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Ecohydrology – process oriented thinking for sustainability of river basins

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Abstract

The ecological and hydrological processes together with the observed global changes should be considered while formulating the strategy for sustainable development. The step forward is to increase carrying capacity of the ecosystems by enhancing the key ecohydrological processes acting in the biogeosphere. The integration of knowledge and information among disciplines is a prerequisite to generate wisdom followed by well-informed and well-planned actions. This was the rationale for the 2nd Conference on Healthy Rivers and Sustainable Water Resource Management that took place in Chongqing, China, in October 2011; and the papers selected for this issue follow the same idea. Short summaries of each of them is given at the end of this article.

Key words: transdisciplinary science, regulation, integration, management.

1. Introduction

The network of river ecosystems determines biodiversity potential in the landscape scale by maintaining gradients of wet and dry habitats. However, rivers are among the most vulnerable ecosystems in the landscape due to their location in the lowest parts of the catchment. Thus, the cumulative effects of all forms of human activities, if not sufficiently purified and properly treated (by e.g. use of sewage treatment plants, ecotones/buffering zones, etc.), due to the intrinsic nature of hydrological cycles, provide pulses of pollutants and nutrients into surface and ground waters.

There is high complexity and gradual change of riverine ecosystem structure and function along the river continuum (see Vannote *et al.* 1980) manifested by a diversified mosaic of habitats, the vivid dynamics of ecological processes and a gradual shift in the hierarchy of abiotic and biotic factors acting along the river course (Zalewski, Naiman 1985).

Riverine ecosystems possess very high resilience – a self-regenerating capacity to recover from the effects of stress-generating factors. Soon after the negative impacts are eliminated or reduced regeneration of the structure and function of the ecosystems may occur (algae, invertebrate, fish) – within days or weeks – thanks to the continuous flow of water. However, in case of reservoirs, the resilience to human impact is much lower than in rivers due to longer retention time and enhanced sedimentation of nutrients and pollutants. For example, in Sulejów Reservoir, central Poland, the retention time may vary between 3 and 90 days depending on the intensity of precipitation and river flow, however, toxic algal blooms appear and significantly increase in intensity when the retention time exceeds 30 days (Tarczyńska *et al.* 2001).

Another important aspect of the ecological performance of river systems is their high absorbing capacity, understood as an ability to retain nutrients and pollutants, including heavy metals, in the sediment and floodplain (Zober, Magnuszewski 1998; Kiedrzyńska *et al.* 2008). In the case of reservoirs, it is manifested as an ability to reduce loads transferred downstream, through in-pool retention, and to reduce the toxicity of harmful substances, e.g. dioxins, deposited in sediments (Urbaniak *et al.* 2012a, 2012b).

What is more, reservoirs in catchments with highly modified hydrological cycles, resulting in increased runoff rates and material transfer downstream due to deforestation and urban development, reduce the stochastic character of river hydrology that allows mitigation of floods and droughts, and lessens nutrients and pollutants transfer downstream (Kentzner *et al.* 2010).

The factors that to greatest extent determine river hydrology and dynamics are geological structures and groundwater reserves. Depletion of the latter is yet another aspect of global change, induced by the combination of climate change and human impact on the hydrological cycle in general, and on surface waters in particular, as for example impervious surfaces limit recharge and enhance surface runoff. A cascade of multipurpose reservoirs should be an important way to increase groundwater recharge under conditions of climatic instability. Groundwater reserves would therefore form an important water stock to be used in times of drought to meet both human and ecosystems water needs. It is necessary, however, that their utilisation be preceded by a thorough understanding of the role of these impoundments coupled with their connected groundwater reserves in climate change, and their possible uses should be precisely controlled to avoid overexploitation (Green *et al.* 2011).

These key processes, although not exhaustive, analysed within the framework of the three ecohydrological principles, have to be considered in the formulation of river basin management plans as required under the European Water Framework Directive (WFD). Especially important is the quantification of the dynamics of the annual patterns of mineral and organic matter, and nutrient and pollutant transfer along the river continuum, because it is these dynamics that determine surface and groundwater quality, habitat diversity, river trophy, and biodiversity. Analysis of the distribution and performance of ecosystems in the catchment should be done with special emphasis on pristine ecosystems, which should be protected as the cultural and ecological heritage of humanity. "Novel ecosystems" (Hobbs *et al.* 2006), on the other hand, that are an effect of combined human interventions and ecological succession, can be the subject of and a tool for ecohydrological "dual regulation" interventions.

