ECOHYDROLOGY - THE USE OF WATER AND ECOSYSTEM PROCESSES FOR HEALTHY URBAN ENVIRONMENTS

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ABSTRACT

Water in the urban space has been considered up to now mostly from the perspective of water supply, sewage purification and storm water management, with increasing awareness of the necessity of freshwater ecosystems conservation. However there has been little holistic consideration of the freshwater and terrestrial ecosystems for moderation and control of the hydrological cycle in the city.
Considering the Millennium Development Goals, one of primary dimensions for reduction of poverty, especially at increasing urbanization, is access to save drinking water and a friendly environment. Ecohydrology is a cost efficient technology of water and ecosystems management. Based on the 10-year work developed within the Ecohydrology programme of UNESCO IHP V and VI, it is possible and necessary to translate the experience gained in natural and semi natural ecosystems to problem solving in cities. Existing data proofs that integrating the recently developed engineering solutions with holistic ecohydrological methods based on current understanding of ecosystem functioning as a highly complex system provides the opportunity to increase efficiency of solutions and reduction of costs.
Ecohydrology principles provide a new framework for urban water management where the use of ecosystem properties as an integrating management tool should serve to reduce hydro peaking, improve storm water quality and retention, and convert excess nutrients, pollutants and conversion of pollutants into usable goods. In parallel, enhancement of fresh water and green spaces in the city improve human health and quality of life.

Key words: Ecohydrology, urban water management, river rehabilitation, city, development

1. INTRODUCTION

The general assumption of Ecohydrology is that in the face of growing human population and its aspirations, that both amplify progressing landscape transformations and urbanization, there is a need to increase absorbing capacity of both aquatic and terrestrial ecosystems. They both together complementary control different aspects of the water cycle (Zalewski at al. 1997). This should be done on the basis of understanding the reactions of biocenosis to such factors as temperature and water dynamics.

Ecohydrology as a new paradigm of basin management addresses two aspects: firstly, it provides new “know how“ for freshwater ecosystem restoration and management and the empirical knowledge how to use ecosystem properties as a complementary tool to the civil engineering and hydrotechnical solutions; secondly, it formulates a system approach to use transdisciplinary science for integrated river basin management (IWRM).

The world-wide dynamic increase of urban population has not been followed by the appropriate development of water management and creating friendly urban environments. The problem is increasing in scale, and especially the one related to meso- to mega-cities calls for new solutions. Despite the permanent progress, the XXI Century urban environment is ecologically far from perfection, especially from the point of wise integration of its anthropogenic functions with ecosystem goods and services required for society (Zalewski and Wagner, 2005).

In the postindustrial era, as the level of education of societies increases and environmental consciousness improves, there is a rising demand to improve the quality of life of society. As a consequence, this is not only elimination of infectious diseases and provisioning of basic services, such as safe drinking water, sanitation or relatively non polluted air are expected. There is also a need to provide access to recreation areas, the quality of which is determined to a major extent by the amount and quality of "green areas" and especially by the distribution of freshwater ecosystems. There is also a need to go beyond the decorative and recreational attributes of the green landscape, as usually considered by city planners and civil engineers. Their function as detention facilities connected with the major water cycle pattern - storm water management and sewage purification should be also better recognized, as it is happening only in last decades (eg. Abustan, Nabsiah 2002; Marsalek *et al.*2006).

Access to save drinking water and a friendly environment is also, one of the primary dimensions for reduction of poverty, especially at increasing urbanization, which is crucial for achieving Millennium Development Goals. Ecohydrology is a cost efficient technology of water and ecosystems management. Taking account of its 10-years development and implementation in the framework of UNESCO IHP V and VI, it is now possible and necessary to translate the experience gained in natural and semi natural ecosystems (eg. Zalewski 2002; Wagner-Lotkowska et al., 2004; Zalewski et al., 2004) to problem solving in cities. Existing data proofs that integrating the recently developed engineering solutions with holistic ecohydrological methods based on current understanding of ecosystem functioning as a highly complex system provides the opportunity to increase efficiency of solutions and reduction of costs (Zalewski and Wagner, 2005).

2. THREE LEVELS FOR EFFICIENT APPLICATION OF ECOHYDROLOGY

Following the idea that science is distillation of a general patterns from surrounding commonalities, ecohydrology is a paradigm which provides three general rules guiding toward efficient application of know how for problem solving.

