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Retain Water,

Forecasts suggest that the freshwater resources available to our civilization will shrink by 30% in the coming two decades. How can we reverse the degradation of water resources and create a balance between the society's demand for water and the capacity of the hydrosphere?

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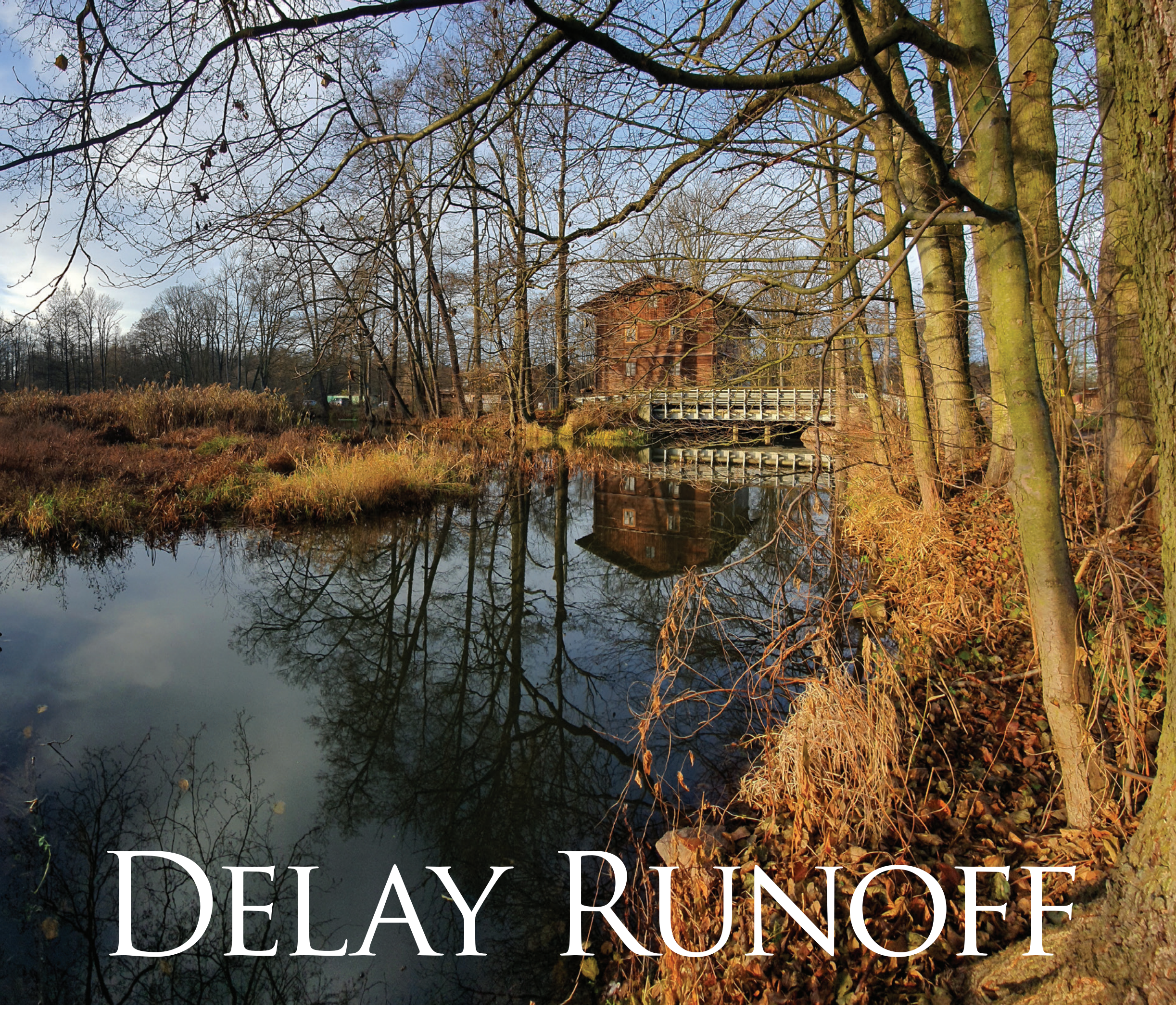
The water deficits recently observed in Poland (corroborated by research) and constantly decreasing river flows have become a pressing problem. They are mainly caused by a lack of snow cover in winter and by extended drought periods. On the Vistula River, the water level measured at the gauging station of Warsaw-Bulwary this spring consistently remained extremely low. For instance, on 28 May 2020 the Vistula in that particular profile reached an unprecedented low level of 64 cm, which corresponds to a water flow of just 280.8 m^3/s – severely less than the average flow (based on information from the Institute of Meteorology and Water Economy). The trend observable over the last decade has been definitely downward; such a situation has led to water deficits, decreased flows and, as a consequence, not only raises concerns about the availability of water supply for the general public, agriculture, industry, water and waste-

