Challenges innovative methods and systemic solutions for reduction of pollutions in river systems and oceans

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Editor in Chief International Journal „ECOHYDROLOGY & HYDROBIOLOGY” Elsevier
How to accelerate SDG and GREEN DEAL

1. Change of PARADIGM

2. Change of MONITORING (to Process oriented)

3. Go for TRANSDYSCIPLINARY SCIENCE AND EDUCATION
Evolution of relations between Man & Environment

Believe in unlimited nature potential

Conquest of nature
Exploitation of nature
Protection of nature
Restoration of ecology

Increasing consciousness of the decline of ecosystem services

Recognition of structure of nature (Linnaeus)
Consciousness of decline of biodiversity

Understanding of ecological succession
Increasing number of evidences of the decline of cultural and aesthetic values of nature

Regulation of ecohydrological processes - Water/Biota interplay, to use ecosystem properties as management tool (NBS), towards enhancement of sustainability Multidimensional Potential WBSR and harmonization with the society's needs CE+LPG.

(Zalewski 2011)
Why World become dry and polluted? Why biodiversity and ecosystem services decline?

1/ **Acceleration of hydrological cycles** by:
   - Catchment homogenization by industrial agriculture and urbanization
   - Catchment fragmentation (urban sprawl, industrialization, and transport)
   - River channalization, aquatic habitats degradation.

2/ **Pollution and Eutrophication** freshwater and costal zones due to:
   A/ point source pollution
   B/ non point source pollution
   C/ degradation of catchments biocomplexity and rivers selfpurification

3/ **Decline of soils fertility and resilience to climate** due to „homogenisation of agricultural landscapes by the industrial agriculture (Zalewski, 2022)
FILTERING FUNCTION OF THE FORESTS IN THE LANDSCAPE:

N-NO$_3^-$ concentration (N) in groundwaters at:

the intensive agriculture area (RED) and at the pine forest (BLUE).

Average = 52.4 mg/l
Cv = 36%

Average = 2.7 mg/l
Cv = 27%

(A. Kędziora)
Acceleration of water outflow from catchment and habitats degradation

UNESCO
Ecohydrology
Danube
Demosite
(Janauer 2010)
Negative feedback between society and environment due to lack of environmental education - Initial stage of the toxic algal bloom generated by the septic tanks at recreational settlement
ETHIOPIA - demography and declining water and soil resources – urgent need for enhancement of sustainability WBSR +CE+ LP

Polish Aid Programme for Ethiopia, on ECOHYDROLOGY for enhancement of water resources and sustainability, by ERCE PAN u/a UNESCOc, financed by MFA of Poland resulted of the establishment African Centre for Ecohydrology u/a UNESCO at Ministry of Water and Energy of Ethiopia

Foto M. Zalewski
Lake Tanganyika, Burundi

UNESCO MaB program (DANIDA)

Decline of fisheries due to siltation of costal zone

Foto M. Zalewski
Ecohydrology - Process-oriented thinking

Modification of water cycle due to

- Deforestation
- Unification of agricultural landscape
- Stream channelization
- Impermeable urbanised space
- Storm water and drainage systems

Catchment’s deforestation in Ethiopia

Climate change Warta River Poland

\[ M = \frac{D \times V \times R}{100} \]

- Atmospheric water vapour deficit [hPa]
- Wind speed [ms\(^{-1}\)]
- Solar radiation balance [Wm\(^{-2}\)]

Drought area (%) in central Poland

Kedziora 2012-2014
RESILIENCE - Effect of ground water level restoration on ecosystem Bioproductivity and Biodiversity (Spain, Donana)

Prof. I. Llamas
„We cannot solve our problems with the same thinking we used when we created them”
• Albert Einstein

November 2000
The importance of innovative ideas and paradigms for development

Lack of new Technologies – slower growth of GDP

Lack of innovative ideas – technologies are not applied on the optimal way

GDP = 50% Ideas + 50% Technologies (Paul Romer; Stanford University)

Without innovative technologies GDP is growing slower, however without innovative ideas there is loss of resources, human capital and degradation of Biosphere.

