, and decorative properties
(5) Plants to be characterized by high resistance to gases, smoke, and dust (Beauford et al 1975)

Zones are built in peripheral areas and suburbs of urban centers, which have roads and other infrastructure, and are of interest to particular industries and companies of importance to the local community (Peric et al 2014) (Table 1).

Circular economy of sustainable cities

So far, the linear development model proved to be unsustainable. The result of this approach is resource depletion and waste generation. With conventional linear industrial production, raw materials are ending at the end of the process as waste. This model is known as the "take-make-dispose."

The traditional linear approach to industrial production proved to be unsustainable in the following aspects:

(1) It relies on current availability of resources, not taking into account the problem of their future scarcity.
(2) It is subject to price volatility and market oscillations.
(3) It does not take into account sufficiently environmental pollution on the local and global levels. Sustainable development offers a new way of thinking that is associated with human requirements for improving the quality of life, taking into account the limitations imposed on us by our global system (Biocanin 2011, Biocanin &Bakic 2011,

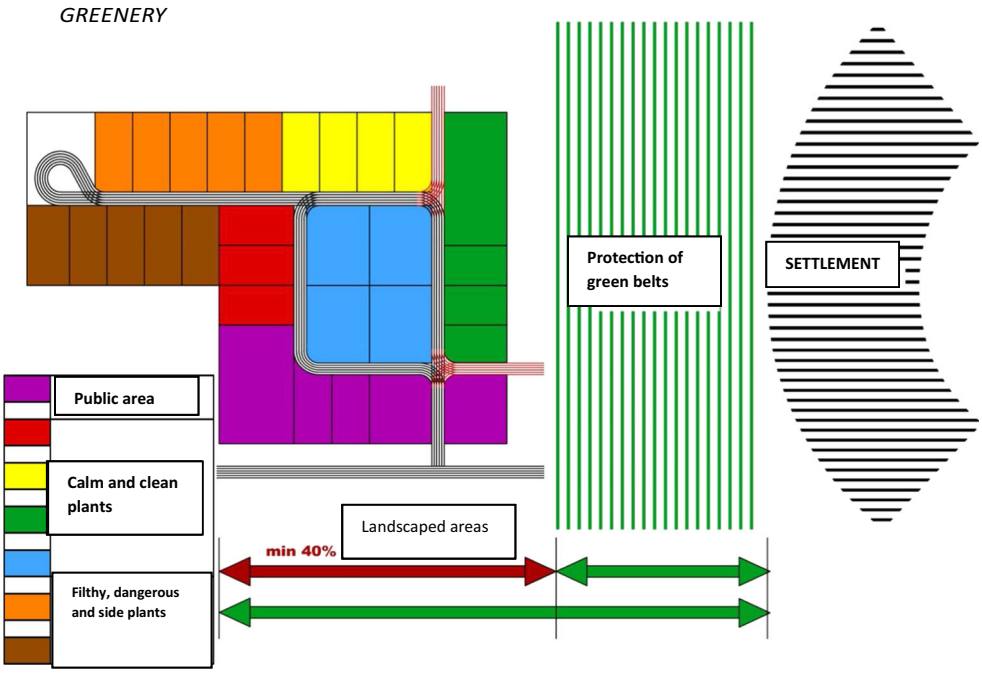

Fig. 4 Greenery in an eco-industrial park/zone

Table 1 Width of sanitary-protective zones according to the degree of harmfulness of industry and noise levels

Classification according to the degree of harmfulness of emitted substances	Width of sanitary-protective zones
Class I	1000 m
Class II	500 m
Class III	300 m
Class IV	100 m
Class V	50 m
Noise level	Width of sanitary protection zone—distance of the residential area from noise sources
120 dbl	3000 m
100 dbl	500 m
80 dbl	150 m

Biocanin & Stefanov 2012, Biocanin et al 2012). Since sustainability is a dynamic concept, not a static condition, it requires flexibility in decision-making and willingness to modify the approach in line with changes in the environment, human needs, and desires or technological advancement.