DELAY RUNOFF



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Grabia River

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water management, but also has a negative impact on groundwater replenishment. In Poland, approx. 6 to 6.5% of average annual runoff is currently retained in reservoirs, compared to nearly twice as much (over 10%) in the neighboring countries with similar natural conditions. Since terrestrial ecosystems (forests) stabilize 50% of water circulation in Poland, measures have been initiated to improve retention and slow down water discharge to the Baltic Sea.

However, applying advanced technologies and implementing large-scale and cost-intensive hydroengineering projects can only partially decelerate the runoff from the catchment area to the sea. For this reason, it is recommended that nature-based solutions (NBS) should also be pursued, as these measures not only help increase the volume of water resources but above all improve their quality.

Such systemic, ecohydrological solutions are intended to boost the volume of water resources by regulating the interactions between water and biocenoses, on scales ranging from the molecular up to the whole-catchment level.

Integrated knowledge in the field of ecology and hydrology, aligned with classical hydroengineering solutions, may enhance the potential for sustainable development in a given catchment area – this approach, known as the WBSRC strategy, comprises water (W), biodiversity (B), ecosystem services (S), resilience to anthropogenic stress and climate change (R), culture and education (C). Certain ecohydrological measures may be easy to implement, such as planting trees in agricultural fields to decrease the velocity of winds drying out the arable soil and increase organic matter content, thereby improving soil wetness and quality. Tree planting does not involve substantial costs and can be carried out by local farmers. Examples of other measures, more complicated and involving greater human intervention, include wetland and pond restoration, restoration of river and stream valleys or building polders and reservoirs in floodplains, which should store only pure water.

Ecohydrological water retention

To ensure their maximum efficiency, ecohydrological measures need to be tailored to fit the existing hydrological infrastructure. An apt example is the Łask Reservoir project being developed in the basin of the Grabia River in the municipality and town of Łask. The design, authored by the ERCE PAS team, allows the reservoir to be blended with the landscape so as to maximize its multifunctional WBSRC potential. Since the reservoir's major function is recreation, the project aims to minimize the likelihood of toxic blue-green algae blooms and preserve a section of the river with valuable natural assets. The proposed ecohydrological solution maintains the river's natural character while ensuring environmental flow and good water quality in the reservoir by designing a water quality monitoring system. Whenever the

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pollutant concentration increases, the system will automatically shut off the inflow of water to the reservoir.

