Ecohydrology for the Enhancement of Biosphere Sustainability Potential (WBSRC)

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We are living in the Anthropocene Era when almost 80% of our usable ecosphere has been conditioned, converted, and consumed by humans, usually without understanding the full consequences of our actions. 

*Columbus Declaration*
*(EcoSummit 2014)*

„Legal system and politics in the range of non material values, moral and believes, changes much slower than economic processes.” *W.F Ogburn 2010*
UNESCO Ecohydrology Programme

1. UN Vision of Sustainable Future (SDG)

2. UNESCO IHP (Ecohydrology) mission: To cover the gap between vision and action

3. How to cover the gap? – Innovative, integrative science (EH) – use ecosystem processes as a management tool
Water-related risks

Changes in future rainfall patterns will alter drought occurrence, and consequently, soil moisture availability for vegetation in many parts of the world.

Predicted future changes in the mean soil moisture content in the top 10 cm layer in percentage change.

Source: Dai (2013)
Degradation of nutrients cycles

Loss of organic matter and fertilizers from the soil as a result of soil erosion and simplification of structure of agricultural area.

Transport of organic matter, fertilizers, and pesticides along the slope gradient.

Elimination of wetlands and land/water ecotones at stream valley.

- Mountain areas
- Periodical water deficit
- Significant water deficit
- Sufficient water resources
Acceleration of the rivers outflow and habitats / biodiversity degradation by the overengineering river valley
Ecohydrology and Evolutionary Paradigm:

WATER:
- determinant of the bioproductivity and sustainability
- common denominator for the ecological, social and economical processes.

Ecohydrology „Use ecosystem processes as management tool for the enhancement of sustainability potential WBSRC”
Ecological processes driven by vegetation and soils in forests, grasslands, wetlands, as well as in agricultural and urban landscapes, play a major role in the movement, storage and transformation of water.
The relationship between ecosystems and the water cycle

Ecosystems – water „recyclers” - Evaporation from the vegetation and soils from terrestrial ecosystems can be a very important source of precipitation for other areas.

Continental precipitation recycling ratio \( \rho_c = \rho_{c,i} + \rho_{c,t} \)

Source: Van der Ent et al., 2014
Enhancement of the Biosphere Sustainability Potential (WBSRC)

- Ecohydrology and Nature-Based Solutions for enhancement sustainability potential
  - Reduction emission of pollutants
  - Habitats degradation and other risks
- Circular Economy
- Sustainable management of natural resources
  - Enhanced sustainability of environment
- Environmental safety
- Degraded environment
  - Amplification of opportunities
  - Elimination of risks

Environmental safety

Environmental hazard

Sustainable management of natural resources

Environmental safety
Deductive background of Ecohydrology:

(Zalewski, Naiman 1985)
Quantification of interactions between phytoplankton-filtering zooplankton-predatory zooplankton–juvenile Percids in pelagic zone of the Sulejow Reservoir using mathematical model

Hydrological regulation of biotoc interactions

Early spring and spring (ESp and Sp): short retention time, low temp., low density of Daphnia, lack of cyanobacteria.

Hydrologically unstable late spring/summer (HunLSp and Sm): low biomass of cyanobacteria

Late spring and summer (LSp/Sm): longer retention time, high density of Daphnia = clear water phase.

Summer (Sm) and Hot summer (HotSm): long retention time, high temp., high biom. of cyanobacteria

The 24 SOM output neurons were grouped into six sub-clusters through hierarchical cluster analysis.

Wojtal-Frankiewicz et al., 2015; PLoS ONE
ECOHYDROLOGY – framework for the implementation of NATURE BASED SOLUTIONS

WATER CYCLE QUANTIFICATION and IMPACT MAPPING

ECOSYSTEMS DISTRIBUTION

Ecohydrological Biotechnologies and Systemic Solutions (NATURE BASED SOLUTIONS)
Ecological Engineering
DUAL REGULATION

ECOHYDROLOGY

Ecohydrological Biotechnologies and Systemic Solutions (NATURE BASED SOLUTIONS)
Ecological Engineering
DUAL REGULATION

HYDRO

BIOTA

Dual Regulation

Zalewski, 2000; 2008; 2011; 2015

Land cover, land use, vegetation mapping & analysis

Sequential biofiltration systems & constructed wetlands

e.g. rainfall-runoff model
Mathematical model **SWAT** of non-source pollutions from Pilica River Catchment