2.1. Ecohydrology at operational level

The key “know how” of ecohydrology provides methods for shaping ecosystems structure and controlling their function that allows for regulation of ecosystem processes toward providing optimal services required by society. According the first ecohydrology principle (e.g., Zalewski 2000) this should be done on the basis of quantification of hydrological dynamics and biological structure and dynamics in basin scale. Moreover this should provide an information about spatial distribution of the areas of threats for the system, potential opportunities to apply ecohydrological solutions and to identify opportunities to achieve synergy between different solutions e.g. defining the sequence of constructed wetlands combining anaerobic (for intensive denitrification) and aerobic conditions (for phosphorus trapping in iron enriched sediments); identifying width, length, morphology and plant composition of vegetation ecotone zones, and many others.

Elimination of flood hazards in a city landscape and separation of water versus nutrients and pollutant cycle (Maksimovic 2001; Tejada-Guibert, Maksimovic 2001; Marsalek *et al.* 2006) should be a target supported and integrated with ecohydrological measures. Implementing the above approach should however be realistic, considering all range of the cities considering the existing ability of separating and controlling the pathways of water and pollutants (sanitary and storm water sewers). In modern cities the general storm water management strategy has been based on fast transfer of excess water across the city landscape. In cities where point sources of pollution are limited water discharge is mainly composed of storm water, and as a consequence the surface and groundwater contain low concentrations of nutrients and pollutants. In such cases the ecohydrological measures developed for natural biological system processes can be easily incorporated and adopted for improvement of water quality and groundwater recharge (Zalewski 2002; Zalewski, Wagner-Lotkowska 2004). A more complicated situation might appear if the discharge into urban rivers sewage is mixed with the surface storm water. The absorbing capacity of the biological system can be often overloaded and efficiency of self-purification usually dramatically declines. Therefore additional ecosystem structures of high pollutant absorption, such as constructed wetlands, has to be considered and harmonized with the specifics of the hydrological pattern and adjusted to loads of pollutants (Zalewski and Wagner, 2005).

2.2. Tactical level

Ecohydrology is a transdisciplinary science. It uses the understanding of relationships between hydrological and biological processes at the catchment scale to achieve water quality improvement, biodiversity enhancement and sustainable development. Ecohydrology is based on the three principles:

- Hydrological: the hydrological cycle at the basin scale should be considered as the template for quantification of both impact and opportunities relevant to the biological performance of the ecosystem.

- Ecological: freshwater ecosystem robustness can be enhanced on the basis of understanding the evolutionary established resistance and resilience of the ecosystems.

- Ecological engineering: enhancement of ecosystem resistance/resilience can be achieved by "dual regulation" - biocoenosis by hydrology, and vice versa. Thus by shaping the biota, both water retention and quality can be improved (Zalewski 2006).

The whole basin view identify opportunities for application the key know how of ecohydrology “dual regulation” considering necessity of synergy among number of methods implemented at the basin. The analysis of the interplay between hydrological dynamics and biotic structure and performance provides the scientific basis for this approach. If we understand the specific and patterns of the reactions of biocenosis to hydrological conditions and the range of moderation of hydrological processes on biocenosis, we can use such knowledge to regulate processes from molecular to basin scale. For example, shaping terrestrial vegetation cover can to a certain extent regulate water retention and infiltration and in consequence reduce hydro peaking and erosion in some urban streams. This contributes to reduction of nutrients and pollutants transfer to and within the aquatic systems. The examples of the integration of different solutions in the basin have been presented in many publications (e.g., Zalewski 2000, Zalewski et al., 2004, Zalewski 2006). As far as the density population and form of impact in the urban space is much more condensed than in rural landscape thus the application of ecohydological solutions toward synergy between them should be precisely tuned up on the basis the elimination of the flood potential (control of the water cycle) in the first place.