The concept of circular economy emerged in the last decade of the last century as a reaction to the need to find a balance between the economic growth needed to meet the needs of the growing population and the increasing need to respect the path of sustainable development. This concept comes from the paradigm of industrial ecology, and in its center is the idea of circular (closed) flow of materials through several stages (Biocanin 2011, Biocanin 2012, Biocanin & Obhodjas 2011). The concept of circular economy, in the broadest sense, is a replica of the functional optimization of flows of matter and energy inherent in the nature of or living organisms (v. Angilletta, Sears 2011: 653–66).

In a circular model, the output waste streams are used for other processes or industries (Fig. 5). Ideally, all material flows are circulating and produce no waste. Industry and society should function as a natural ecological system, which, when in balance, do not produce waste.

Effects of the circular economy on the living environment, the economy, and humans are cost-effective in the long run and certainly lead to a higher level of water sustainability in the future.

The circular economy is based on a few simple principles:

(1) *Design of waste*. Waste does not exist if the materials that constitute a product are intended for degradation or reuse, whether in technical or biological sense.

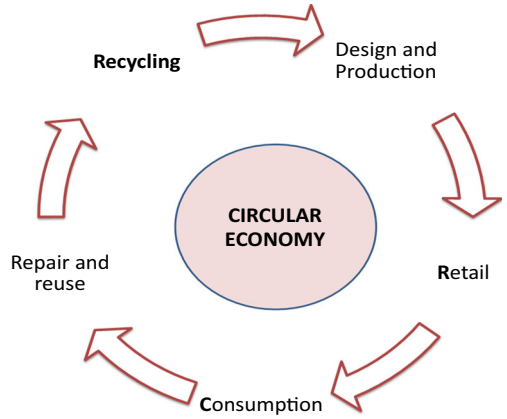

Fig. 5 Circular model of economy

(2) *Building of resistance with flexibility*. The diversity and flexibility are characteristics that should be promoted.
(3) *The use of renewable energy sources*. All systems should strive to use renewable and sustainable energy sources.
(4) *Human activity is supported by the* ecosystems and building of natural capital, human health and happiness, healthy and connected societies, and culture.
(5) *Resources are exploited in order to achieve value* (financial and other types).
(6) *Thinking about* "*systems*." The main thing is to understand how the components interact with one another within the totality and how the totality affects the parts. Elements are considered in the context of the environment and society.
(7) *Thinking in layers*. In biodegradable material, value is in the way that their components can be degraded or reused.

The concept of a circular economy should include *two basic approaches of sustainable development* (industrial ecology and cleaner production) and their application for the eco-industrial development. The central strategy should be to move towards the establishment of eco-industrial parks and networks within their borders. On the other hand, eco-industrial parks are limited to the basic idea: one company to use waste from the other, which is inconsistent with the idea that the parks are established in order to meet the goal of creating a circular economy in the region. Countries must focus on meeting the requirements of a circular economy, not just the formation of eco-industrial parks, which were previous activity. Some principles of industrial ecology, significant to a circular economy, imply:

(1) Connection of individual firms in industrial ecosystems:

- Closing of cycles through reuse and recycling
- Maximization of the efficiency of materials and efficiency of energy use
- Reduction of waste and