Acceleration of Sustainable Development Goals of UN has to be based in 50% on IDEAS + 50% on TECHNOLOGIES (Zalewski 2022)
Paradigm change for achievement of Sustainable Development Goals
Sociocentric-Mechanistic to Evolutionary Ecosystemic

SOCIOCENTRIC /MECHANISTIC approach – believe that technology and society will solve all the problems created by Men.

Watson, Kundzewicz, Borrell-Damián 2022, Science of The Total Environment

Te extension of the Sociocentric /Mechanistic by the Evolutionary /Ecosystemic paradigm (Zalewski 2022, in press)
Ecosystems – water „recyclers” - Evaporation from the vegetation and soils from terrestrial ecosystems can be a very important source of precipitation for other areas. Moreover ecosystems are retaining and purifying

Continental precipitation recycling ratio $\rho_c = \rho_{c,l} + \rho_{c,t}$

Source: Van der Ent et al., 2014

Role of ecosystems in stabilization of hydrological cycle will be increasing with climate change
How and Why Transdisciplinary ECOHYDROLOGY is fundamental for development of Nature-Based and Systemic Solutions for Sustainable Water Resources and Environment?
Healthy rivers = Flowing rivers

Flow = defining characteristics of rivers
River Continuum Concept underpins the structural and functional integrity of rivers
Deductive model - abiotic-biotic regulatory continuum (ABRC)

A – abiotic factors
B – biotic factors
E – equilibrium level of A-B

The model defines the main axis which is the hierarchy of drivers determining natural processes. Understanding this hierarchy is fundamental for translating these processes into innovative NBS and systemic solutions.

(Zalewski i Naiman 1985)
Role of biocenosis metabolism in reduction of phosphorus concentrations in winter and summer and low and high flow of river

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<thead>
<tr>
<th>POLROCE: zimowe (XI - IV)</th>
<th>POLROCE: zimowe (XI - IV)</th>
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<td>0.449</td>
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<tr>
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Role of biocenosis metabolism in reduction of phosphorus concentrations in winter and summer and low and high flow of river

(Wagner, Zalewski 2012)

Pilica River, VI 1997

(Wagner, 2001)
River ecosystem metabolism changes along the River Continuum

Fig. 2. The relation between temperature and oxygen content during mid-summer in a twenty-four hour cycle. ○—day; ●—night.

*J. Fish Biol.* (1985) 27 (Supplement A), 59–73
River ecosystem metabolism and physical factors

Dependence of maximum consumption and growth rate on temperature in thermophilic fish *Lepomis gibosus*

**Figure 2.** The energy-expenditure/energy-gain relationship for drift-feeding fish as a function of water velocity (based on Bachman 1982).

The mutual interaction between holistic concepts and reductionist experiments, improving understanding of process complexity across the scales. (Zalewski 2001). This has to be transalated into innovation - NBS, systemic solutions and management towards enhancement of WBSR+CE.
Empirical testing of the deductive ABRC model stimulate discovery of emerging properties of system – „dual regulation”

B –H: Denitrification barrier and phytotechnology for reduction of nutrients fluxes from agricultural land in to freshwater ecosystems

H –B: Complex interactions between hydrological status and the trophic cascade influencing water quality and ecosystem services (WBSR) (hydrological processes → biotic interactions → water quality and ecosystem services; Zalewski et al 1990)

Highly efficient buffer zones: denitrification barrier, geochemical barrier and phytotechnology – EKOROB project (awarded Best of Life+ by the European Commission)

Low water level at spawning season, high biofiltration by Daphnia

High water level and reproduction success of fish reduce Daphnia density and biofiltration

Good water quality

Toxic algal bloom
The integration of understanding ecological and hydrological processes for development of Nature Based Solutions integrated with hydroengineering into Systemic Solutions for catchment.