2.3. Ecohydrology for strategic level – planning the city for the future

The process of globalization accelerate migration of societies into the urban space. However the vital factor for development of cities is related to their ability to attract highly qualified professionals and developers. Quality of life in overcrowded cities declines, due to air and water pollution and limited space for recreation. In such cases the city dwellers tend to select suburban or rural areas as the places of residence. This in turn negatively effects the city economy, e.g., thought outflow of wealthy inhabitants, diminishing income from taxes, or limiting all types of evening and weekend cultural activities in the cities, because of transportation oblige. In this situation the optimal way to solve such problem is creating mosaics of friendly green spaces providing attractive recreational areas for inhabitants, constituting an option for the sub-urban migrations. Such an approach reduces energy expending for transportation and amplify harmonic development of the city. The nucleus or axis for such green space has to be always attractive clean freshwater ecosystems, which at the same time play servicing functions, such as stabilizing stormwater fluxes, cleaning water (self-purification), increasing groundwater recharge and enhancing biodiversity.

3. RIVER REHABILITATION AND TRIANGLE OF DYNAMIC DEVELOPMENT AT CITY OF LODZ, POLAND.

3.1. Rehabilitation of the Sokolowka River

The City of Lodz with 776,000 inhabitants (2004) is the second biggest city in Poland. Recent development of education, scientific and high-technology centers changes the city’s profile and expectations of the society and rises the need for high quality of life, including e.g., development of infrastructure, revitalisation of industrial architecture and environment rehabilitation.

The city's post-industrial character is a compacted, highly impermeable historical development and stream channelisation, which lowered water retentiveness in the landscape. This is evident particularly during storm events, by increasing surface runoff and river peak flows. Accelerated stormwater flow into sewage treatment plants reduces their treatment efficiency.

The European Regional Centre for Ecohydrology has been recently asked to elaborate recommendations for Spatial Development Plan for the 21 City’s streams and channels. The plan is based on the perception of the river’s valleys as axes for restoration of the environmental values in the city and strengthening provision of the traditional water-related urban services (e.g., stormwater retention and purification, groundwater recharge) by application of ecohydrology. The Sokolowka River catchment (average flow: 0.17 m3 s-1), where the ecohydrology approach has been already applied in a pilot case study, flows across the northern part of the city and is supplied with about 50 storm sever outlets. It was channelised by concrete slabs which straightened the course and deepened the bed. The middle section of the river valley has maintained a semi-natural character with patches of meadows, wetlands and forests. The activities in the project conducted on this area integrate and harmonize the city landscape and its existing hydrotechnical infrastructure with ecohydrological measures, and address the following goals (Zalewski and Wagner, 2005):

- Increase water retentiveness in the landscape for mitigation of extreme flows, increasing groundwater levels and supporting city vegetation by shaping the vegetation and landscape development in the catchment;
- Reduce storm water sewage flow peaks in streams by the construction of series of ponds and reservoirs, creation and restoration of river floodplains and wetlands;
- Develop permanent monitoring systems for hydrology, pollution and climate control, education and rising environmental awareness;
- Increase in the quality of life and aesthetic values in the city by restoration of river corridors, ecotone zones and the landscape;
- Increase human health by reducing the number of allergies and asthma cases due to improved microclimate (increased green spaces and amount of standing water in the city).

The proposed ecohydrological measures have been incorporated into the long-term project of the municipal river restoration elaborated and implemented by the City of Lodz Office.

3.2. Ecohydrology for strategic city planning

The Lodz City case provides an example of ecohydrology application benefits for both ecology and society. The Sokolowka River is located next to one of the most attractive residential area of the city which in turn connects to the southern part of a large forest area with a nature reserve and several impoundments on headwater streams (Figure 1). The valley of the river, with numerous patches of natural vegetation and agricultural land has been neglected in development up to now and considered as a remote area. The creation of a natural extension of this area by constructing impoundments and recreation facilities (including cycle paths, jogging routes, picnic areas), raises the awareness of developers. The river restoration increased attractiveness of this part of the city, which is located not far from the ‘triangle of dynamic development’– the area of the most intensive development of the city. The ongoing project improves the cultural and aesthetic values of the landscape, enhances quality of life, reduces air pollution, improves the microclimate and, consequently, health of the urban population. It also attract the investors and active people to choose this area as a living space, creates employment opportunities and improves economic situation (Figure 2).

