Ecosystem biotechnologies for the enhancement of ecohydrological potential of the catchments – Water, Biodiversity, Ecosystem Services, Resilience, Culture and Education

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Abstract: One of the threats for biosphere sustainability in the face of climatic changes is the amplification of water and nutrient cycling stochasticity, which means intensive floods, droughts, and pollution. This is largely due to the increase of industrial agriculture and random urbanization, which results in a cumulative impact. To reverse the effect of cumulative intermediate impacts, which often are major factors of degradation of the ecological potential at catchments, a profound understanding of the water–biota interplay is most important. This is because water has been the major determinant of ecosystem structure as it drives carbon, phosphorus, and nitrogen cycling and determines ecosystem services for society. Thus the fundamental for the development of innovative Ecohydrological Nature Based Solutions (EH NBS) for water is the profound understanding of water-biota interplay from molecular to catchment scale. The above Ecohydrological framework serves not only to mitigate intermediate forms of impact but also to increase the ecological potential of a river basin expressed by a multi-dimensional goal – Water, Biodiversity, ecosystem Services for society, Resilience to climatic changes, Culture, and Education (WBSRCE), which helps to harmonize the enhanced ecosystem potential with social needs and, in turn, achieve sustainability of river basins. As far as Ecohydrology is empirical science, international advanced study courses where scientists, and pro-activists can share experience at UNESCO IHP Demosites should also be an important tool for dissemination.

1. Introduction
One of the most important and poorly recognized threats for biosphere sustainability in the era of climatic changes is the amplification of water and nutrient cycling stochasticity, which means intensive floods, droughts and pollution [1,2]. This is to a great extent due to increase of the industrial agriculture and random urbanization, which results in a cumulative impact (see example figure 1.): loss of organic matter in soils, especially in an agricultural landscape, reduction of diversified biomass mosaic in the catchment, degradation of aquatic habitats and reduction self-purification potential of the catchment resulting in acceleration of polluted water outflow to the sea.

These negative processes have been further increased by over fertilization by nitrogen and phosphorus, and pollution by pesticides. Due to the unification of catchment landscapes, they have been transferred into freshwater ecosystems and coastal zones in great amounts, causing secondary pollution – algal blooms and bioaccumulation of toxic substances.
Figure 1. A. algal bloom moving with the wind alongside the Hel Peninsula (Jurata, 25 July 2019, 11:57 am, photo: M. Zalewski) caused when a failure which occurred in the sewage pumping station in Gdańsk due to overload with rainwater, additionally enhanced by Vistula River’s floodwaters which reached the Gulf of Gdańsk, Poland. B. The same place, one year later, during low flow of Vistula River.

2. What is ecohydrology? - Integrative subdiscipline Hydrology and Sustainability Science.

As far as complexity and strength of human impacts have been growing worldwide, to accelerate and enhance the SDG implementation, there is a need to solve the environment/sustainability problems by analyzing the complexity of ecological processes and avoiding tunnel (silos) thinking. The key driver of the biosphere, that humanity depends on, is water which also drives carbon, phosphorus, and nitrogen cycling and determines ecosystem services for society. Thus fundamental for the development of innovative Ecohydrological Nature Based Solutions (EH NBS) for water management is the profound understanding of water-biota interplay from molecular to catchment scale.

The first step for the development of Ecohydrology was the Abiotic-Biotic Regulatory Continuum Model [3], which provided a deductive model for integration of hydrological and ecological processes reduced to basic physics laws (fig. 2.). Next step was hydrobiomanipulation - the discovery that by changing the water level in reservoirs it is possible to regulate the biotic structure of ecosystems and that enhancing the filtrator’s activity can improve water quality and eliminate toxic algal blooms (NBS dual regulation) [4].