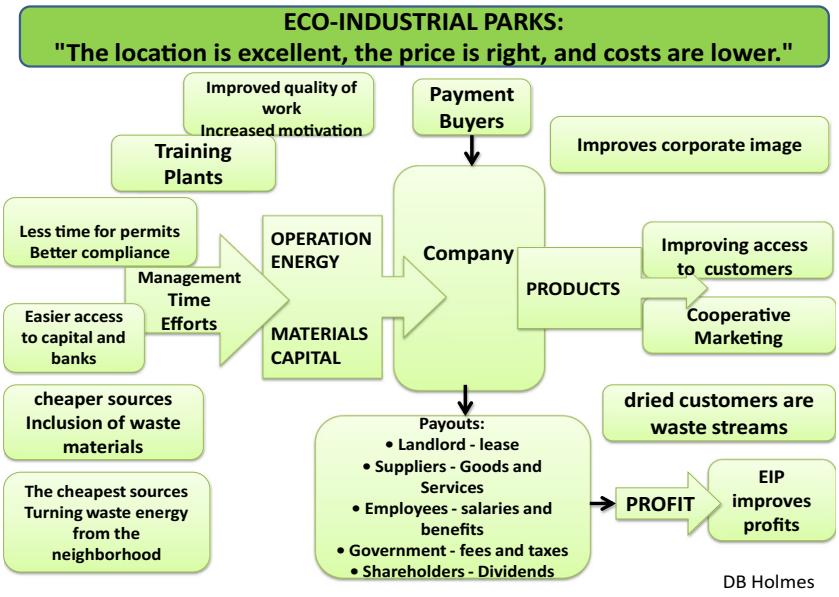

Fig. 6 Eco-industrial parks/zones (specific characteristics)

- Define all waste as a potential product and find a market for them

(2) Balancing of input and output elements:

- Reduction of load to the living environment, created by the discharge of energy and materials in the natural environment
- To design industry interface as a natural system in terms of characteristics and sensitivity that receives natural environment and
- Avoiding or minimizing the formation and transport of toxic and hazardous materials (Mayer & Tomic 2008, Stojcev 2006)

(3) Changing the way of industrial use of energy and materials:

Table 2 General metaphors of natural and technical systems

Biosphere	Technosphere
Living environment	Market
Organism	Enterprise
Natural product	Industrial product
Natural selection	Competition
Ecosystem	Eco-industrial park
Ecological notch	Market notch
Anabolism/catabolism	Production/waste management
Mutation and selection	Ecological design
Heritage	Economical growth
Adaptation	Innovations
Food chain	Lifespan of the product

- Redesign of the process in order to reduce energy consumption
- Surrogate-replacement technology and product design in order to reduce the use of material to be sprayed and
- Do more with less (scientifically called dematerialization)

(4) To harmonize policies and development strategies on the long-term prospects for the development of industrial systems (Guinée et al 1999)

Results and discussion

Eco-industrial zones/parks

The general development concept of an *eco-industrial* park integrates business success, excellence related to environmental protection, and relationships of the community to create economic opportunity and the protection of ecosystems. As the eco-industrial development manifests itself in the local community, it is the result of a partnership between local government agencies, community members, as well as commercial and industrial planners. It represents a model of modern management of resources and partnerships between the public and private sectors and the possibility that environmental protection is realized on sustainable economic grounds. The aim is to encourage practical linkages between waste generation and use of waste as a source.

In the eco-park, with concerted actions, community members and the business environment are seeking collective benefit that is greater than the sum of individual

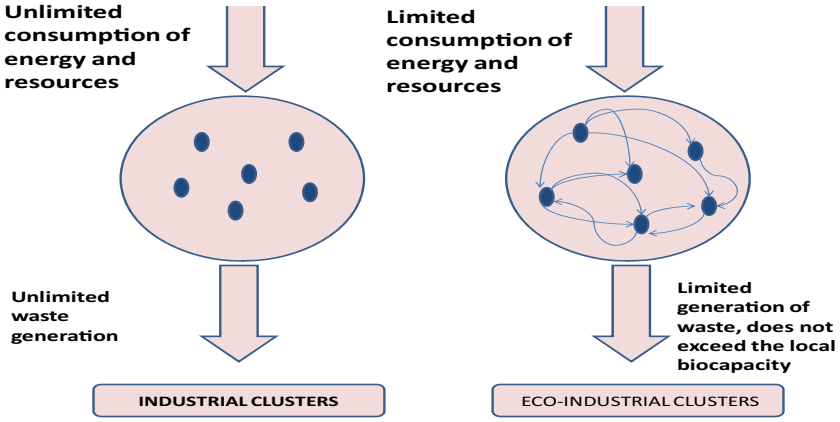

Fig. 7 Industrial and eco-industrial clusters

benefits that each company can achieve by optimizing its individual performance (Fig. 6). The aim of eco-industrial parks is to improve the economic effects of the firm's participants while minimizing their impact on the living environment.