A. Discovering emergic properties of Ecosystems

ECOLOGY

Mean annual fish biomass (g/100m²)

Calcium concentration (mg/L)

HYDROLOGY

Condensing stage fluxes

Hydrograph

Pollution concentration

Flow (m³/s)

Time (h)

B. Quantifying hydrological patterns (water quality)

D. HYBRID system integration hygroengineering with EH NBS for purification of urban stormwater

E. Ecohydrological Systemic solutions integrating EH NBS with hydroengineering in catchment scale for enhancement of IWRM

C. Sequential Biofiltration System (SBS) with geochemical barrier (enhanced river self-purification proces)

DEVELOPED IN TO HYBRID

Jurczak, Zalewski
Ecohydrology Principles for reversing cumulative impact

Natural Conditions Assessment
- precipitation
- geology

Landuse and ecosystems distribution

Human Impact Assessment
- point-source pollution
- dispersed pollution
QUANTIFICATION OF FLOOD PROCESSES AND SEDIMENTATION IN THE VALLEY

Identification of the flooding areas in the valley

Retention of nutrients and sediments’ load

DTM of the 30 km section of the Pilica River valley

Model of the flooding for the highest water level

1007 ha  560 tons  8 tons  129 tons

Kiedrzyńska E. et al. (in preparation).
Molecular biology for Ecohydrology: methods for early warning and biotechnologies enhancement

**Early warning**
detection of toxigenic (potentially toxic) strain of cyanobacteria

- Mankiewicz-Boczek et al., Environ. Toxicol. 2011, 26, 10-20
- Mankiewicz-Boczek et al., Harmful Algae 2011, 10: 356-365

**Cause-effect analysis**
toxigenic cyanobacteria and physicochemical parameters of water


**New research**

**Analisis of relationship between organisms**
cyanobacteria/bacteria/cyanophages
- detection of cyanophages degrading cyanobacterial cells
- detection of bacteria degrading cyanotoxins

**Ecohydrological biotechnologies - process optimization**
selection and implementation of bacteria in denitrifying barriers to removal of nitrate compounds

... for regulation of processes towards:
1. Reversing degradation;
2. Development of cost efficient measures
3. Enhancing the carrying capacity of ecosystems
Ecohydrology - integration of understanding of hydrological and ecological processes from molecular to catchment scale towards using ecosystem processes as a management tool for enhancement of catchment sustainability potential: WBSRC

- **ENHANCEMENT Sustainability Potential – WBSRC** – it is necessary for mitigation of cumulative effect increasing human impact, to set the multidimensional goal of catchment management: improve 4+5 crucial elements of sustainability – WATER, BIODIVERSITY, ECOSYSTEM SERVICES, RESILIENCE + CULTURE EDUCATION + LAW, POLICY, GOVERNANCE

- **INTEGRATION** of Hydroengineering with Ecohydrological Nature-Based Solutions

- **HARMONIZATION** of society’s needs with enhanced ecosystem potential (WBSR+CE+LPG)

(Zalewski 2022)
Enhancement Biosphere Sustainability Potential WBSR

Ecohydrology and Nature-Based Solutions for enhancement sustainability potential

Reduction emission of pollutants habitats degradation and other risks Circular Economy
First principle: mathematical model of total phosphorus emissions in catchment

Total phosphorus load from the catchment to water bodies in basic scenario

Ecohydrology – use ecological processes as management tool

Highly efficient buffer zones: denitrification barrier, geochemical barrier and phytotechnology – EKOROB project (awarded Best of Life+ by the European Commission)

Izydorczyk et al. 2019
The use of chemically treated organic recycling materials for enhancement of purification freshwater

Katarzyna Dąbrowska a, Bogusław Kowalski a, Wacław Jan a, Agnieszka Rubniewicz b, Sebastian Stolarz b and Mariusz Zalewski b

Institute of Sustainable Technologies National Research Institute, The Textile Technologies Department in Lodz, 6 Hipoteczna, 91-333 Lodz, Poland

European Regional Centre for Ecomycology of the Polish Academy of Science, 31 Ylras, 90-264 Lodz, Poland

Phosphorus supplying the water ecosystem comes mainly from erosion process in agriculture sectors and point sources. The reversing a degradation of freshwaters demands integrating many disciplines of science. The reduction of the phosphorus pollution is being performed by the method of precipitation and sedimentation.

The aim of the study was to build system solution which include filter bed which was made of the suitable prepared phytagenic materials (fibre, flax, hat) derived from different production process and recycling. Filter bed also contains the connected additionally or interchangeably calcium, iron and aluminium compounds that binding the phosphorus.

