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Water Quality Improvement Through an Integrated Approach to Point and Non-Point Sources Pollution and Management of River Floodplain Wetlands

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1. Introduction

The world is faced with problems related to quality and quantity of water resources due to extensive industrialization, increasing population density and a highly urbanized society. Global scenarios suggest that almost two-thirds of the world's population will experience some water stress by 2025, which will accelerate the water environmental degradation to a unimaginable crisis scale (Momba, 2010).

Wetland are among the most important ecosystems on the Earth. The extent of the world's wetlands is now thought to be from 7 to 10 million km^2, or about 5 to 8 % of the land surface of the Earth (Mitsch and Gosselink, 2007). Wetlands include swamps, bogs, marshes, mires, fens, and also river floodplain wetlands.

River floodplain wetlands are very important hydrosystems that retain a significant part of the global freshwater bodies, and because of their location at lower elevations in the landscape, they are also highly exposed to accumulation of large loads of nutrients and other pollutants. This results in eutrophication, which in turn leads to degradation of biological diversity and the appearance of toxic cyanobacterial blooms, which pose threats to human and animal health.

This chapter will try to answer the frequently asked question "What exactly is a wetland?" and "What is the hydrological and biological characteristics of wetlands?" and "What are point and non-point sources pollution?". A section will also be presented on the role of river floodplain wetlands as key ecosystems important for regulation of the water, sediments and nutrients retention, and as a natural buffering system that can be considered as a tool for the reduction of nutrients and other pollutants transport by a river to downstream water ecosystems, and thus contributing to freshwater quality improvement. Part of the chapter will be devoted to application of the ecohydrological sustainable management of floodplain-wetland ecosystems, which is based on the restoration of natural mechanisms determining these ecosystems and functioning of the landscape for the increasing efficiency of water purification, and reducing the negative impact of pollution on the freshwater resources. The third part of the chapter will present a general assumption of the crucial international document "The Declaration on Sustainable Floodplain Management".

2. What is a wetland?

Wetlands sometimes are described as „the kidneys of the landscape" because they function as the downstream receivers of water and waste from both national and human sources. Furthermore, wetlands stabilize water supplies and water balance of the catchment area, thus ameliorating both floods and drought, and they have been found to clean polluted waters, protect shorelines, and recharge groundwater aquifers (Mitsch et al., 2009).

These ecosystems also have been called „ecological supermarkets" due to the extensive food chain and rich biodiversity they support. They play major roles in the landscape by providing unique habitats for a wide variety of flora and fauna. Now that we have focused our attention on the health of our entire planet, wetlands are being described by some as important carbon sinks and climate stabilisation on a global scale (Mitsch and Gosselink, 2007).

Wetland definitions and terms are many and are often confusing or even contradictory. Nevertheless, definitions are important both for the scientific understanding of these systems and for their proper management (Mitsch and Gosselink, 2007), and above all for using the wetlands for water quality improvement .

The Ramsar Convention on Wetlands (signed in Ramsar, Iran 1971) defines wetlands as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or saline, including areas of marine water, the depth of which at low tide does not exceed six meters.

According to the U.S. Environmental Protection Agency wetlands are areas where water covers the soil, or is present either at or near the surface of the soil all year or for varying periods of time during the year, including the growing season. Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation and other factors, including human disturbance. Indeed, wetlands are found from the tundra to the tropics and on every continent except Antarctica.

According to the wetland definition given by Mitsch and Gosselink (2007), it should include three main components: (i) wetlands are distinguished by the presence of water, either at the surface or within the root zone; (ii) wetlands often have unique soil conditions that differ from adjacent uplands; (iii) wetlands support biota such as vegetation adapted to wet conditions (hydrophytes) and, conversely, are characterized by the absence of flooding-intolerant biota.

Floodplain wetlands are one of the types of natural wetlands and are transitional between terrestrial of the river valley and open water river ecosystems (Fig. 1). Factors such as climate and geomorphology define the degree to which wetlands can exist, however the starting point is the hydrology, which, in turn, affects the physiochemical environment, including the soils, which in turn, together with the hydrology, determines what and how much of the biota, including vegetation, is found in a wetland (Mitsch et al., 2009).

