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No Frames, No Borders

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Professor Paweł Rowiński, Vice-President of the PAS and a researcher at the PAS Institute of Geophysics, explains why rivers are such a fascinating subject of study and describes the innovative approach being taken to organizing the IAHR Congress in Poland.

What are the expectations towards the IAHR Congress from the perspective of Polish science?

PAWEŁ M. ROWIŃSKI: I believe the upcoming Congress is one of the most important events in Poland's post-war history in terms of the broadly-construed field of water-related research. What is more, no country in Central Europe has ever hosted a general congress held under the auspices of the IAHR. Only thematic meetings have been organized, on a much smaller scale. We are particularly proud, because many would like to organize such a prestigious event, but the IAHR selected the proposal made jointly by the Polish Academy of Sciences, the PAS Institute of Geophysics, and the Warsaw University of Life Sciences.

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is a corresponding member and Vice-President of the Polish Academy of Sciences (PAS). He served as the director of the PAS Institute of Geophysics in 2008–2015. He was a co-founder and first president of the GeoPlanet Center for Earth and Planetary Research, Polish Academy of Sciences. Since 2016, he has served as vice chair of the Europe Division of the International Association for Hydro-Environment Engineering and Research (IAHR). Since 2006, he has been the head of the International School of Hydraulics under the auspices of the IAHR and the PAS Committee on Water Resources Management. He is author or co-author of more than 160 research publications and 19 books or special issues of research journals, a member of the board of the European Federation of Academies of Sciences and Humanities (ALLEA); and the creator and editor-in-chief of the publication series "Geoplanet: Earth and Planetary Sciences." He specializes in environmental hydrodynamics and hydrology, working with mathematical modeling of hydrological processes. He is a passionate educator and popularizer of science and a member of the PAS Science Promotion Council.

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The Congress is a scientific event, so it is expected to showcase current trends in hydro-environment research. We have invited in prominent speakers from the most reputable scientific centers in Europe. Professors Jochen Aberle, Ian Guymer, Thomas Hein, Patrick Meire, and Silke Wieprecht represent the champion's league of European science. They will give lectures on topics at the intersection of many disciplines, because the issues we address are highly interdisciplinary. It would be hard to discuss technological solutions in isolation from environmental factors.

The motto of the sixth Congress is "Hydro-environment research and engineering: No frames, no borders." I'd like to place special emphasis on the main purpose of the Congress, which is to discuss ways not only to study but also to protect water resources, across and above the traditional borderlines between scientific disciplines. Issues related to hydrology and hydraulics straddle across the fields of geophysics, physics, environmental research, civil and environmental engineering, as well as mathematics, chemistry, biology, and computer science. Other "borders" as mentioned in the title of the congress include administrative borders, including between specific states. After all, nature does not recognize any such boundaries.

Unfortunately, the congress coincided with the unexpected crisis caused by the epidemiological threat posed by the spread of SARS-CoV-2. Therefore, it has proved especially difficult to organize the event.

What will make this IAHR Congress distinctive?

The Congress offers Polish research centers and Polish scholars an exceptional chance to establish their presence in the international arena. Although it is hosted by the PAS, the PAS Institute of Geophysics, and the Warsaw University of Life Sciences, we have adopted a format that also allows researchers from other institutions to present their achievements. By acting as the hosts of study visits, Polish universities and institutes have the opportunity to attract the most prominent European scholars. This mechanism is being used by the PAS Institute of Hydroengineering, the Białystok University of Technology, the Kraków University of Technology, the PiS Institute of Nature Conservation, and the European Regional Center for Ecohydrology. All these units have offered foreign guests attractive programs, which I believe promotes the development of this novel tool for pursuing closer international collaboration.

Unlike other congresses, we have also made it possible for scholars from all over the world to propose and organize special sessions. Thanks to this, such sessions will be devoted to issues suggested directly by scientists. This ability to propose topics and thereby to actually help co-organize the conference boosts interest in the event. Consequently, next year's Congress stands a chance of being the biggest European IAHR congress ever.

Your own field of research is environmental hydrodynamics. What are the most important challenges facing researchers in this field?