Integration of our understanding of the hydrological cycle, ecological processes, societal status, and development potential, and ecosystems conservation needs, has to be considered in the formulation of strategies of ecohydrological process regulation on the catchment scale. Every ecohydrological regulation ought to be based on an understanding of the evolution of the observed phenomena and processes (Alverson *et al.* 2003), with a special emphasis on the role of human in the modification of the hierarchy of drivers and impacts. All in all, the efforts undertaken should well address the overall goal which is to increase global and river basin carrying capacities to achieve sustainability in the face of global change, which is generated by demographic impacts and climate change (Vörösmarty *et al.* 2000). The enhancement of carrying capacity in ecohydrology is understood as a state of the environment where simultaneous improvement of water resources, biodiversity, ecosystem services and resilience in a catchment can be observed.

Having said that, we come to the rationale for this issue and its preceding conference. If the strategic goal of Ecohydrology is the regulation of water and biota, as interconnected processes for sustainability, the efficient regulation of the processes ranging from the molecular to the catchment scale is not possible unless we deepen our understanding of those processes in various types of riverine ecosystems. This is also important from the ethical and financial points of view, because ad-hoc and ill-informed actions on a large scale may cause unexpected human suffering and generate excessive or unreasonably high costs of remediation. This issue emerged as an outcome of the 2nd Conference on Healthy Rivers and Sustainable Water Resource Management that took place in Chongqing, China, between 20-22 October, 2011. It consists of a set of papers linked together by process oriented thinking and aimed at the quantification of key ecohydrological processes for better water resource management. A short summary of each paper follows.

Assessment of hydrological alterations over a 40-years period in Tibet (Chen this issue) shows that, due to the increased stochasticity of the hydrological cycle, induced by global climate change, the low-pulse flow duration is amplified by 200% and the high-pulse duration by up to 10 times. In contrast, population growth and agricultural activities contributed up to 30% of the alterations.

Increasing the magnitude of pulses and reduced flows result in the increased area of the water level fluctuation zone. In the case of reservoirs, Zhang *et al.* (this issue) analyse the nutrient content of the water level fluctuation zone of the Three Gorges Reservoir determining that nitrogen especially can play an important role in the eutrophication of waters. This can be explained by accelerated mineralisation and decomposition in fertile sediments deposited within this water fluctuation zone that is exposed to the terrestrial environment after water recession.

Another aspect of reservoir functioning is organic matter decomposition, resulting, among others, in fisheries yield declines in deltaic areas (compare the Nile case in Africa, e.g. Aleem 1972). What is more, organic matter trapped in reservoirs may find suitable conditions for enhancing the generation of greenhouse gas (GHG) emissions, especially in areas of high biological production. Goldenfum (this issue) provides a synthesis of available information on this process and proposes the adoption of coordinated monitoring guidelines that arose from recommendations formulated through the cooperative efforts of UNESCO-IHP and the International Hydropower Association.

The decomposition of organic matter deposited in reservoirs together with the organic matter carried into the reservoirs by rivers is the main cause of eutrophication and associated toxic algal blooms. The precise monitoring of the timing, patterns, intensity and toxicity of algal blooms (Mankiewicz this issue) is fundamental for the identification of cause-effect relationships between the drivers and symptoms of eutrophication-related harmful algal blooms, and is essential for cost effective regulation of river basin/reservoir processes leading towards sustainability of balanced reservoir ecosystems.

The paper by Azime Tezer *et al.* (this issue) underlines the need for integrated planning for enhancing the resilience of urban ecosystems. Under conditions of climate change, which can threaten both the socio-economic and environmental assets of urban riverine systems, the integration of ecosystem services into watershed management is especially important. The ecosystem services approach is presented through a case study of the Istanbul-Omerli watershed in Turkey.