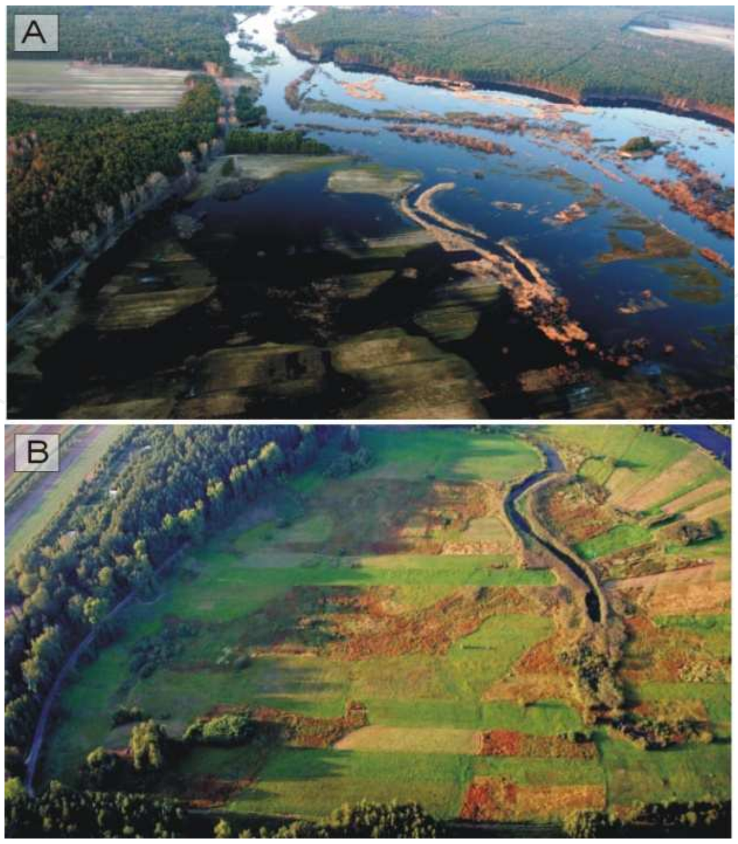

Fig. 1. The Pilica River floodplain, upstream of the Sulejów Reservoir (central Poland); A – situation of high discharge (Q=83.2 $m^3 s^{-1}$) in spring 2006 (Photo by Piotr Wysocki); B - low discharge (Q= 6.7 $m^3 s^{-1}$) in summer 2006 (Photo by Mariusz Koch).

3. Wetland hydrology

Hydrologic conditions are extremely important for the maintenance of a floodplain wetland's structure and function, because they affect many abiotic factors, including soil anaerobiosis, nutrient availability (Mitsch and Gosselink, 2007; Vorosmarty and Sahagian, 2000). The hydrology of a river wetland creates unique physiochemical conditions that make such an ecosystem different from both well-drained floodplain systems and deeper old river bed systems.

The major components of river wetland's water budget include precipitation, evapotranspiration, surface flow, ground water fluxes, and other overbank flooding in floodplain wetlands. Water depth, flow patterns, and duration and frequency of flooding, sediments and nutrients transport (Kadlec and Knight, 1996; Magnuszewski et al., 2007; Altinakar et al., 2006; Kiedrzyńska et al., 2008a; Kiedrzyńska et al., 2008b), which result from all hydrologic inputs and outputs, influence the biochemistry of the soils and are major factors in the ultimate selection of the biota of wetlands (Mitsch and Gosselink, 2007; Kiedrzyńska et al., 2008a). The water status of a wetland defines its extent and determines the species composition in a natural floodplain wetland (Mitsch and Gosselink, 1993). However, biota components are active in altering the wetland hydrology and other physiochemical conditions (Zalewski 2000; 2006; Mitsch and Gosselink, 2007; Kiedrzyńska et al., 2008a).

4. Wetland biology

Hydrology affects biological processes in wetlands, such as species composition and biodiversity, efficiency of primary productivity, organic accumulation, and nutrient cycling and retention in wetlands.

Floodplain wetland environments are characterized by stresses that most organisms are ill equipped to handle. Aquatic organisms are not adapted to deal with the periodic drying that occurs in many wetlands, and terrestrial organisms are stressed by long periods of flooding. Because of the shallow water, the temperature extremes on the wetland surface are greater than would be expected in aquatic environments (Mitsch and Gosselink, 2007).

The genetic and functional responses of wetland organisms (microbial and macrophytes) are essentially limitless and result in the ability of natural systems to adapt to changing environmental conditions, such as flooding in natural wetlands or some addition of wastewaters in the treatment of wetlands (Kadlec and Knight, 1996; Kiedrzyńska et al., 2008a). This adaptation allows living organisms to use the constituents from wastewaters for their growth and biomass production. Primary productivity is the highest in wetlands with high flow of water and nutrients, but also in wetlands with pulsing hydroperiods.