The apparatus for preparation of natural organic fibrous materials

Results of applying innovative system solution based on mediated fibrous gellan, possibility of very effective purification of water from phosphorus. The highest purification effect was observed for filter bed which contain calcium ions, even to 98%.

The filter beds before and behind outflow fish-breeding pond

The effectiveness of filter beds in purification freshwater

The authors are grateful for financial support given by: H2020 No. 6451004 OPT 2009 GROWTHAT - Development of model geo-fibrous, biodegradable biobased composite for use in wastewater and phosphorus in threatened areas of agricultural landscape.
Prototypa Sedimentation Biofiltration System
Czy konieczne jest betonowanie zbiorników wodnych?

Gazeta Wyborcza
25.02.2020

EH Nature Based solutions vs. „Concrete paradigm” - Paradigm lock

EC Project SWITCH (Blue-Green City Network Concept)

Stary Rynek i Park Staromiejski

Nowe życie ważnych miejsc

Góra saneczowa i nowe fontanny w parku Staromiejskim, a na Starym Rynku restauracje, stragany i granitowa nawierzchnia – to plany magistratu, które obejmuje ogłoszony właśnie przetarg.

Gazeta Wyborcza
25.02.2020
The effect of urban stormwater inflow to the coast (Calpe Beach, Spain)

EH NBS - Sequential Sedimentation-Biofiltration System for urban storm water purification (City of Łódz, Sokołówka River)
Eenhancing the effectiveness of treatment plants by sedimentation-biofiltration system (SBS)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Zone</th>
<th>Monitoring Stations</th>
<th>Regeneration System</th>
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<tbody>
<tr>
<td>I</td>
<td>Limstone zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Coal zone</td>
<td>Blue</td>
<td></td>
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<tr>
<td>III</td>
<td>Sawdust zone</td>
<td>Yellow</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Wetland with macrophytes</td>
<td>Green</td>
<td></td>
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</tbody>
</table>

Mean TP reduction: 26%
Max. TP reduction 76%

Mean TN reduction: 48%
Max. TN reduction 97%

Sequential filtration of pollutants

Biological treatment of pollutants

Outflow from Treatment Plant to the SBS

Outflow of the purified WW to the river

Kiedrzyńska et al. 2017
HYBRID SYSTEM (EH NBS + HYDRO ENG) AND BIOMANIPULATION for ELIMINATION OF TOXIC ALGAL BLOOMS

Toxic algal bloom before EH NBS

LIFE08 ENV/PL/000517
RESTORATION OF RESERVOIRS IN THE
UPPER BZURA CATCHMENT

TSS-165.0 mg/l
TSS-3.4 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

Stormwater from roads, roofs, parking, bicycle/walking pass

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

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

After implementation of EH NBS

Best of the Best LIFE + 2018

Jurczak, Zalewski
Ecohydrological framework for hydroengineering
Reservoir construction for improvement of sustainability potential (WBSRCE) of river valley without degradation of river continuum

Zalewski 2020
Integration of hydroengineering and ecohydrological NBS... 
... for upgrading the navigation potential and improvement of ecological status (WFD) and sustainability potential (WBSR+CE+ LPG)

Zalewski, Jarosiewcz 2020
Methodology of Science

Adaptive transfer of EH NBS solutions in to Ethiopia

*Polish Aid Programe 2014-2019*

Implementation and adaptive management in other catchments (e.g. Ethiopia)

Pure science research on E&H

Holistic models of processes E+H (np. ABRC)

Ecohydrological NBS

SWITCH; EHREK

Testing of EH models in the catchment

Adaptation of urban stormwater system (SWITCH, Zalewski 2012) for improvement of water quality in a small reservoir in Ethiopia (sediments used as fertilizer – circular economy)