The modification of river basins by dams, if the possibility for ecological migration is maintained, usually reduces the stochasticity of hydrological processes that negatively affect water resources and ecosystems status in highly modified catchments. Maintenance of the possibility for ecological migration moderates the negative ecological effects on freshwater biota. However, if sediment transport downstream is curbed, dams can still seriously affect coastal zone ecology, especially by enhancing shoreline erosion as a result of diminished sediment flows in the system. One of the options to compensate for reduced mineral matter loads in seashore sedimentary areas is beach nourishment which could be accomplished through extraction of sand deposits from the sea bottom. Such a solution can be expected to be efficient for decades (Sylaios *et al.* this issue).

Well informed actions are not possible without a good database, with proper spatial and time resolution. The paper of Jelev and Jelev (this issue) demonstrates how, within the framework of Ecohydrology, the extensive monitoring and observation system of the Black Sea basin could be used to achieve sustainable watershed management. Several specific applications for the Black Sea, Danube River and Delta are presented.

Integration of the knowledge of the processes acting in a river basin with human decision-making processes creates a background for development of water management policies. The paper by Richard Allan (this issue) introduces the key elements of the Water Framework Directive (WFD), which are mainly legislative regulations, designed to achieve a sound ecological status in, and support the implementation of transdisciplinary ecohydrology sciences into, river basin management planning. An example from Scotland is described.

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References

Aleem, A.A. 1972. Effect of river outflow management of marine life. *Marine Biology* **15**, 200-208.

Alverson, K.D., Bradley, R.S., Pedersen, T.F. [Eds] 2003. *Paleoclimate, global change and the future*. Springer, pp. 220.

Green, T.R., Taniguchi, M., Kooi, H., Gurdak, J.J., Allen, D.M., Hiscock, K.M., Treidel, H., Aureli, A. 2011. Beneath the surface of global change: Impacts of climate change on groundwater. *Journal of Hydrology* **405**, 532-560.

Hobbs, R.J., Arico, S., Aronson, J., Baron, J.S., Bridgewater, P., Cramer, V.A., Epstein, P.R., Ewel, J.J., Klink, C.A., Lugo, A.E., Norton, D., Ojima, D., Richardson, D.M., Sanderson, E.W., Valladares, F., Vilà, M., Zamora, R., Zobel, M. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. *Global Ecol Biogeogr* **15**, 1-7.

Kentzer, A., Dembowska, E., Giziński, A., Napiórkowski, P. 2010, Influence of the Włocławek Reservoir on hydrochemistry and plankton of a large, lowland river (the Lower Vistula River, Poland). *Ecological Engineering* **36**, 1747-1753.

Kiedrzyńska, E., Wagner, I., Zalewski, M. 2008. Quantification of phosphorus retention efficiency by floodplain vegetation and a management strategy for a eutrophic reservoir restoration. *Ecological Engineering* **33**, 15-25.

Tarczynska, M., Romanowska-Duda, Z., Jurczak, T., Zalewski, M. 2001a. Toxic cyanobacterial blooms in drinking water reservoir - causes, consequences and management strategy. *Water Sci. Techn. Water Supply* **1**, 237-246.

Urbaniak, M., Kiedrzyńska, E., Zalewski, M. 2012a. The role of a lowland reservoir in the transport of micropollutants, nutrients and the suspended particulate matter along the river continuum. *Hydrology Research* **43**(4), 400-411.

Urbaniak, M., Skowron, A., Zieliński, M., Zalewski, M. 2012b. Hydrological and environmental conditions as key drivers for spatial and seasonal changes in PCDD/PCDF concentrations, transport and deposition along urban cascade reservoirs. *Chemosphere* **88**, 1358-1367.

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R., Cushing, C.E. 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences* **37**(1), 130-137.

Vörösmarty, C.J., Green, P., Salisbury, J., Lammers, R. 2000. Global water resources: Vulnerability from climate change and population growth. *Science* **289**, 284-288.

Zalewski, M., Naiman, R.J. 1985. The regulation of riverine fish communities by a continuum of abiotic-biotic factors. In: Alabaster, J.S. [Ed.] *Habitat Modifications and Freshwater Fisheries*. FAO UN, Butterworths, London. 3-9.

Zober, S., Magnuszewski A. 1998. Hydrological explanation of the heavy metals concentration in the Wyszogrod Island (Vistula River near Plock, Poland). *Journal of Geochemical Exploration* **64**, 35-45.