High efficiency buffering zone for reduction of non-source pollutions from agricultural catchement

Generation of the algal blooms due to the groundwater influx

(Izydorczyk, Frątczak. 2015)
Ecohydrology – tool for the mitigation of intermediate impacts

Ecohydrology & Ecosystem biotechnologies

Environmental technologies (sewage treatment, hydroengineering, civil engineering)

Catchment resistance & resilience

Efficiency

% 100 80 60 40 20

Nutrient concentration

mg P L⁻¹

0.03 0.1 1 10

Natural background

Non-point source pollution

Point-source pollution

(Zalewski 2017)
Molecular biology for Ecohydrology:

Early warning
detection of toxigenic (potentially toxic) strains of cyanobacteria

Cause-effect analysis
toxigenic cyanobacteria and physicochemical parameters of water

Analyses of the relationship between organisms

Ecosystem Biotechnologies provide knowledge how to convert forms of the matter for improving water quality by using low energy methods e.g. enzymes, microorganisms, plants and trophic cascade interactions.
Ecohydrology for a paradigm shift in the construction of reservoirs with WBSRC multidimensional goal

Proposed traditional hydroengineering solution

Design of the EH systemic solutions to enhance the sustainability of the catchment WBRSC

WBSR+C

Water  Biodiversity  Ecosystem Services  Resilience  Culture/Education

(Zalewski, Belka, Kiedrzynska 2017)
Ecohydrology for the adaptation of navigation system in the transboundary large river

THE ODER RIVER

River Continuum maintenance

Natural habitats and refugium for the biodiversity

NBS for the reduction of diffuse pollutants

NBS for the reduction of point source pollutants

EH Hybrid solutions for the urban catchment
Ecohydrological systemic solution: refugiums for the aquatic organisms for a compensation of decline of spawning and resting areas

1. Outflow from the oxbow – size is depending on the volume of water inside refugium to keep the retention time between 10 and 30 days

2. Nature-based wave protection system designed with natural materials

3. Inflow – open channel constructed with rocks/Stones/gravel and natural woody debris

4. Reduced slope of the oxbow banks to create additional spawning and resting areas

Zalewski, Jarosiewicz et al. 2019
SYSTEMIC SOLUTIONS
Improvement of water quality, human health and quality of life

- Assimilation of CO₂

- New employment opportunities

- Lower emission and cleaner air

- Economic development

- BIOENERGY

- Sewage treatment plants

- Nature-Based Solutions And Biomass Production

- Water quality improvement
Urban-rural differences in the prevalence of asthma and hay fever in children

Kuna, Kuprys-Lipinska, 2009
ECOHYDROLOGY for the City of Future

Health and quality of life

Green infrastructure

Hybrid Grey + Green Infrastructure

Grey infrastructure

M. Zalewski
(In press)
Urban storm water as a major factor generating toxic algal blooms in the small urban reservoirs

Storm waters at City of Lodz (Poland)

The effect

Toxic algal blooms in the recreational reservoir (reduced ecosystem services)
Stormwater inflow into SBS

Enhanced sedimentation zone

$\text{Ca}_3(\text{PO}_4)_2 \downarrow$

Sequential Sedimentation-Biofiltration System

Zalewski 2008
Lowland reservoir protected with the Ecohydrological Solutions
Sequential Biofiltering System for improvement efficiency of the Small Sewage Treatment Plants

Mean TP reduction: 26%
Max. TP reduction 76%
Sequential filtration of pollutants

1 Phase
Limstone zone
2 Phase
Coal zone 3.45
3 Phase
Sawdust zone
4 Phase
Wetland with macrophytes

Mean TN reduction: 48%
Max. TN reduction 97%
Biological treatment of pollutants

Outflow from Treatment Plant
to the SBS

monitoring stations
regeneration system -

Outflow of the purified WW to the river
Hybrid System
Integration of ecohydrological biotechnologies with hydroengineering
EHREK LIFE + at Bzura River catchment

TSS = 3,4 mg/l
TSS = 3,4 mg/l
TN = 0,4 mg/l
TP = 0,3 mg/l

TSS = 17,5 mg/l
TN = 1,5 mg/l
TP = 0,8 mg/l

TSS = 165 mg/l
TSS = 165,0 mg/l
TN = 4,2 mg/l
TP = 3,0 mg/l

Regulation of Biological Processes
Enhancement of filtering zooplankton by predatory fish stocking