When using these nutrients, wetland organisms mediate physical, chemical and biological transformations of pollutants and modify the water quality. In wetlands engineered for water treatment, design is based on the sustainable functions of organisms that provide the desired transformations (Mitsch and Gosselink, 1993; Kadlec and Knight, 1996; Mitsch and Gosselink, 2007) and in natural river floodplain wetlands, we can use autochthonic vegetation of macrophytes (Kiedrzyńska et al., 2008a; Keedy 2010).

Wetland macrophytes are the dominant structural components of most wetland treatment systems, and understanding of the growth requirements and characteristics of these wetland plants is essential for successful river floodplain and a treatment wetland design and its operation (Kadlec and Knight, 1996).

Water pollution control and water quality improvement using macrophytes has been discussed in the literature (Klopatek, 1978; Athie and Cerri, 1987; Surrency, 1993; Copper, 1994; Kadlec and Knight, 1996; Kiedrzyńska et al., 2008a). Production of macrophyte biomass differs significantly both between seasons and between particular species, and may be restricted by a range of limiting abiotic factors, such as soil quality, climate, hydrology and biotic factors, e.g. intraspecific competition and the condition of mycorrhizal symbionts (Sumorok and Kiedrzyńska, 2007).

According to Kadlec and Knight (1996) and Kiedrzyńska et al. (2008a), the biomass of *Phragmites australis*, per hectare ranges between 6,000 and 35,000 kg d.w., making this macrophyte one of the most effective ones. According to Gołdyn and Grabia (1996) and Kiedrzyńska et al. (2008a), the total harvest of wetland grasses in the summer period ranges between 4,300 and 14,000 kg d.w. ha^{-1}.

Plant productivity may be limited by the availability of phosphorus (Compton and Cole, 1998; Mainstone and Parr, 2002; Olde Venterink et al., 2002, 2003). The amount of phosphorus accumulated in the vegetation biomass depends principally on the ecology and biology of plant species and on edaphic factors (Ozimek and Renman, 1996), and usually ranges from 0.1% to 1% (Fink, 1963).

According to Kiedrzyńska et al. (2008a), the phosphorus content in the floodplain wetland meadow communities was maintained at a relatively constant level of 2.54–2.89 g P kg^{-1} d.w. throughout the growing season. More variation was observed in the case of *Carex* sp., which was characterized by the highest percentage of P content in spring (4.07 g P kg^{-1} d.w.) and significantly lower one for the other seasons (summer: 1.38 g P kg^{-1} d.w.; autumn: 2.17 g P kg^{-1} d.w.). The same studies have shown that the highest values of P accumulation on the floodplain were reached in spring by *P. australis* (3.75 g P kg^{-1} d.w.), which also gradually decreased towards the end of the growing season. Finally, the efficiency of phosphorus accumulation per area unit was between 0.7 and 7.3 kg P ha^{-1} for all communities except those dominated by *P. australis*, which were nearly five times higher (34.7 kg P ha^{-1}) and resulted from the very high summer biomass of this species (Kiedrzyńska et al., 2008a).

5. Wetland ecohydrology

In order to effectively improve the water quality in wetland floodplains, the knowledge of the processes taking place there is required, as well as their identification and quantification. This way of solving the environmental problems suggests the concept of Ecohydrology (Zalewski et al., 1997; Zalewski 2000; 2002; 2007).

In this context, Ecohydrology is a conceptual tool for sustainable management of water–floodplain resources and prevention of anthropogenic landscape transformation results. Therefore, introducing the ecohydrological management in a catchment area based on the restoration of natural mechanisms determining the river-floodplain ecosystems and their functioning, is very important.

Ecohydrology is a subdiscipline of hydrology focused on ecological aspects of the hydrological cycle (Zalewski et al., 1997; Zalewski 2000). It refers specifically to two phases of the hydrological cycle: terrestrial plant - water - soil interactions and aquatic biota - hydrology interactions. Ecohydrology is based on the suggestion that sustainable development of water resources depends on the ability to maintain the evolutionarily established processes of water and nutrient circulation and energy flows at the basin scale (Zalewski 2006).