(Zalewski 2022)
Ecohydrology for impact reduction and resilience enhancement

1. Enhancement of ecosystem resilience

- Modified by Ecological approach according to WBSRC concept

2. Impact reduction by ecotone buffering zone

Impact (nutrients load)

threshold response of ecosystem to impact

ecosystem response to restoration (Schafer, 1993)

low

high

biodiversity

water quality

ecosystem services

high

low
SUSTAINABILITY - ADVANCED EDUCATION

TRADITIONAL MODEL OF EDUCATION

PROFESSIONAL ACTIVITY

Scope of knowledge acquired through life span

1st phase: GENERAL KNOWLEDGE
2nd phase: SPECIALIZATION

NEW FORM OF INTEGRATIVE EDUCATION NECESSARY FOR SUSTAINABLE DEVELOPMENT

PROFESSIONAL ACTIVITY

Scope of knowledge acquired through life span

1st phase: GENERAL KNOWLEDGE
2nd phase: SPECIALIZATION
3rd phase: INTEGRATIVE SCIENCE, e.g. ECOHYDROLOGY

Specialization
Broad background
Broadening understanding of related fields
Specialization
Broad background

(Zalewski 2014)

LIFE-LONG LEARNING
FIELD OF DIALOG
NO DIALOG
ECOHYDROLOGY - Transdisciplinary Science - translation information and knowledge into WISDOM

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

Experimental testing - interdisciplinary science
KNOWLEDGE
Understanding patterns and processes,

Monitoring – sectoral science
INFORMATION
Understanding structure, states and relationships

Problem identification → Problem solving

(Zalewski 2011)
Vision, Strategy, Social Acceptance:

1 / explanation of fundamentals and general principles

2 / construction of prototype solutions integrated into system solutions
UNESCO IHP Intergovernmental Council, 25 April 2022

We need to re-tool our approaches to water based sciences

RECOMENDATIONS

• Mainstream Governance
• Go Beyond IWRM
• Go Beyond Structures
• GO FOR NATURE BASED SOLUTIONS
• GO DIGITAL
• Re-inforce system thinking from data capturing to dissemination
• Reduce the Gap between science and policy studies, go transdisciplinary – include social and political science components
• Ultimetly SD is based on Culture

From left: Dr Andras Szollosi-Nagi (former Director of Division of Water Science UNESCO); Dr Shamila Nair-Bedouelle (Assistant Director-General for Natural Sciences of UNESCO); Dr Abou Amani (Acting Director of Division of Water Science UNESCO)
Ecohydrology Transdisciplinary Science

Ecohydrology for Systemic Solutions integration of EH NBS with Hydrological Engineering towards enhancement of catchment sustainability potential WBSRC

Ecohydrology for innovative methods (EH NBS) towards reduction of impact and enhancement of ecosystem resilience

(Zalewski 2022)
The Water4All partnership aims to accelerate system transformation in the field of water research, also in the field of innovation distribution and connecting the needs of end users with solution providers.

The initiative proposes a multinational, multi-faceted and cross-sectoral approach that covers political, environmental, economic, technological and social issues in its portfolio of activities.

The long-term goal of the partnership is to ensure water safety and access to water for all.

By 2030, the initiative aims to reduce water scarcity, enhance the protection of water resources and ecosystems, and increase the resilience, mitigation and adaptation of water systems to global change.

**EUROPEAN PARTNERSHIP HORIZON EUROPA**

Chair: **Bjørn Kaare Jensen** – University of Copenhagen

Vice-Chair: **Miguel A. Gilarrantz** - Universidad Autónoma de Madrid

Vice-Chair **Maciej Zalewski** – European Regional Centre for Ecohydrology PAN u/a UNESCO
In a broader context, attaining the SDG implies recognizing the complex relation between humans and the biosphere, and in particular the role of water as a key driver of bio-productivity, biodiversity, and nutrient cycles, all fundamental life supporting processes, thus the urgent need to harmonize the demand with enhanced water resources.

Consequently, the most important challenge for water management is how to increase water resources quantity and quality, and in parallel to increase biodiversity, ecosystem services for society, and resilience to impacts (WBSR). The answer is through a holistic approach which incorporates the innovative nature-based and ecohydrological solutions methods (NBS) and catchment scale systemic solutions, based on understanding the water ecosystems interplay, as both recipients and producers of water, as well as promoting society involvement through culture and education of water and sustainability (CE). Culture is deeply embodied in societal behaviour patterns, defining perception and actions, efficiency and effectiveness.
You can find more information on Ecohydrology at:

ercescolodz.org

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