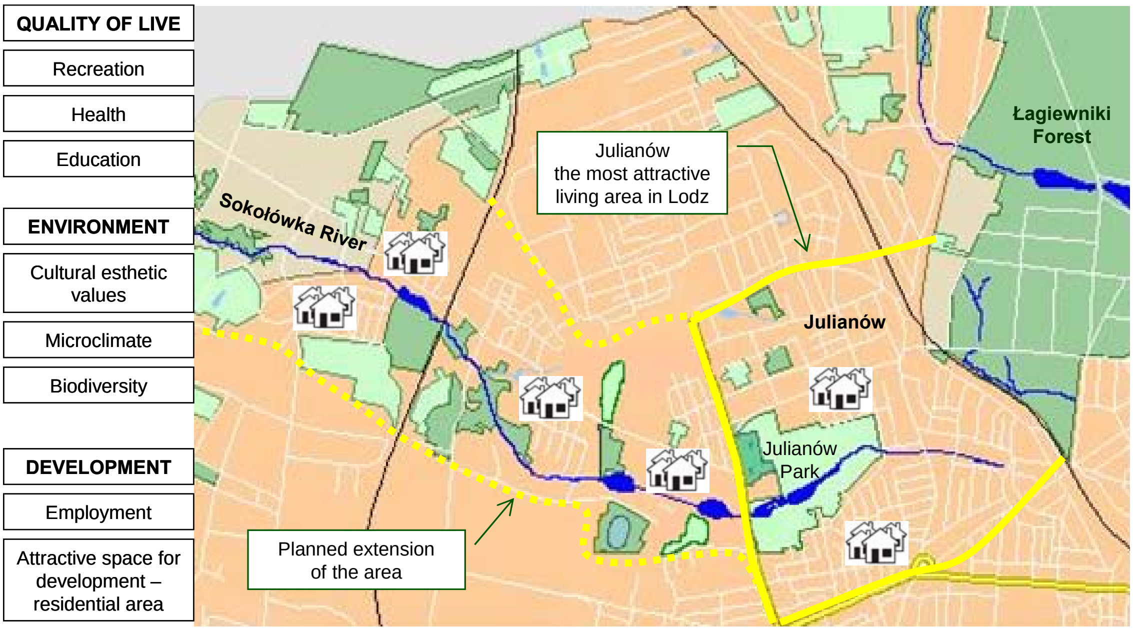

Figure 1. Green belt for recreation / housing - concept and benefits of rehabilitation of the Sokolowka River Valley for recreational space serving the city inhabitants (colour codes: orange - urban area, green - tree cover, grey – agriculture; yellow lines delineate the area considered for rehabilitation).

4. VISION LEVEL - HOW ECOHYDROLOGY CONTRIBUTES TO THE CITY OF THE FUTURE: ACCESS TO HEALTHY WATER AND ENVIRONMENT, REDUCTION OF POVERTY

The critical point of the implementation of new scientific inventions and technologies (prototypes) is their calibration and then testing to develop the "know-how". This allows for easy implementing of the solutions at reduced costs in less developed cities. The low-cost and high-technology ecohydrological methods are however labor intensive. Maintaining well functioning biocenosis in the highly modified urban system needs regulatory actions e.g. biomass cropping, water level monitoring and adjustment, conducting monitoring measurements and laboratory tests. As a consequence, its application creates numerous employment opportunities for both low qualification staff conducting the technical maintenance, as well as for high qualified personnel, conducting permanent monitoring of the system and using decision support mathematical models to conduct the fine-tuning of the system performance (of both hydrological and biotic sub-systems).

The strategy of success assumes elimination of threats and amplification of opportunities. The proposed system approach in which ecosystem functioning is considered as a complementary tool to technical solutions should be key for sustainable cities. The systemic mathematic model for decision support system with consideration of constraints and opportunities and its synergistic integration should be an important tool for testing the development decisions making process. All above measures have to be implemented to achieve synergy in the sense of water quality, flood mitigation and biodiversity (Zalewski and Wagner, 2005).

The above measures have to be developed together with consideration of socio-economic conditions. The prerequisite of the implementation of ecohydrology is public involvement, which encourages decision makers and the public to accept and follow the new way of thinking. Up to now education and stakeholders' discussions were considered to be the best ways. However, comparative research on several ecohydrology projects seems to imply that a good starting point is the opportunistic character of human nature, seeking demonstration of the tangible benefits, such as reduction of threats (e.g. droughts and floods) and enhancement of ecosystem services (e.g. water quality improvement, biomass/bioenergy production and biodiversity).