Environmental hydrodynamics is a relatively new branch of science. It is often referred to as environmental hydraulics, or as environmental fluid mechanics. Whatever name is chosen, this is a discipline that draws upon classical fluid mechanics, continuum physics, and the theory of differential equations to describe phenomena taking place in natural water bodies, i.e. rivers, lakes, and coastal waters. Earth, water, and air make up the environmental continuum that surround living things. These three components of the environment influence one another in a dynamic way. This means that the environment should be seen as an integrated system, and this is precisely how it is treated in environmental hydrodynamics. This discipline is often seen as being limited to studying the processes of mass and heat transfer in the aquatic environment, taking into account the geometric complexity of the object being studied (for example plants). Here, we must use our knowledge about the physics of transport phenomena as well as the nature of chemical and biological transformations. The relevant tools are provided by classical hydrodynamics, typically used to describe technological structures. However, the quintessence of research in environmental hydrodynamics lies in recognizing the vast differences between environmental flows and their engineering counterparts. In technical contexts, it's hard to imagine a man-made object with a structure as complex as a wild river flowing in many channels whose banks are covered by diverse plants and whose geometry changes over time. We try to capture and describe such differences.

Attempts to understand the processes that are taking place for example in rivers and to describe them using the language of mathematics (which is what I mainly do) have a centuries-long history. However, we have never had to study the complexity of such processes in such great detail. Today, we know that rivers are very important ecological corridors characterized by abundant wildlife. We are likewise aware of growing threats caused by the human transformation of river channels. We are moreover facing new conditions caused by population growth and climate change as well as the necessity of managing water resources in keeping with the principles of sustainable development.

A good friend of mine, Prof. Robert Ettema currently of Colorado State University, together with Cornelia Mutel recently published an excellent biography of Hans Albert Einstein, one of Albert Einstein's sons. Not everyone knows that he was an excellent engineer who constructed many classical models of water and sediment movements in rivers. The book describes fascinating correspondence between the father and the son on the processes taking place in rivers. It shows that Albert Einstein himself had difficulty understanding them. Hans Albert also revealed why he did not follow in his father's footsteps – because practically everything in the theory of relativity had already been clarified: "When someone else has picked up all the good shells from a beach, you go to another beach."

So what are the best shells in environmental hydrodynamics?

The main challenge and difficulty facing researchers is the fact that the flow of water in rivers is always turbulent, and turbulence still remains one of the least understood phenomena. Water in rivers is subject to chaotic swirling motions even though the overall bulk of water flows in a specific direction. This is turbulence, which occurs when the velocity of the flow exceeds the value above which the viscous forces in water can no longer attenuate the chaotic motions of water molecules. This value is exceeded in practically all rivers. This phenomenon is extremely complex, as is the geometry of every river, which further complicates the process we describe, for example the transport of pollutants. Turbulence varies randomly over space and time, so it's very hard to capture it in equations and include it in calculations.

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Moreover, we must remember about the uniqueness of the physical processes in rivers. After all, no two rivers are identical. Every river is different in terms of its shape, size, and bottom as well as the extent to which specific areas are covered by vegetation. These different conditions make it harder to make uniform measurements. Water velocity fluctuations measured at specific points determine the turbulence level and then the course of mixing processes, or how a river transports pollutants, sediments, or heat. Describing these phenomena is extremely complicated, even for experts in this field. Especially if we want to describe them in a language understandable to computers.

How do you study the processes taking place in rivers?
My fellow researchers and I perform various kinds of experiments in rivers with very different characteristics. These experiments require sophisticated devices and advanced logistics and allow us to better understand many physical processes taking place in rivers. Such measurements are not limited to taking samples. Unlike in studies investigating the chemical and biological properties of water, where you take samples off to labs, we have to grapple with many problems in difficult conditions out in the field. Based on the data we collect, we create mathematical models that describe the kinds of processes I've already discussed. Interactions between plants in river beds, water flows, and bottom deformations are the center of attention in environmental hydrodynamics. Understanding these phenomena and describing them in a reliable way will help resolve technical problems in the future and better describe the movement of flood waters or river pollutants.

What do studies of river pollution involve?
We can examine pollutants in different contexts. At the PAS Institute of Geophysics, we focus on tracer studies, which involve simulating an accident by releasing a safe dye into a river and observing what happens to this substance, where it gets deposited, and how long it stays in the river. The results teach us how to better respond to actual environmental disasters or terrorist attacks, when toxic substances may get introduced into water. Such studies are performed in different rivers in many countries, which teaches us about the transport of pollutants in different conditions. Based on such experiments, we can build a reliable mathematical model. There are places in the world (for example the Rhine River) where such models are used to predict the consequences of different accidents. If we had had such an operational model for the Vistula River, we would have been able to precisely anticipate the effects of the failure which occurred in Warsaw in late August 2019, of the system discharging sewage to the Czajka wastewater treatment plant. Although we have sufficient knowledge, there are not enough financial resources for the development of such a model for the Vistula River.