The industrial system can be, to some extent, designed according to the model on natural ecosystems. Eco-industrial parks are the main elements in the formation of sustainable communities and the embodiment of the idea of forming a "closed cycle" and "waste less technologies" (Biocanin 2015).

Ecosystems in nature demonstrate many strategies of spending "waste" that are relevant for industry, for example:

(1) The only source of power supply in natural ecosystems is solar energy.
(2) Concentrated toxic materials are generated and used locally (Jusufranic et al 2014).
(3) Efficiency and productivity are in dynamic equilibrium towards resistance.
(4) Ecosystems remain resistant to changes through high biodiversity of species, organized in complex relationships. Many relationships are maintained through a self-organization process, not control from the top down.
(5) In an ecosystem, each individual acts independently, but its activities form a cooperative network connecting with other types of forms. Cooperation and competition are mutual balance.
(6) Both social and technological systems are bounded within the biosphere and do not exist outside of it (Hillier 2009). Natural systems use reusable material and have a largely closed-cycle circulation of nutrients. Table 2 shows a general metaphor.

An eco-industrial park not only consists of the physical structure of the park; it also represents a commitment to continuous improvement of the environment and commitment to

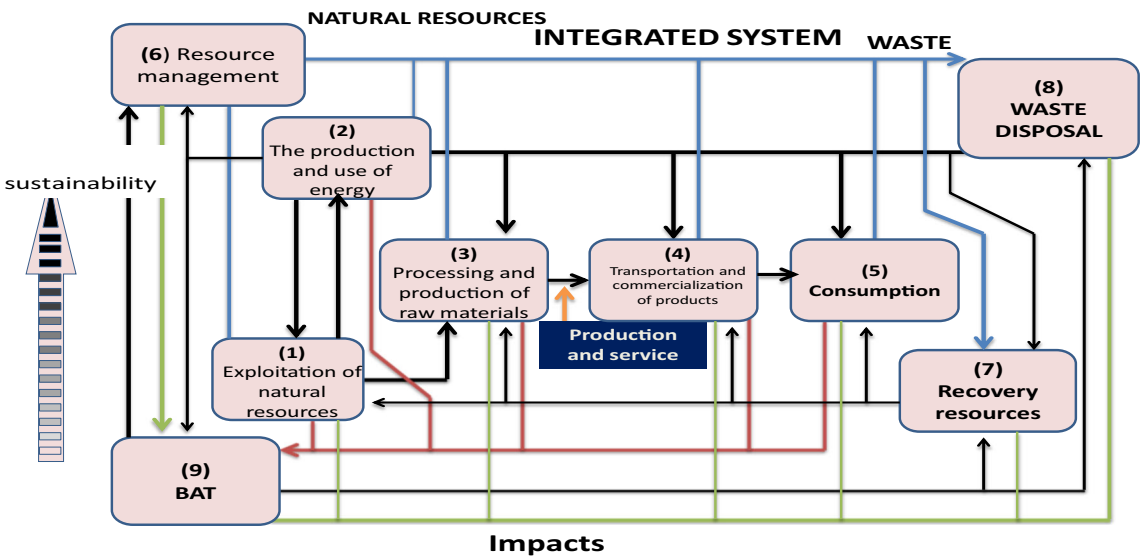

Fig. 8 Integrated system that includes subsystems, in "response" to challenges of sustainability

Table 3 Comparison of the obtained maximum range of pollutants for calculated, modeled, and design values (Ketin et al. 2014)