Ecohydrological measures to mitigate pollution

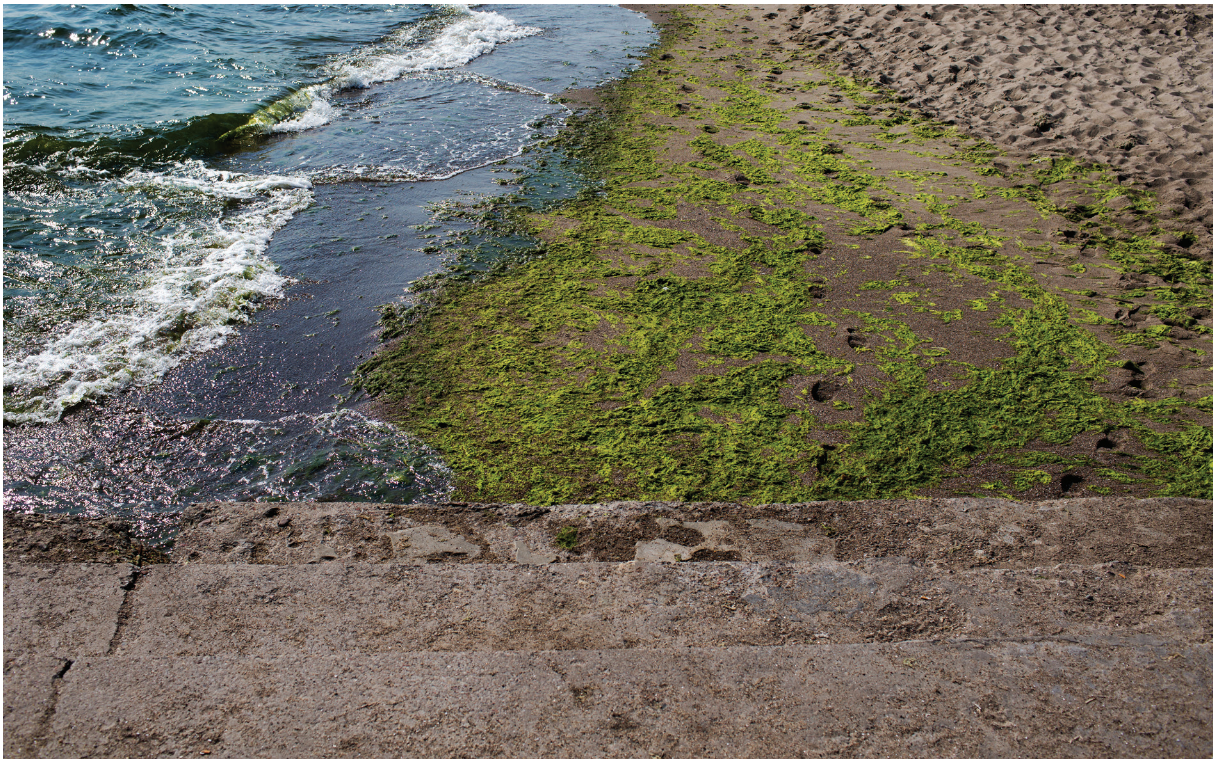
Ecohydrological measures implemented in Poland are aimed at reducing overfertilization, the eutrophication process, and pollution of both inland and Baltic Sea water (among other objectives). The Baltic Sea receives water from a catchment area that is four times larger than the sea's own surface area. In addition, water that flows into the Baltic comes from highly industrialized areas, which makes the sea one of the most polluted marine areas worldwide. For instance, in 2014 the Baltic Sea took in a total of 825,800 tons of total nitrogen and 30,900 tons of total phosphorus, of which 169,900 tons of nitrogen and 12,800 tons of phosphorus originated from Poland (mostly via the Vistula and Oder Rivers), which represented, respectively, 21% and 41% of the total load deposited into the Baltic.

The biogenic loads discharged from the territory of Poland originate mainly from diffuse sources, i.e. agriculture, and point sources such as sewage discharge sites. For nitrogen, point sources account for 31% and agriculture for 45%; conversely, in the case of phosphorus, the share of point sources (42%) is higher than that of agriculture (34%). Long-term analyses of pollution drained into the Baltic from the territory of Poland show that in 2014 the load of total nitrogen and phosphorus decreased, respectively, by 92,200 tons of total nitrogen and 2,100 tons of total phosphorus as compared to 1995 (HELCOM, 2018).

To reduce the volume of diffuse pollutants drained into rivers and in effect into the Baltic Sea, caused by intensive and improper fertilization of the catchment area of the Pilica River and other factors, a pilot solution drawing on natural processes was designed, i.e. highly-effective ecotones. Mathematical modelling of the Pilica River basin was applied to identify the spatial distribution of areas where diffuse pollution originates. To this end, the Soil and Water Assessment Tool (SWAT) model was used to identify such areas, representing some 6.6% of the aggregate river basin. In those areas, it is recommended to build highly effective buffer zones that can serve as examples of nature-based solutions. The removal of biogenic compounds by plant assemblies has been made more efficient thanks to denitrification zones or geochemical barriers. Prototypes of two such highly efficient buffer zones have been built and tested on the coastline of the Sulejów Reservoir as part of the LIFE+ EKOROB project.

Despite considerable outlays on improving water quality and the commissioning of many new wastewater treatment facilities, small wastewater treatment plants (serving populations equivalent to <2000) still make up most of Poland's point-source pollution sources and need to have their treatment efficiency

Blue-green algae on a beach in Gdynia



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enhanced, as they often discharge wastewater loaded with two or even three times more than the permitted norms for phosphorus and nitrogen content, in addition to considerable amounts of dioxins and compounds similar to dioxins, pathogens, drug-resistant bacteria, and antimicrobial resistance genes.