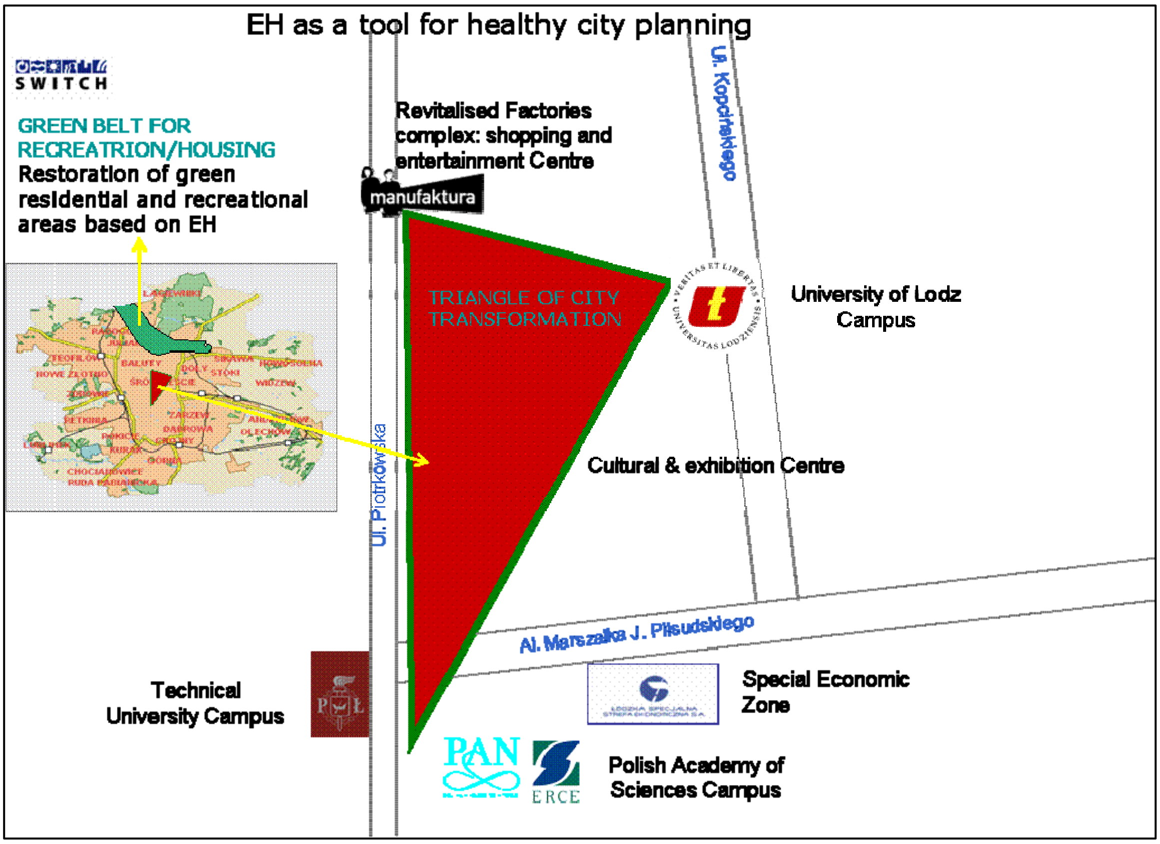

Figure 2. Location of the Sokolowka River valley in the City of Lodz (Poland) and its relation to the "Triangle of Dynamic Development" of the City.

In many societies, especially those in countries of limited resources and low economic status, environmental conservation is considered as a luxury or at least as target with questionable value to the society. This is why it is important to demonstrate that environmental conservation may generate ecosystem services and, as a consequence, employment, which then amplifies the cascade of the positive socioeconomic/ environmental feedbacks. The experience from the UNESCO & UNEP Demonstration Project in the Pilica River valley (e.g., Wagner-Lotkowska et al., 2004) contributed to the conclusion that, especially in the cases of increasing tensions between the society and water /environmental resources, the most efficient stimulation for public involvement should the assumption of "ecosystem services first". A visible and profitable outcome for the society should be provided in the first stage of implementation. This is why adaptive assessment management, taking into account possible drivers and adapting to them, becomes the best way not only for understanding the complexity of the ecohydrology feedbacks and revising the new management strategy, but also for further progress of implementation on the basis of social acceptance.

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