Emitter	Pollutant	"Worst case" value (km)	Modeled value (km)			Design (theoretical-licensing) value (km)
			Foreign		National	
A1	NO_2	*10*	EPA 0.67	Russia 10	3.7	–
A2	NO_2	*1.9*	0.075	1.9	0.394	–
A3	NO_2	*0.338*	0.013	0.338	0.067	–
A4	NO_2	*10*	1.00	10	5.7	10.00
A5	NO_2	*10*	0.896	10	4.9	10.00
A6	NO_2	*10*	1.7	10	9.3	10.00
A7	NO_2	*10*	0.764	10	4.2	–
A8	NO_2	*10*	1.2	10	6.8	–
A9	NO_2	*10*	0.968	10	5.3	–
A10	NO_2	*10*	0.506	10	2.7	–
P1	NO_2	*10*	0.460	10	5.600	0.892
P2	NO_2	*10*	0.460	10	5.700	0.892
P3	NO_2	*10*	0.336	10	4.100	0.892
P4	SO_2	*0.711*	–	0.711	0.513	1.4
P5	NO_2	*2.2*	–	2.2	0.450	2.0
P6	SO_2	*0.028*	–	0.028	–	–
R1	SO_2	*10*	10	10	10.00	0.625
R2	NO_2	*10*	2.3	10	2.400	0.625
R3	NO_2	*10*	2.3	10	4.100	1.4
R4	SO_2	*5.6*	1.3	5.6	1.900	1.4
R5	NO_2	*2.6*	0.344	2.6	0.512	1.4
R6	NO_2	*2.4*	0.095	2.4	0.880	0.306
R7	SO_2	*2.9*	0.28	1.2	2.900	0.178
R8	NO_2	*10*	0.545	10	4.700	2.9
R9	SO_2	*6.3*	1.5	6.3	3.700	1.8
R10	NO_2	*10*	0.703	10	4.300	1.5
R11	SO_2	*5.8*	1.4	5.8	–	1.3
R12	NO_2	*1.2*	–	1.2	–	–
R13	SO_2	*0.062*	–	0.062	–	0.133
R14	NO_2	*1.7*	0.086	1.7	0.589	0.297
R15	SO_2	*4.5*	0.193	0.818	4.500	0.297
R16	SO_2	*6.0*	1.4	6.0	2.100	–
R17	SO_2	*2.9*	0.687	2.9	0.789	0.891
R18	SO_2	*1.1*	0.262	1.1	1.100	0.891
R19	SO_2	*3.9*	0.358	1.5	3.900	0.891
R20	SO_2	*5.3*	0.545	5.3	2.300	1.4
R21	NO_2	*10*	0.184	10	2.000	1.4
R22	NO_2	*9.4*	0.383	9.4	3.500	1.2
R23	SO_2	*4.7*	–	4.7	1.000	4.7

the networking of all activities within the park, regions, and communities (Pace 2000) (Fig. 7).

In order to achieve these objectives, the management of the eco-industrial park usually refers to one or more of the following functions (UNEP 1997):

(1) Planning:

- Identification of possible locations
- Conducting an impact assessment of the living environment

- Choice of location
- Ventures before planning
- Transport of goods, materials, and people
- Layout and design
- Developing environmental protection policy and setting of goals of ecological performance
- Establishment of a regulatory framework (i.e., codes, obligations, and restrictions) and
- Identification of funding sources

(2) Work activities:

- Construction of infrastructure and services
- Operationalization of infrastructure and services
- Design of individual websites
- Construction of facility
- Landscaping of the site
- Marketing quality of the living environment
- Attraction of industry and
- Networking

(3) Control:

- Monitoring of emissions and quality of the media
- Motivation to achieve efficiency and living environmental protection
- Implementation of regulations or agreements
- Audits
- Reporting on the environmental performance of companies and parks/zones, and at the end
- Issues of common security

One of the characteristics of the management structure of an eco-industrial park is the inclusion in the environmental management system. There are different approaches, including formal systems such as ISO 14000 (Stajkovac et al 2006). Other approaches include the planning of environmental protection, eco-design, cleaner production, and exchange of by-products. The purpose of the environmental management system is the following: the preservation of the environment for future generations, protection of the environment, with significant economic benefits, the sustainable use of natural resources, waste reduction, renewable energy use, and marketing of safe products and services. Water used in the system of water supply for food production and consumption, after their use, is directly discharged without prior treatment into the environment (Councile Directive nd, Moolenar 1998).

Sustainable development offers a new way of thinking that is associated with human requirements for improving the quality of life, taking into account the limitations imposed on us by our global system. Since sustainability is a dynamic concept, not a static condition, it requires flexibility in decision-making and willingness to modify the approach in line with changes in the environment, with human needs and desires or technological advancement (Djukanovic 1996, Kovacevic 2011).