Biofiltration Zone
Assimilation of nutrients (N, P) into plant biomass

Geochemical Barrier
Reduction of nutrients by dolomite structure

Sedimentation Zone
Reduction of suspended solids

Interception of surface stormwaters by infiltration through dolomite/gravel bed

Underground System Separators
Reduction of oil substances and suspended solids

Jurczak, Zalewski
CITY OF LODZ
Implementation Blue - Green Network Concept LIFE+ EHREK

2010
Mitigation of urban stormwater impact

Green
Grey
Hybrid infrastructure

2014
Reservoir

Toxic algal blooms in reservoir at upper Bzura River catchment

Water quality after implementation hybrid (grey + green) infrastructure in upper Bzura River catchment (July 15, 2014)

M. Zalewski (In press)
EU Program LIFE, Award Ceremony
18 May Brussels 2018

The BEST of the BEST LIFE Projects
Most Recent Developments:
Innovative technologies

BIOKER - Innovative solution for plant growth, microorganisms application and water purification
## The evolution of paradigm in environmental sciences from descriptive to problem solving and demand driven science

### Process-oriented thinking

### Structure-oriented thinking

<table>
<thead>
<tr>
<th>CONSERVATION</th>
<th>RESTORATION</th>
<th>ECOLOGICAL ENGINEERING</th>
<th>ECOHYDROLOGY</th>
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</thead>
<tbody>
<tr>
<td>Goal</td>
<td>Reversing degradation of the structure of ecosystems</td>
<td>'Design of ecosystems for the mutual benefit of humans and nature' (Mitsch 1992)</td>
<td>Regulation of water-biota interplay for the enhancement of ecosystem potential and its harmonisation with society needs</td>
</tr>
<tr>
<td>Unit</td>
<td>Ecosystem(patch)</td>
<td>Ecosystems</td>
<td>Catchment's hydrological mezocycle</td>
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<tr>
<td>Population</td>
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<td>UNESCO MaB Bisphere Reserve</td>
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<tr>
<td>Status</td>
<td>MAINTAINING</td>
<td>ENHANCEMENT</td>
<td>SHAPING</td>
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<td></td>
<td>'status quo'</td>
<td>of secondary succession processes at terrestrial ecosystems or reversing eutrophication in aquatic ecosystems</td>
<td>of the functions of ecosystem</td>
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Białowieża National Park
Recultivated spoil heap of Bełchatów Mine
Constructed ecosystem - Wetland Research Park, Ohio

The concept of EH sustainability threshold

Integration of Ecohydrology and Nature-Based Solutions And Circular Economy, creates fundamentals for low-cost advanced environmental technologies, biotechnologies and systemic solutions

Zalewski 2011
Enhancement of the efficiency and costs reduction by the integration of ecohydrological engineering and biotechnology

Human impact in catchment scale
 expressed as the phosphorus concentration
Integration of the knowledge

Hydrology

Ecology & Evolution

Society & Social Science

Economy

(Zalewski 2013)
Problem solving

**Holistic**

- System solutions – Transdisciplinary science
  - Use of information and knowledge for problem solving – Formulation of principles for action

**Reductionistic**

- Experimental testing - interdisciplinary science
  - Knowledge for understanding patterns and processes,

**Approach**

- Monitoring – sectoral science
  - Information
    - Understanding structure, states and relationships

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**Ecohydrology Education Concept for the desirable and sustainable future**

(Zalewski 2014)
Conclusion

Global security, stability and humanitarian values can be achieved only by implementing evolutionary paradigm where the low cost, low energy, innovations and advanced systemic solutions based on Ecohydrology and Nature Based Solutions are equally important as Circular Economy and Bioeconomy.
Putrajaya - The Global Importance
UNESCO IHP Ecohydrology Demosite
Ecohydrology & Hydrobiology is an international journal that aims to advance ecohydrology as the study of the interplay between ecological and hydrological processes from molecular to river basin scales, and to promote its implementation as an integrative management tool to harmonize societal needs with biosphere potential.

CiteScore trend

CiteScore 2018

1.77 = \frac{\text{Citation Count 2018}}{\text{Documents 2015 - 2017}^*}

Impact Factor 1.59
Thank you