To improve the efficiency of such wastewater treatment plants, a hybrid sequential sedimentation and biofiltration system has been designed. When the phosphorus concentration in shallow groundwater is high, a geochemical barrier needs to be put up. In the first year of its operation, the prototype barrier helped reduce the phosphorus concentration by 58%. Like sequential sedimentation and biofiltration systems, highly efficient buffer zones are very useful in reducing pesticides originating from agriculture. The research currently being conducted at ERCE PAS in collaboration with the Institute of Agriculture in Skierniewice has found that concentrations of the popular herbicide MCPA (2-metyl-4-chlorophenoxiacetic acid) in the tributaries in the lower Pilica River basin exceed 6 µg/l (with the maximum value of the norm in the European countries being 1.6 µg/l), and its presence was confirmed in 65% of the analyzed water samples. The research conducted in 2018–2019 identified a total of 30 various pesticides in four tributaries of the Pilica River. Poland's State Environmental Monitoring, an authority that operates under the Framework Water Directive 2000/60/CE, focuses its efforts on substances which have predominantly been withdrawn from production or use in Europe, and therefore the State of the Environment Reports in EU Member States often will not reflect the actual scale of the impact of xenobiotics in water systems.

Biotechnology in the service of ecohydrology

In every climate zone, the biological productivity of ecosystems, the resultant biodiversity and its benefits for human societies are determined by the accessibility of water. For instance, since it is the hydrological cycle that drives the circulation of carbon, phosphorus, nitrogen and other elements, the hydrological mesocycle in a given river basin or catchment area should be regarded as a system of reference for sustainable water management activities. Such an approach allows hydrological and natural processes to be thoroughly analyzed, understood, and quantified, and in effect for hydroengineering measures that incorporate nature-based hydrological solutions to be put in place.

One important aspect of the development and implementation of ecohydrology in water management is to understand how organisms interact. Research on genes and proteins provides us with knowledge needed to understand the essential processes that affect what organisms do and how they behave, which includes susceptibility to environmental factors and dependence on the environment. A multifaceted approach to this question, encompassing the scales from molecular (individual) to macro (ecosystem), may give us the complete knowledge we need to improve the quality of water and enhance the potential for sustainable development (WBSRC) at the whole-catchment level.

The ability to observe the bacteria accompanying toxic blue-green algae and knowledge of their characteristics is the first step towards designing future biotechnological solutions aimed at regulating the occurrence of cyanobacteria and their toxins in reservoirs and lakes. Such an approach will also facilitate early assessment of the risks posed by toxic blue-green algae blooms occurring due to eutrophication, i.e. the overfertilization of water. Blue-green algae blooms may lead to the production of microcystins (hepatoxins), causing digestive system disorders and increasing the risk of liver cancer in humans. Gathering quantitative data on blue-green algae genes is crucial for better understanding the environmental conditions which can stimulate such blooms, as well as the role and incidence of toxicogenic blue-green algae genes (*mcy* genes) which are responsible for such traits as the production of microcystins.

Research conducted in the Jeziorsko Reservoir has identified certain bacteria, members of the *Sphingosinicella* genus, that are able to degrade microcystins. It is estimated that a strain of JEZ8L bacteria acquired from the environment may be able to reduce the concentration of microcystins by as much as 90% within seven days.

Knowledge of microorganisms responsible for transforming and breaking down nitrogen and phosphorus compounds in surface water and groundwater is essential for designing and optimizing biotechnological solutions to be applied on the catchment-wide scale. Genetic and enzymatic analyses can be used to monitor the incidence and activity of microorganisms in their natural environment; they can also help develop bacteria strains that are most effective in improving the efficiency and environmental responsiveness of denitrification barriers as well as such hybrid, sedimentation and biofiltration systems as the reservoir on the Rosprza River.

In sum, even this short overview of the threats to both the quantity and quality of water in Poland should motivate us to remodel the current paradigm governing the use of the country's water resources. More broadly, by applying technical solutions and ecohydrological measures underpinned by transdisciplinary knowledge, each of us can have a positive effect on the condition of the environment – the sum of such impacts is what will determine our future.

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