Ecohydrology for elimination of water threats and to amplify opportunities for sustainable development

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International Conference
Ecohydrological Processes and Sustainable Floodplain Management
Opportunities and Concepts for Water Hazard Mitigation, and Ecological and Socioeconomic Sustainability in the Face of Global Changes

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Content of presentation:

1. Introduction: water, ecosystems and humanity - global perspective
2. Ecohydrology integrative problem solving science: concept and principles
3. Ecohydrology of floodplain: new tool for IWRM
4. Ecohydrology of urban areas for reduction of flood, improvement of human health and quality of life
5. Does large dams if constructed according ecohydrology principles can be friendly for ecosystems and societies?
6. Mathematical modeling of ecohydrological processes for decision support systems
7. Foresight methodology for engineering harmony between water resources, ecosystems and societies toward sustainable future.
Global water resources at the beginning of XXI Century

- Almost 80% of the surface of the Earth modified by Man, so that recent era is called Anthropocene

- Freshwater ecosystems situated in the lowest point of the landscape – exposed to cumulative impact due to various forms of catchment exploitation

- According to Maybeck (2001) rivers are one of the most modified aquatic ecosystems
Strategy of sustainable water resources, ecosystems and societies

Opportunities for sustainable development

Amplification opportunities

Elimination of threats

Degradation of water resources and environment

Development and implementation - ecohydrology for engineering harmony between environment and society

Reduction of flood droughts and pollutants emission by engineering methods
Flood and groundwater level at river valley, key factor for recovery of aquatic and terrestrial biodiversity - Donyana case

November 2000

December 2001

October 2002

November 2003

3 years
Eutrophisation - Monitoring of threats

Application of molecular methods for risk assessment and an early warning system

Blue-green algae blooms due to reservoir eutrophication

Molecular monitoring as an early warning system against toxic blue-green algae blooms

Demaged DNA in human limphocytes

(Zalewski 1999; Mankiewicz et al., 2005)
Vision

Many options exist to conserve or enhance specific ecosystem services in ways that reduce negative trade-offs or that provide positive synergies with other ecosystem services.

*Millenium Ecosystem Assessment*
The major body of the Ecohydrology theory

“DUAL REGULATION”
Regulation of biota
by altering hydrology
and regulation of hydrology
by shaping biota

HYDROLOGY

REGULATION
„use ecosystem processes as management tool”

BIOTA

HARMONIZATION
of ecohydrological measures
with necessary hydrotechnical infrastructure

INTEGRATION
of various regulations acting in a synergistic way to stabilize and improve the quality of water resources

ERCE, Poland
I – FIRST PRINCIPLE

“Quantification of hydrological cycle as a template for biogeochemical cycle in a catchment scale”

Precipitation

Evapo-transpiration

Infiltration

Retention

Total runoff

Subsurface runoff

Surface runoff

Underground runoff

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II – SECOND PRINCIPLE

“Identification of the potential areas for the enhancement of ecosystem carrying capacity”

**Hot spots**

- **RETENTION IN THE CATCHMENT**
  - by enhancement of landscape diversity

- **TRANSFORMATION**
  - into biomass in land water ecotones

- **TRAPPING**
  - in plant biomass (seasonally removed)
  - storage in the unavailable pool in bottom sediments

- **SEDIMENTATION**
  - pondage
  - at the floodplain

- **DENITRIFICATION**
  - in anaerobic conditions of wetlands

- **SELFPURIFICATION**
  - mineralisation of organic matter
  - reduction of spiralling transport rate

- **RECIRCULATION**
  - reduction of resuspension
  - phosphatase – enzymatic release
  - zooplankton excretion

- **HYDROLOGICAL CONTROL**
  - hydrological control of biotic feed back towards water quality improvement in reservoirs

- **BIOFILTRATION**
  - reduction of algae biomass by biota

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III – THIRD PRINCIPLE

“The using of biota to control hydrological processes and vice versa, using hydrology to regulate biota”

Dual regulation

- H REGULATION
- B

- Woodlands
- Buffer stripes (ecotones)
- Land reclamations
- Small ponds
- Small impoundments
- By-pass (fish-ladder)
- Sediment release system
- Constructed wetland
- Bioenergy generation

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Ecohydrology for IWRM

„Dual regulation” as ecological engineering technique

➢ To maintain the ecological flow with flood pulses, which can be done by science, conflict resolution and law enforcement;

➢ Overloading the freshwater ecosystems by nutrients and pollutants. Additionally to reduction of emission from point source pollution and good agricultural practices, the „dual regulation” has to be used for enhancement of resilience of ecosystems against human impact and the conversion of the excess nutrients and pollutants at aquatic ecosystems into non available pool.

➢ To prevent floods and droughts
a) Understanding of the past (e.g. paleohydrology, ecological succession patterns)

Fig. Changes in the rates of precipitation (P), runoff (R), and evaporation (E) along a European - African transect: 18,000 years BP, 9,000 years BP, and at present. $E_{\text{max}} =$ present day potential evaporation (changed from Starkel 1988)
b) Integration of specific knowledge of various disciplines

Optimization of the biological structure of the Pilica River floodplain for the enhancement of self-purification

Velocity (m/s)

Legend:
- Mown meadows
- Caricetum gracilis
- Phragmitetum australis
- Scirpetum silvatici
- Riverine bush with Salix sp.
- Mixed wood

Distribution of water velocities on the floodplain during floods and high discharges

Distribution of wetland vegetation corresponding to the sequence of floodplain inundation

(Magnuszewski et al., 2005; Kiedrzyńska et al., in press)
STUDY AREA

Area I
Experimental Pilica River floodplain

Area II
30 km section of the valley between Przedbórz and Sulejów
Present – macrophytes accumulation 
255 kg P per floodplain