Figure 2. A model of variation in the impact of abiotic and biotic factors along the river continuum, defining the hierarchy of factors regulating processes in the catchment and initiating the integration of hydrological and biological processes to increasing the potential of the river basin [3].
The third step was the UNESCO MAB Ecotone Programme [5, 6], where land water ecotones were initiated as a tool for landscape management, restoration, and reduction of non-point source pollution, thus reduction of pressures on freshwater ecosystem. However, the UNESCO IHP initiated Ecohydrology as one of the priorities and stimulated it by long-term international cooperation and the network of Ecohydrological Demosites, allowing the development of a new Evolutionary-Ecosystemic paradigm. In this initial phase, one of the important leaders was Peter Hehanussa from Indonesia, who first proposed to incorporating indigenous knowledge into ecohydrological solutions.

The above knowledge has been a fundamental element of the integrative science – Ecohydrology (EH), which by identifying a plethora of water–biota interactions, provides a scientific background for the development, and quantification of problem-solving methodology: principles of EH, “dual regulation” and EH biotechnologies. The above EH framework serves not only to mitigate intermediate forms of impact but also to increase the ecological potential of a river basin expressed by a multi-dimensional goal – Water, Biodiversity, ecosystem Services for society, Resilience to climatic changes, Culture and Education (WBSRCE), which helps to harmonize the enhanced ecosystem potential with social needs and, in turn, achieve sustainability of river basins. This should be done by means of EH NBS (figure 3.).

**Figure 3.** Extreme degradation of the natural land/water ecotone leading to an increase in surface flow and a load of nutrients washed from the “homogenized” agricultural landscape into the water ecosystems, increasing eutrophication and the risk of toxic algal bloom occurrence [7].

### 3. Ecohydrological Nature Based-Solutions – practical examples for enhancement of catchment sustainability potential

Ecohydrology provides innovative methods for enhancing of catchment sustainability potential WBSRCE [7,8], which has two stages: 1/ reduction of the broad scope of impacts, and 2/ increase resilience of freshwater ecosystems to impacts – both anthropopression and climate change. Moreover, it provides a framework for harmonization of EH NBS with hydroengineering infrastructure - hybrid systems. Such solution applied in Poland during the European LIFE + Project EH-REK for the upper Bzura river catchment, towards the elimination of toxic algal blooms in three reservoirs in the Arturów Complex in Łódź. The project was awarded by the European Commission with the prize “Best of the Best LIFE + 2018” (www.en.arturowek.pl)[9].

As freshwater ecosystems are very diversified as well as human priorities, there is a need to disseminate the highly complex Ecohydrological approach based on the integration of environmental
scientific disciplines, highlighting how the integrative understanding of hydrology and ecology can be applied for catchment management [10, 7,8]. As far as Ecohydrology is an empirical science, international advanced study courses where scientists and pro-activists can share experience at UNESCO IHP Demosities should be an important tool for dissemination.

To reverse forms of cumulative intermediate impacts, which often are major factors of degradation of the catchment ecological potential, a profound understanding of the water–biota interplay is most important. This is because water has been the major determinant of ecosystem structure. Moreover, the dynamics of the hydrological cycle combined with temperature patterns determine the productivity and biodiversity of ecosystems, both terrestrial and aquatic. On the other hand, biocenoses modify the hydrological cycle to a great extent, especially in water shortage areas (see fig. 3, increasing water retentiveness in the catchment landscape and reducing the stochastic character of hydrological pulses and occurrence of floods, landslides, and pollution.

Ecohydrology provides tools for such harmonization of various biotechnologies, classified as Nature-Based Solutions (NBS), which use natural processes and properties of the ecosystem as management tools for enhancement of sustainability potential. An example of such is highly efficient buffer zones. These plant land/water ecotones recommended for agricultural areas under intense nutrient pollution, e.g., fertilizers and intensive agriculture [11]. Highly efficient buffer zones are additionally enhanced by denitrification or biogeochemical barrier, constructed for further efficiency in reducing pollutions from nitrogen and phosphorus, respectively. Prototypes of two barriers were constructed and tested in Sulejów Reservoir in Poland during the LIFE+ EKOROB project (www.ekorob.pl) [12] (figure 4).

**Figure 4.** Highly efficient ecotone zones, constructed near the reservoir for a decrease of nutrient and non-point source pollution loads, were washed into the reservoir with the surface flow from agricultural landscapes [11].