Ecohydrology provides three new aspects to environmental sciences (Zalewski, 2000; 2011) that can be adopted and used for sustainable management of the river floodplain ecosystems, water quality improvement and achievement of 'good' ecological, chemical and hydrological status of water bodies (Zalewski 2011; Zalewski and Kiedrzyńska 2010):

1. Integration of the catchment, river valley, floodplain and river together with its biota into a specific superorganism (Framework aspect). This covers the following dimensions: a) the *Scale of processes* - the meso-scale cycle of water circulation within a basin (the terrestrial/aquatic ecosystem coupling) provides a template for the quantification of ecological processes; b) *Dynamics of processes* – water and temperature have been the driving forces for both terrestrial and freshwater ecosystems; c) *Hierarchy of factors* - abiotic processes are dominant (e.g. hydrological processes), biotic interactions may manifest themselves when they are stable and predictable (Zalewski and Naiman, 1985). This is based on the assumption that abiotic factors are of primary importance and once they become stable and predictable, the biotic interactions start to

manifest themselves (Zalewski and Naiman, 1985). The quantification of hydrological pulses along the river continuum (Junk et al., 1989; Vannote et al., 1980; Agostinho et al., 2004; Altinakar et al., 2006; Magnuszewski et al., 2007; Kiedrzyńska et al., 2008b) and monitoring of threats (Wagner and Zalewski, 2000; Mankiewicz-Boczek et al., 2006; Bednarek and Zalewski, 2007a, 2007b; Kiedrzyńska et al., 2008b; Urbaniak et al., in press), such as point and nonpoint source pollution (Takeda et al., 1997; Borah and Bera, 2003; Tian et al., 2010; Kiedrzyńska et al., 2010), are necessary for optimal regulation of processes towards the sustainable water and ecosystems management.

2. Increasing the carrying capacity of ecosystems that is their evolutionarily established resistance and resilience to absorb human-induced impacts (Target aspect). This aspect of ecohydrology expresses the rationale for a proactive approach to the sustainable management of freshwater resources. It assumes that it is not enough to simply protect the ecosystems, but in the face of increasing global changes, which are manifested in the growth of the population, energy consumption, material and human aspirations, it is necessary to increase the capacity of ecosystems. This can be achieved by regulation the interplay between hydrology and biota; analysis of dynamic oscillations of an ecosystem and its productivity and succession (as reflected by nutrient/pollutant absorbing capacity versus human impacts) should be the solution to process regulation (Bednarek and Zalewski, 2007a, 2007b; Kiedrzyńska et al., 2008a, Zalewski 2011).
3. Application of "dual regulation" in shaping and management of processes in river floodplain wetlands for purification and water quality improvement, biodiversity and ecosystem services for society (Methodology aspect). This means that a biotic component (macrophytes, bacteria) of a floodplain ecosystem can control and shape the chemical parameters of water and hydrological processes through effects on shaping the substrate roughness. These relationships also occur in the opposite direction - *vice versa*, what means using hydrology to regulate the biota (Zalewski, 2006, Zalewski and Kiedrzyńska, 2010). Great potential of the knowledge, which has been generated by dynamically developing ecological engineering (Mitsch 1993; Jorgensen 1996; Chicharo, 2009), should to a large extent accelerate the implementation of the above concept.

Sustainable management of the river floodplain wetlands gives a number of positive implications on the global ecosystem by improving the water quality, which depends on the development, dissemination and implementation of these principles and interdisciplinary knowledge, based on the latest achievements in environmental protection (Fig. 2).

The success of these actions depends on the profound understanding of the whole range of multi-dimensional processes involved. The first dimension is temporal: spanning a time frame from the past, paleohydrological conditions till the present, with a due consideration of future, global change scenarios. The second dimension is spatial: understanding the dynamic role of river and floodplain biota over a range of scales, from the molecular- to the valley-scale. Both dimensions should serve as a reference system for enhancing the buffering capacity of floodplain wetlands as key ecosystems important for the regulation of water, sediments and nutrients retention, and reduction of nutrients and other pollutants transport by a river to downstream water ecosystems, and thus contributing to freshwater quality improvement.