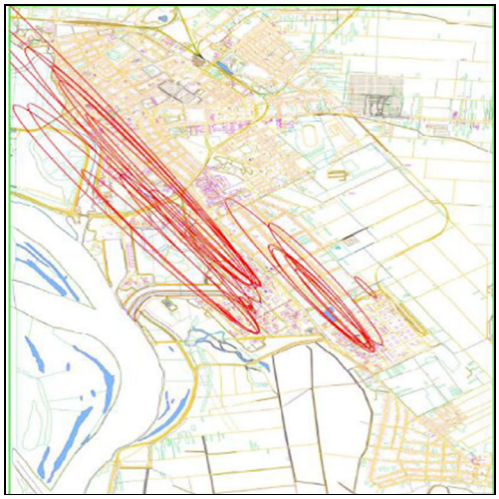

Fig. 9 Cumulative effect of dispersion of NO_2 in the oil and petrochemical complex for the emission value (Ketin et al. 2014: Stefanov et al. 2013)

Instead of a linear process, the new approach represents a *closed-cycle system*. The integrated system also includes a total of five systems, as described above as part of the linear system, and in addition, it includes four new subsystems, each in response to specific challenges of sustainability of a city (Fig. 8) (Milutinovic 2004).

Example

Table 3 shows the comparison of the obtained maximum ranges of pollutants for the modeled values (EPA, national and Russian concentration limit values) and the design of values of pollutants' range. Modeled value is the column originated as a result of research of scenario 1 and scenario 4; the design value of pollutants' range is the result of research of scenario 3. The column "worst case" emerged as the highest score of all four scenarios. "Worst case" is necessary in research and modeling as the highest values are obtained. From the table, it can be concluded that the "worst case" is formed from the modeled values of Russian emissions except for the emitters R15 and R19. The worst case scenario for emitters R15 and R19 was formed in the modeling of the pollutants for the national limit values (Stefanov et al 2011, Stefanov & Biocanin 2013). Graphically presented are the cumulative effects of the dispersion for pollutants SO_2 and NO_2 in the oil and petrochemical complex. Shown are all emitters in the oil and petrochemical complex of the pollutants SO_2 and NO_2 with emission limit values and maximum allowable concentration (MAC) (Stefanov et al. 2013). The largest contribution is to the emerging of the pollutant SO_2 for IPP3, then for IPP2 and lowest for

IPP1. The largest contribution to the emerging of pollutant NO_2 is in IPP1, then in IPP3 and lowest in IPP2. In Fig. 9, the cumulative dispersion of pollutant NO_2 is presented, which takes into consideration all of the high emitters and the maximum ranges of the pollutant for IPP1, IPP2, and IPP3. The figure shows that the maximum range is up to city. Wind direction is south-east because the least favorable option is considered (Ketin et al. 2014).

Conclusion

Any eco-industrial park is interdependent with the local community and relies on its human and material resources, services, and trade. The workforce of the eco-industrial parks mainly comes from nearby cities and may require the training of local educational institutions. New employees in this area have a need for housing in the local community (Ljesevic 2005). The local economy provides sources of raw materials, materials, parts, and services to companies in the park. Water and sewerage, energy, solid waste, and transportation infrastructure usually are under the jurisdiction-administration of local authorities. An eco-industrial park represents a public/private partnership between the community, the development of society, companies involved in the park, and national agencies.

For most companies, an eco-industrial park offers the opportunity to reduce production costs by increasing energy efficiency and material efficiency, increasing recycling of waste, and reducing environmental impacts (Lambic 2009). Increased efficiency can also allow members of the park production of competitive products. In addition, the companies in the park can share some common business services. This includes joint waste management, training, purchasing, management of emergency teams, information systems, environmental protection, and other support services. Such a division of the costs of industrial parks can help members to achieve greater economic efficiency through their cooperation.

Eco-industrial parks will reduce many sources of pollution and waste sources, as well as reducing the demand for excessive use natural resources, strengthening the economic growth of the city, creating new jobs, and attracting new customers. Such parks are likely to attract leading corporations and open the ways for new or expanded local ventures.

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