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Apart from that incident, are Polish rivers in good condition?
I should start by saying that Poland is a country very poor in water resources. The annual *per capita* amount of water resources is around 1,600 cubic meters, which is nearly three times less than the average in other EU countries. The number of people who have access to a safe water supply and sanitation systems is growing steadily. This results in a certain improvement in the situation, but if I were to sum things up in just a few words, I'd have to say the condition of the surface waters in Poland is not good. The condition of 90% of the country's 2,500 surface water bodies (which are the basic units in water resources management) is less than "good," which means that at least one of its indices, namely water transparency, dissolved oxygen content, the content of nitrogen, phosphorous chlorides and so on, exceeds permitted standards.

It's also worth mentioning a completely new threat posed by pharmaceuticals. They are designed to be effective in low concentrations in order to avoid having to introduce foreign substances in high doses into our bodies. That makes them particularly dangerous to people as well as flora and fauna. In Poland, the content of pharmaceuticals in water is tested sporadically, but recently all the hormones and antibiotics being tested for were found in concentrations above the limits of detection, which is very alarming. The question is: how do these substances get into rivers? The wastewater treatment methods currently in use are insufficient, and pharmaceuticals enter the environment supply together with wastewater from sewage treatment plants. This is why the proper disposal of medicines past their expiration dates is so important. Pharmaceuticals also reach waters together with animal manure, because they are added to fodder.

Is there a link between the quality of water in rivers and climate change?
The condition of water in Poland's rivers depends on many factors, including climate change. In this year's UNESCO report *Water and Climate Change*, the degradation of ecosystems and water quality is listed among the most important consequences of climate change. Above all, higher temperatures are lowering the dissolved oxygen content in water, which inhibits the self-purifying capacity of water bodies. In addition, the growing frequency of floods and droughts is affecting water quality. Floods result in the faster spread of pollutants, whereas droughts mean higher concentrations of such substances. Climate warming also means increased nutrient enrichment in water bodies, with consequences that can

Preparations for tracer studies in Cheongmi Creek, South Korea, September 2014

be extremely costly. Visible examples of this include cyanobacteria blooms, for instance affecting popular bathing sites, and reduced water transparency. The UNESCO report shows that the losses caused by this amount to over $2 billion a year in the United States alone. Also, I would like to point out to the reverse dependence. Wastewater treatment facilities and processes are responsible for 3–7% of greenhouse gas emissions, so they contribute substantially to global warming. Consequently, we can see that the use of relevant technologies might foster a reduction in these emissions.

What basic functions do rivers fulfill in ecosystems and water resources management in Poland?

This is a topic for a very long academic debate, and I admit that giving a short answer is particularly tough. But let me cite an example. Periodical overflows of water in rivers are of great importance for the functioning of floodplains. Such a large injection of water has strong influence on biotic processes, the development of aquatic organisms, and the transfer of matter between ecosystems. There is a theory in ecology known as the river continuum concept. It describes idealized rivers flowing without human interference from source to mouth, showing the continuity of abiotic factors (water velocity, temperature, bottom structure), which affect the structure of the river benthos – the plants and animals that live on the bottom of the river. If we can talk about an idealized state (without human interference), we should compare it to the role of rivers that have been modified (with channels that have been regulated). A river whose channel has been altered loses the connectivity between the main channel and the floodplain. This has a huge impact on habitats, geomorphological processes, and the distribution of plants in the littoral zone and in the river bed. This example shows clearly how interference in the functioning of a river may upset the whole delicate ecosystem. Although the rivers in Poland have been transformed by people to a substantial degree, it is still a lot less than in Western Europe.

As for water resources management, water infrastructure is developed for the purposes of inland navigation, water and heat energy, water supply, water retention, and flood control. We must also not forget about tourism and recreation. The trick lies in finding a smart combination of these two roles of rivers – in ecosystems and in water management. This is the main challenge for science and for the people responsible for water resource management. We have been talking about the role of rivers in Poland, but what I've said is universal and applies everywhere on Earth. The special challenges particularly facing Poland have their roots in the neglected and poor infrastructure and the still unresolved problems of water quality resulting from insufficient water treatment, insufficient monitoring, the low level of public awareness, and finally the fact that geographically we really do have too many water resources. This is coupled with the losses caused by periodic large-scale floods. We must not forget about climate change, which may cause even greater water stress in many regions in Poland.

Interview by **Dr. Justyna Orłowska**