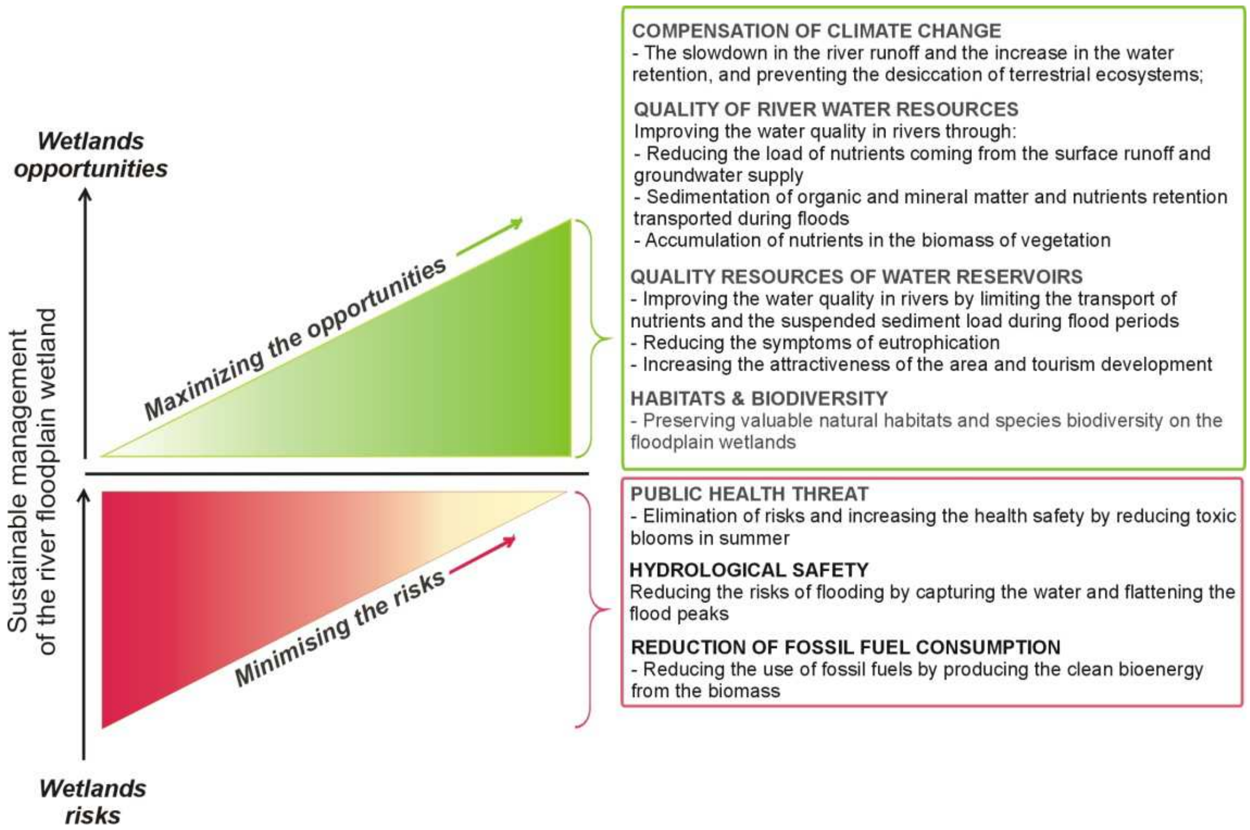

Fig. 2. Implications of the sustainable management of the floodplain wetlands.

6. Wetland water quality improvement – A new way of thinking

6.1 Water pollution – Point and non-point sources pollution

Water pollution is a crucial global problem, which requires ongoing evaluation and revision of water resource policy at all levels (from the international one down to individual aquifers and wells). It has been suggested that it is the leading worldwide cause of deaths and diseases, and that it accounts for the deaths of more than 14,000 people daily (West, 2006).

Water resources are usually referred to as polluted when they are impaired by anthropogenic contaminants and either do not support a human use, such as drinking water, and/or undergo a considerable shift in their ability to support their constituent biotic communities, such as fish. Natural phenomena, such as algae blooms, storms, and earthquakes, also cause major changes in the water quality and the ecological status of the water.

Surface water and groundwater have often been studied and managed as separate resources, although they are interrelated. Surface water seeps through the soil and becomes groundwater. Conversely, groundwater can also feed surface water sources. Sources of surface water pollution are generally grouped into two categories based on their origin (Winter, 1998).

Point source (PS) water pollution refers to contaminants that enter a waterway from a single, identifiable source, such as a pipe or ditch. Examples of sources in this category include discharges from a sewage treatment plant, a factory, or a city storm drain. Non–

point source (NPS) pollution refers to diffuse contamination that does not originate from a single discrete source. NPS pollution is often the cumulative effect of small amounts of contaminants gathered from a large area. A common example is the leaching of phosphorus and nitrogen compounds from fertilized agricultural lands. Nutrients runoff in stormwater from "sheet flow" over an agricultural field or forest are also cited as examples of NPS pollution. Excessive export of nutrients from PS and NPS pollution are the leading causes of eutrophication in lakes, reservoirs and rivers, and coastal water bodies worldwide (Alexander et al., 2008; Diaz and Rosenberg, 2008; Tian et al., 2010).

