МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

Sustainable Development of River Ecosystems in a Vulnerable World Using Optimization of Monitoring Networks and the Entropy-Based Approach to Water Quality Control

- Vitalii Bezsonnyi, Simon Kuznets Kharkiv National University of Economics

1 INTRODUCTION AND MAJOR CHALLENGES

Importance of River Monitoring

- **Global Context:** This research aligns with the UN Sustainable Development Goals (SDGs), specifically:
  - **Goal 6:** Ensure availability and sustainable management of water and sanitation for all.
  - **Goal 12:** Promote sustainable consumption and production patterns.
- **Ukrainian Context:**
  - Rivers in Ukraine face significant anthropogenic impacts.
  - Effective ecological monitoring is crucial to mitigate pollution and manage resources.
- **Main Challenge:**
  - Identify a minimal yet highly informative set of parameters to optimize river monitoring.

2 AIM AND RESEARCH TASKS

Aim of the Study:

- To develop an optimized methodology for river monitoring based on the **Maximum Informativeness with Minimum Redundancy (MIMH)** principle.

Research Tasks:

Identify key parameters for water quality monitoring of three major rivers in Ukraine:

- Southern Bug
- Dniester
- Siverskyi Donets

Apply the MIMH principle to ensure informativeness while minimizing redundancy.

Propose a cost-effective and scalable framework for ecological monitoring.

Methodology Overview

Why Maximum Informativeness with Minimum Redundancy (MIMH)?

- Traditional methods (e.g., PCA, cluster analysis) are subjective and require large datasets.
- MIMH:
  - Maximizes informational content of selected parameters.
  - Reduces data duplication and redundancy.
  - Focuses on efficient monitoring of critical water quality indicators.
- **Equations**:
  Present equations for entropy calculation and redundancy reduction, such as:

$$\textbf{Max}: H(X_{S1}, \dots X_{Sk}) + \sum_{i=1}^{m} T(X_{S1:Sk}; X_{Fi})$$

Key Indicators:

- Chemical: Phosphates, nitrates, sulfates, chlorides.
- Biological: Dissolved oxygen, biochemical oxygen demand (BOD5).

Physical: Suspended solids.

Data Collection and Analysis

Data Sources:

- Monitoring data from three Ukrainian rivers.
- Longitudinal data on water quality parameters, including seasonal and regional variations.

Steps in Analysis:

Use entropy theory to calculate joint information and redundancy among parameters.

Identify key parameters with the highest mutual information.

Optimize parameter selection to achieve balance between informativeness and cost.

Results – Southern Bug River

The mutual information calculations for each parameter relative to the overall state of water quality identified the following parameters as the most informative:

- Phosphates with mutual information of 1.2912;
- Chemical Oxygen Demand (COD) with mutual information of 1.2815;
- Nitrates with mutual information of 1.1903;
- Dissolved Oxygen with mutual information of 1.1834;
- Biochemical Oxygen Demand (BOD_5) with mutual information of 1.1664.

Results – Southern Bug River

	Phosphates	COD	Nitrates	Dissolved Oxygen	BOD_5
Phosphates	1	0,991	0,994	0,965	0,997
COD	0,991	1	0,997	0,969	0,991
Nitrates	0,994	0,997	1	0,968	0,993
Dissolved Oxygen	0,965	0,969	0,968	1	0,964
BOD_5	0,997	0,991	0,993	0,964	1

Results – Southern Bug River

Optimal Parameters:

- **Phosphates**: High informativeness for assessing nutrient pollution.
- **Nitrates**: Critical for identifying agricultural runoff impacts.
- **Dissolved Oxygen (or BOD5)**:
  - Reflects biological activity and organic pollution.
  - Selection depends on specific monitoring objectives.

Key Insight:

- Reduction in redundant parameters enhances monitoring efficiency while maintaining accuracy.

Results – Dniester River

Optimal Parameters:

- **BOD5**: Essential for assessing organic pollution levels.
- **Nitrates**: Indicates hazardous nitrogen levels from agricultural sources.
- **Dissolved Oxygen (or Sulfates):**
  - Supports assessment of biological activity and chemical pollution.

Significance:

- This parameter set ensures comprehensive coverage of water quality challenges specific to the Dniester River.

Results – Siverskyi Donets River

Optimal Parameters:

- **Sulfates (or Chlorides):** Reflect chemical pollutants from industrial discharges.
- **BOD5**: Indicates organic pollution levels.
- **Suspended Solids (or Dissolved Oxygen):**
  - Provides insights into sedimentation and biological health.

Key Takeaway:

- The selected parameters balance chemical, biological, and physical indicators for effective monitoring.

Comparative Results for All Rivers

River	Key Parameters	Focus
Southern Bug	Phosphates, Nitrates, Dissolved Oxygen/BOD5	Nutrient pollution and oxygenation
Dniester	BOD5, Nitrates, Dissolved Oxygen/Sulfates	Organic and chemical pollution
Siverskyi Donets	Sulfates, BOD5, Suspended Solids/Dissolved Oxygen	Industrial and sediment impacts

Efficiency Gains:

Up to 30% reduction in redundancy.

Cost-effective allocation of resources.

Practical Applications

Benefits of the MIMH Approach:

Improved Monitoring Systems:

- Higher frequency of observations for selected parameters.
- Better resource allocation for monitoring programs.

Enhanced Decision-Making:

- Supports policymakers with accurate and concise data.
- Provides actionable insights for water resource management.

Scalability:

- Can be applied to other river systems in Ukraine and globally.

CONCLUSIONS

Summary of Contributions:

- MIMH ensures optimal parameter selection for effective river monitoring.
- The approach provides a balance of cost, accuracy, and informativeness.
- Proposed frameworks are tailored to the unique ecological challenges of each river.

Future Directions:

- Integration with digital monitoring technologies.
- Expansion of the methodology to other ecosystems and regions.

CONTACTS

Vitalii Bezsonnyi

av. Nauky 9-a

+38095 78 093078

vitalii.bezsonnyi@hneu.net

https://www.hneu.edu.ua/

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

THANK YOU VERY MUCH FOR YOUR ATTENTION!

МІНІСТЕРСТВО
ОСВІТИ І НАУКИ
УКРАЇНИ