Enhancement of absorbing capacity of the floodplain for phosphorus accumulation

24% of area with willows
332 kg P per floodplain

48% of area with willows
399 kg P per floodplain

Identification of the flooding areas in the valley and retention of nutrients and suspended sediment load

Digital Terrain Model of the Pilica River valley (30 km section between Przedbórz-Sulejów)

<table>
<thead>
<tr>
<th>Models of the flooding for characteristic water level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water (248 cm)</td>
</tr>
<tr>
<td>818,3 ha</td>
</tr>
<tr>
<td>Retention suspended sediment load</td>
</tr>
<tr>
<td>455 tons</td>
</tr>
<tr>
<td>Retention TP</td>
</tr>
<tr>
<td>7 tons</td>
</tr>
<tr>
<td>Retention TN</td>
</tr>
<tr>
<td>105 tons</td>
</tr>
<tr>
<td>The Highest Water (260 cm)</td>
</tr>
<tr>
<td>1006,6 ha</td>
</tr>
<tr>
<td>Retention suspended sediment load</td>
</tr>
<tr>
<td>560 tons</td>
</tr>
<tr>
<td>Retention TP</td>
</tr>
<tr>
<td>8 tons</td>
</tr>
<tr>
<td>Retention TN</td>
</tr>
<tr>
<td>129 tons</td>
</tr>
</tbody>
</table>
System solutions

Improvement of water quality, human health and quality of life

- CO₂ assimilation
- Reduction of fossil sewage reduction
- Fossil fuel use decreases CO₂ emission
- Employment opportunities
- Bioenergy
- Tourism development stimulates economic growth of the region

Sewage treatment plant
- Constructed wetland - willow plantation
- Water quality improvement

(Zalewski, 2000)
THE CITY OF LODZ, POLAND

LODZ - the City of Water

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University of Lodz; European Regional Centre for Ecohydrology u/a UNESCO, Poland
Wydział Gospodarki Komunalnej
Urząd Miasta Łodzi

A = 0,44 ha
c) Considering the society’s priorities vs. ecosystem carrying capacity

Conversion of sludge into bioenergy at willow plantation at buffer zone of sewage treatment plant.

Comparative experiments on different species and varieties of willow:

I: Salix viminalis clones;
II: Tordis (Salix schwerini x S. viminalis) x S. viminalis;
III: Salix viminalis gigantea;
IV: Salix viminalis (clone 192)
The algorithm of the mathematical model for optimisation the sludge use at bioenergy plantation.
Ecohydrological approach for sustainability of Nieszawa dam construction (Vistula River)

- Reduction of blue-green algae blooms in Baltic main tourist zone:
  - 6 mln tourists = 6 bln $

- Elimination of the danger of flood up to 1 bln $

- Use of water for agriculture 0.3 bln $

- Hydro energy (100 mln $ annually) = zero CO₂ emission

- Elevation of ground water level for biodiversity maintenance in the area of hydrological drought
Implementation of ecohydology for harmonisation of new dam reservoir on Vistula river with Water Framework Directive of UE

Permanent bypass channel

Biodiversity refuge

Enhanced sedimentation areas

Bioenergy plantation
Technological Foresight is the system approach for evaluation of new trends on the basis of knowledge and technologies from the point of view economy, quality of life and sustainable development.

Technological Foresight has 3 main goals:

1. **FORECAST OF FUTURE** – enable of undertaking the adaptative attempts, preparation for unpredictable events, reduction of negative consequences of events that can not be changed

2. **MANAGEMENT OF FUTURE** – means the proactive (management of probable crisis) and positive (management by goals)

3. **CREATION OF FUTURE** – means mainly the proactive creation of needed vision of future
Identification of the future scenarios for Łódź region by using „foresight” methodology
Ecohydrology for sustainable water, biodiversity, ecosystem services & preventing of floods and droughts

PROBLEM
Flooding, drought, water quality and sustainability of ecosystem services

VISION
Millennium Development Goals

POLICY
eg. Water Framework Directive

ASSESSMENT
- Ecological status
- Hydrology
- Hydrochemistry
- Biomonitoring
  Considering remote sensing data of catchment and specific of its anthropogenic modifications from the point of view of integrity

ECOHYDROLOGY
Integrative analysis of DYNAMICS OF HYDROLOGICAL AND BIOLOGICAL PROCESSES

Identification of REGULATORY FEEDBACKS between hydrology and biota for potential application in water management

INTEGRATION AND HARMONISATION
all range of regulatory feedbacks (E-H) and hydrotechnical facilities in basin scale for restoration and enhancement of carrying capacity considering socio-economic and climatic scenarios

ADAPTATIVE IMPLEMENTATION
The use of ecosystem properties as an complementary tool to hydrotechnical solutions:
- Consultation with authorities, stakeholders
- Adaptative assessment and management

GOAL
MDG of UN, Good ecological status

(Zalewski 2004)
What Ecohydrology propose in respect to above challenge:

For ECOLOGY:
- enhancement of ecosystem carrying capacity understand as improvement of water quality, biodiversity and ecosystem services

For SOCIETY:
- low-cost high technologies for sustainable water and ecosystems;

For WATER SCIENCE:
- use of ecosystem properties as a management tool;
Implementation

For implementation of new approach and solutions for sustainable floodplain management, three steps, have to be done:

- The decision makers and society environmental consciousness has to be expanded by education—(e.g., ecological engineering, ecohydrology)
- Foresight methodology has to be applied for development of scenarios toward sustainable future
- Legal framework has to be adopted to the recent progress in environmental sciences