Eutrophication is a shift in the trophic status of a given water body in the direction of increasing plant biomass, by adding some artificial or natural substances, such as nitrates and phosphates, through e.g. fertilizers or sewage, to an aquatic system.

In other terms, it is a water bloom resulting from a great increase of phytoplankton in a water body. Negative environmental effects include hypoxia, the depletion of oxygen in the water, which induces reductions in specific fish and other animal populations. Thus, eutrophication of water resources leads to degradation of biological diversity and the appearance of toxic cyanobacterial blooms, which pose threats to human health and animals (Tarczyńska et al., 2001; Mankiewicz et al., 2001, 2005; Jurczak et al. 2004).

River wetlands are altered by the runoff of pollutants from point and diffuse sources of pollution flowing from the upper catchment areas and thus are purified. The effects of polluted water on wetlands have not received yet enough attention.

6.2 Wetlands as key ecosystems improving the water quality

Rivers and floodplain wetlands are the ecosystems that are particularly exposed to eutrophication and high anthropogenic stress (Meybeck 2003, Zalewski and Kiedrzyńska 2010). This is because they are situated in landscape depressions, into which the whole range of catchment anthropogenic modifications and impacts are transferred and accumulated (Altinakar et al., 2006; Zalewski, 2006; Magnuszewki et al., 2007), e.g. sediments and nutrients (Kiedrzyńska et al., 2008a; Kiedrzyńska et al., 2008b), dioxins (Urbaniak et al., 2009; Urbaniak et al., in press), microbial contamination (Gągała et al., 2009). These dramatically progressing disturbances are sometimes negatively amplified by degradation of the hydrological cycle and the loss of integrity between fluvial ecosystems and floodplains, which can result in the increased eutrophication (Tarczyńska et al., 2001; Izydorczyk et al., 2005; Izydorczyk et al., 2008) and the reduction of biodiversity and ecosystem services for societies (Zalewski 2008; Zalewski and Kiedrzyńska, 2010). However, the river valley with natural floodplain wetlands are areas that may be used in water purification.

Water quality improvement by the use of wetlands has been broadly discussed (Bastian and Hammer, 1993; Raisin and Mitchell, 1995; Nairn and Mitsch, 2000; Trepel and Kluge, 2002; Mitsch et al., 2005; Mitsch and Gosselink, 2007; Mitsch et al., 2009), especially the importance of natural floodplains for river self-purification and freshwater quality protection (Bayley, 1995; Loeb and Lamers, 2003; Zalewski 2006; Kiedrzyńska et al. 2008a; Kiedrzyńska et al. 2008b). An example can be the area of 24 km^2 of wetlands that collected the water from the Zala River catchment, and which has been reconstructed within the confines of a multidisciplinary research programme on the protection of the Lake Balaton (Hungary).

According to Pomogyi (1993), 96% of PO_4-P, 87% of NO_3-N and 58% of TP were retained in this area in 1990. Interesting studies conducted by Wassen (1995) in the Biebrza Valley in Poland reported that the floodplain vegetation is an important sink for nutrients, especially for N and P. Wetlands are also used in other European countries, e.g. in the Netherlands, Germany, Finland (Wassen et al., 2002; Olde Venterink et al., 2002) and in the United States, and around the world (Weller et al., 1996; Mitsch et al., 2005; Thullen et al., 2005; Mitsch et al. 2009).

Floodplains can optimize nutrient retention in the river ecosystem, especially in catchments with large areas of agriculture and can be considered as a tool for the reduction of nutrient transport by a river to downstream reservoirs and estuaries (Kiedrzyńska et al., 2008a; Kiedrzyńska et al., 2008b).