An important element of ecohydrological solutions is the of water resources and ecosystem capacity with society’s needs. An example of such a solution is a water reservoir concept in the City of Łask, in the Grabia River catchment (figure 5.). The project created by the European Regional Centre for Ecohydrology PAS was designed to fit the reservoir into the natural landscape to preserve the natural, meandering river bed and maximize the potential sustainability WBSRCE of the catchment.
Figure 5. proposed by hydroengineers design of a reservoir on the river, which eliminates a section of the natural, meandering river of high biodiversity. Moreover, the observed periodical high flux of P in the river will eliminate recreational use (Ecosystem services) because it will stimulate toxic algal blooms. Hydrological analysis of the concentration of phosphorus and hydrological pulses indicate that concentration in pulses is very variable from 80 μg to 600; the values above 100 - 200 might stimulate toxic algal blooms. That is why the reservoir constructed on the floodplain, still maintaining natural river (B), will increase biodiversity and will be supplied by an automatic system that will provide water from river to reservoir only during the periods of good environmental flow, when the concentration of P is below 100 μg (approximately 100 days per year). Additionally, the biofiltration zone in the reservoir will protect it if short-term failure on the control system appears [8; Kiedrzyńska, Zalewski, Jarosiewicz in press].

The above approach maintaining river continuum enhances water retentiveness in the river valley, biodiversity in the meandering river, in addition, the reservoir waterbody will provide new habitats and increase biodiversity. Ecosystem services for society, beach area, adaptation to climate change by lifting the groundwater level in the area, thus enhancing the resilience of wetlands and water availability from wells. The education centre will disseminate the necessity of involvement of society for the development of an integrative Ecohydrological approach. Culture – archaeological exhibition in the centre on local culture and historical importance of river valley will strengthen society’s psychological link with the region and its history and encourage participatory management and citizen science. Its basic function being a recreation, it was crucial to preserve the natural and valuable character of river Grabia and minimalize the risk of toxic algal blooms occurrence in the reservoir. This was done by constructing a special system analysing the quality of water flowing in the river and automatically blocking the water input into the reservoir during the condensing stage when the concentration of nutrients and pollutants is high. The system reduces the risk of toxic algal blooms in the reservoir and preserves the ecological flow of the river.
4. Conclusions
Proactive education of society: in coping with uncertainty in changing world and especially climate, there is an urgent need for shaping society’s attitude and understanding of Sustainability: understanding the biosphere as a dynamic system where water serves as the primary driver of carbon, phosphorus, and nitrogen cycling and that these processes are influenced by each of us and in turn determine the amount and quality of the ecosystem services we receive. This approach requires proactive education, which will stimulate a shift from a Sociocentric/Mechanistic to an Evolutionary/Ecosystemic paradigm based on three assumptions: 1/the unity of Man and Nature, 2/consciousness that happiness is not correlated with consumption but first and foremost, a fair and good relationship with other people, and with functioning in a healthy environment, 3/our positive mental status is to a great extent, defined by the quality of our environment. Such beliefs can, to a great extent stimulate social capital – confidence and cooperation.

Social capital is an important factor for the translating of knowledge into wisdom and innovations in catchment management. The philosophy exchanging ideas and openness for controversial opinions has been broadening the holistic perception of the problems to be solved and generate the most efficient innovations. It is worth to underline that there appear to be many examples that both encourage team spirit and seniority and leadership towards the achievement of strategic goals first and foremost reversing the degradation of the biosphere, synergies of both should also amplify the translation of Science into Technology.

Socio-economic Foresight of the catchment as a tool for creating a desirable future. Action without vision and strategies have typically resulted in a waste of human potential and resources. Hence, the primary tool used for the development of responsible vision and strategy in achieving SDG UN should be the foresight methodology, which should consider the circular economy, i.e., reduction of impact and bioeconomy production of commodities from renewable resources, and the enhancement of sustainability potential WBSRCE, where the water mesocycle has to be used as a framework for assessment, planning, and management.

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