The highest nutrients' loads transported by rivers usually occurred during rising water stages of floods and they should be directed to floodplain areas upstream the reservoir at the very initial stages of floods, in order to diminish the load in a reservoir. The research on the Pilica River floodplain (central Poland) looked into the possibilities of enhancing this process, both through sedimentation and assimilation in the vegetation biomass. The research that was based on the DTM and hydraulic models demonstrated that sedimentation of flood sediments in the floodplain essentially reduces the transport to the reservoir. During floods, the sediment is effectively deposited and phosphorus is retained in the 30-kilometer section of the Pilica River floodplain. In the flooding area of 1007 ha, fine-grained flood sediments reached 500 t and the retention of P was 1.5 t. Furthermore, the efficiency in the assimilation of nutrients and the biomass production by autochthonous plant communities, with special emphasis on willow patches, was examined against a background of a hydroperiod. The potential of vegetation in the Pilica River floodplain (26.6 ha) for summer phosphorus accumulation was estimated at 255 kg P y^{-1}, however, a conversion of 24% or 48% of the area into fast-growing managed willow patches can increase the phosphorus retention up to 332 kg P y^{-1} or 399 kg P y^{-1}, respectively (Kiedrzyńska et al., 2008a). Theoretically, 1 kg of P can lead to some 1-2 t of algal biomass in a reservoir (Zalewski, 2005). Therefore, floodplain wetlands are mostly enriched with the riverine material and, at the same time, river water is purified by deposition of this material. Floodplains can, therefore, serve as natural, cleaning and biofiltering systems for reducing the concentrations of sediments, nutrients, micropollutants and, other pollutants coming from upper sections of the catchment area.

7. Wetland management – The Declaration on Sustainable Floodplain Management

In the 21st century, wetlands management should focus not only on the conservative protection of these valuable ecosystems, but also on the sustainable use and optimization of abiotic-biotic processes for problem solving and improving the water quality.

Floodplain wetlands are an integral part of river systems and therefore they play a fundamental role in the exchange of water masses and matter between a river and terrestrial ecosystems (Mitsch et al., 1979; Junk et al., 1989; Tockner et al., 1999; Mitsch et al., 2008; Kiedrzyńska et al., 2008b). Floodplains are "dynamic spatial mosaics", where water acts as a connector between various components (Thoms 2003; Kiedrzyńska et al., 2008a). This specific connection is crucial for maintaining the function and integrity of floodplain-river systems (Tockner et al., 1999; Amoros and Bornette, 2002; Thoms 2003). They are the hot spots of terrestrial and aquatic biodiversity in the catchment landscape due to a mosaic of plant communities and their spatio-temporal dynamics (Zalewski, 2008). Sustainable development of the river and floodplain environment needs to take into account the fact that biological structures and fundamental ecological processes, such as water and nutrients cycles, are to a large extent, suffering from deterioration (Zalewski, 2009).

The sustainable management of floodplains, which are the most diversified ecosystems and most resilient to human impact due to their hydrological pulse-driven self-regenerative capacity, is obviously very important. Therefore, there is still a further need for insights into these and other processes, whereas "engineering harmony" between river floodplain ecosystems and societies (UN MDGs) requires solutions from integrative, interdisciplinary science such as ecohydrology, a subdiscipline of sustainability science focused on ecological aspects of the hydrological cycle (Zalewski and Kiedrzyńska, 2010).

Such an integrated ecohydrological approach to sustainable management of wetlands is contained in the presented below Floodplain Declaration "Declaration on Sustainable Floodplain Management", which was elaborated based on presentations and discussions at the International Conference under the auspices of IHP of UNESCO "Ecohydrological Processes and Sustainable Floodplain Management: Opportunities and Concepts for Water Hazard Mitigation, and Ecological and Socioeconomic Sustainability in the Face of Global Changes" (19^{th} – 23^{rd} of May 2008, Lodz, Poland).

7.1 Declaration on Sustainable Floodplain Management

7.1.1 Recognition: Properties and values of floodplains

Floodplains are dynamic wetlands, an integral part of river basins with a high potential for biological productivity, biodiversity, flood mitigation, groundwater recharge, river purification and regulation of exchanges of nutrients between land and water, and other ecosystem services, all maintained by the pulse-regulated hydrology of running waters.

Floodplains are threatened by increasing population and improper management. Development of floodplains without consideration of the specifics of their ecological structure and dynamics thus diminishes biodiversity, reduces benefits to society related to water quality, cultural aesthetic values and – in consequence – causes economic losses.

7.1.2 Floodplains and global climate change

Floodplains are an important component of global environmental security and resilience because of their high compensatory potential to mitigate environmental change due to their capacity for water retention, food production, CO_2 sequestration, production of bio-fuels, and the diversity of habitats that they support.

7.1.3 Integrative science for problem solving

Understanding the functioning of floodplains and their potential for socio-economic benefits, requires integration of recent knowledge of:

- geomorphological and paleohydrological evolution of river valleys,
- hydrological processes and patterns of ecological succession,
- societal interactions and learning alliances,
- climate scenarios,
- strategic forecasts based on integrative modelling and adaptive management

In order to reverse floodplain degradation and increase ecological resilience and economic benefits, a shift in strategy from floodplain exploitation to floodplain sustainable use is necessary. Accordingly we need a change of public perception from sectoral, structural and reactive responses to an integrated, process-regulation-oriented and proactive approach.

7.1.4 Methodology for provisioning sustainable ecological services of floodplains

- *Ecohydrological management* of floodplains, will require "dual regulation" - a framework for harmonisation of biodiversity conservation with such human needs as flood mitigation, food and energy production, transport and recreation.
- *Hydrotechnical infrastructure* harmonised on the basis of integrative science and best management practices incorporating catchment scale ecosystem processes, will be a powerful tool for reversing degradation of biodiversity, and enhancing sustainable development and compensation of global changes
- *Cultural heritage* of the catchment should become an important element for spatial reconnection of floodplains to the adjacent landscape, as well as restoration of links to social, economic and cultural values.
- *People's perception* and attitudes to the changing environment can only be shaped by new solutions based on integrative science, which depend upon development of programs and methodologies for education and communication.

7.1.5 Tools for implementation

Policies by national and international institutions for water resources, energy, transportation, and environmental management must elevate the protection of pristine sections of the floodplains and promote sustainable use, and restoration of degraded floodplains on rivers, lakes and coastal zones.

Land use integrated planning, financial incentives, economic instruments, and environmental regulatory frameworks are essential tools for implementing the ecohydrological standards and criteria. In case of "novel floodplains", created by secondary succession after human impact, floodplain loss due to essential new development of e.g. transport systems should be mitigated through restoration of at least twice the area of degraded floodplain.

A network of long-term ecological processes, research sites, responsible institutions, and data bases is needed for improving progress and transfer of knowledge, and transfer and sharing of technology.

Public participation, facilitated by modern communication approaches, is fundamental to accommodating conflicting interests and uses of floodplains.

7.1.6 Recommendations for action plan

- Classification of different types of floodplains with special consideration of catchment perspective and ecosystem services;
- Development of methodology to assess rate and type of flood pulses necessary to maintain floodplain functions and structures and to reconcile protection and social needs;
- Formulation of principles for floodplain management, sustainable food and renewable energy production based on integrative science and the relevant science/policy interface.

8. Conclusion

Floodplain wetlands can purify and improve the water quality because they have a significant role in the water retention, sedimentation of mineral and organic matter, nutrients and pollutants. Furthermore, the floodplain wetland vegetation has a great biological potential for the assimilation and accumulation of nutrients in biomass and especially for the uptake of phosphorus.

Therefore well-managed river wetlands can serve as natural cleaning and biofiltering systems for reducing the concentrations of sediments, nutrients, micropollutants and, other serious pollutants.

On the one hand, in the 21st century, the floodplain wetlands management should focus on the protection of biodiversity and values of these important ecosystems, but on the other hand, also on the sustainable use and optimization of abiotic-biotic processes for problem solving and improving the water quality.

In accordance with the conclusions of the Floodplain Declaration, the successful reversal of degradation of floodplain ecosystems should become the objective for the development of a sound vision of co-evolution of Ecosphere and Anthroposphere, by engineering harmony between three dynamic and evolving components: catchment areas, water resources and a society, with an emphasis on the change from exploitative to participatory environmental consciousness. For this purpose, it is necessary to continue the integration of studies of highly specialized disciplines of environmental and social sciences into the framework of Ecohydrology - a holistic problem-solving concept. The system approach, foresight methodology and learning alliances are these important new components of the trans-disciplinary sustainability science that should be used for sustainable water management in the catchment area, and also the ecological and socio-economic potential of the basin should be used for the improvement of human health and the quality of life following the UN MDGs.

9. Acknowledgment

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10. References

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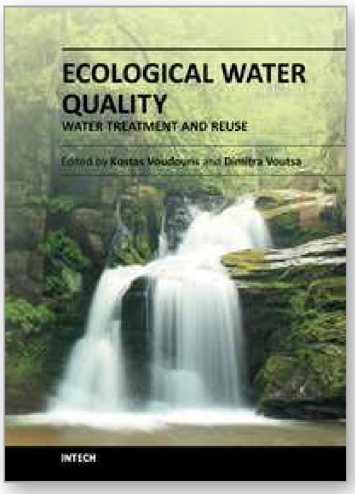

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This book attempts to cover various issues of water quality in the fields of Hydroecology and Hydrobiology and present various Water Treatment Technologies. Sustainable choices of water use that prevent water quality problems aiming at the protection of available water resources and the enhancement of the aquatic ecosystems should be our main target.