A Palace Pond in a Beaker

When the use of detergents increased after the Second World War, every year, thousands of tons of phosphates ended up in streams, rivers and lakes. **Hans Jürgen Overbeck**, who later became Director at the **Max Planck Institute for Limnology** in Plön, carried out research in the 1950s on how bacteria and algae reacted to this. A pond in Sanssouci Palace Park in Potsdam provided him with some crucial insights.

TEXT **ELKE MAIER**

The artificial pond on the garden side of Orangery Palace was a constant thorn in the side of the park management of Sanssouci: The pond, which forms part of the terrace complex, contained a thick green algal soup and exuded an odor that was not quite in keeping with the royal setting. And yet the water in the 1,000-square-meter and approximately 70-centimeter-deep pond was changed regularly. A fountain fed it with water drawn directly from the Havel River once a week. However, this failed to bring about any improvement – on the contrary.

Like many inland waters, the Havel had been oversaturated with nutrients, and above all phosphorus, since the 1950s. This was caused by the rapid increase in the use of detergents after the War. The phosphates, which acted as softeners, entered rivers and lakes directly with the wastewater. Another contributory factor was artificial phosphorus-based fertilizer, which was generously spread on fields and meadows and flushed directly from them into rivers and lakes, where it also stimulated the growth of algae. Thus, the unattractive green soup had become a familiar sight in many places.

The over-fertilization of water bodies – referred to scientifically as eutrophication – is far from a mere aesthetic problem: When they die, the masses of algae are decomposed by myriad bacteria. This process consumes oxygen, allowing ammonium ions, methane and, soon after, toxic substances like hydrogen sulfide and ammonia to accumulate in the deep, oxygen-free waters. In short: the river or lake "collapses." The process also reinforces itself as, due to the oxygen deficiency, the insoluble phosphate, which is bound with iron in the sediment of the water bodies, is dissolved again and causes renewed algal growth. Although the detergent industry denied the link, it was already obvious at the time that eutrophication was directly related to phosphate inputs. What was unclear was the precise biological and chemical processes at work here. The pond in the Sanssouci Palace gardens therefore provided a very promising research area for an ambitious young scientist like Hans Jürgen Overbeck.

Overbeck was born in 1923 in Schwerin, also renowned as the "city of seven lakes." As a young boy, he was fascinated by the unspoiled nature of Mecklenburg's lake-studded landscape and its Baltic coast. In 1940, he embarked on his studies of biology and chemistry in Rostock. He first encountered the topic of phosphates during his work at the Hiddensee Biological Research Institute: a project on "sea fertilization" carried out there aimed to establish whether it would be possible to increase fish production in the Rügen lagoon through phosphorus fertilization.

It was hoped that it would be possible to accelerate the growth of algae through the addition of phosphate, and in this way to create a nutrient basis for the zooplankton – small, crab-like organisms that drift in oceans and seas and provide food for the fish. "More phytoplankton = more zooplankton = more fish" was the self-evident conclusion to be tested.

From the lake to the laboratory: One of Overbeck's colleagues takes a sample of water that will then be analyzed at the institute.

However, Overbeck and his fellow scientists were quickly forced to acknowledge that the calculation wasn't quite so simple: "We were surprised to discover that the question regarding phosphorus and the nutrient chain was far more complicated than we expected," writes Overbeck in his autobiographical novel *Insel der Kraniche* (Island of the Cranes).

On the one hand, the researchers had overlooked the smallest cells that formed the first link in the chain. On the other hand, like oxygen, hydrogen sulfide, the temperature and the salt content, iron and manganese compounds dissolved in the seawater also affected the availability of the phosphorus. "Big surprises emerged in the early days of the testing. What we were dealing with was a vast, complex ecosystem," concluded Overbeck.

When the young scientist accepted a position at the Botanical Institute of the University of Potsdam upon completing his doctorate, the pond in the Sanssouci Palace gardens provided him with an excellent opportunity to revisit the "phosphorus problem" – this time using a more contained research object – with the aim of answering some fundamental questions.

It was, for example, a mystery why the algae in the pond proliferated so luxuriously, despite the fact that it was almost impossible to detect any dissolved phosphate in the water – free phosphate being the only form in which the algae can absorb phosphorus. Over-

Photo: MPG/Peter Blachian

Rowing for science: Hans Jürgen Overbeck was often out and about on Lake Plußsee for his research.

beck discovered that 90 percent of the phosphorus was stored in biomass and dead organic matter and bound in complex chemical compounds. But how were the algae able to absorb it and use it?

To answer this question, Hans Jürgen Overbeck and his colleagues started to breed the algae from Orangery pond in the laboratory. As was easily identified from their characteristic cell shape, the organisms in question were mainly green algae of the species *Scenedesmus quadricauda*; moreover, large volumes of bacteria were also present in the pond.

To eliminate the bacteria, the researchers filtered their samples and established a pure *Scenedesmus* culture in a nutrient solution. To their astonishment, this did not agree with the algae whatsoever: they wasted away and stopped reproducing in the bacteria-free water. Yet when the scientists added bacteria again, they started to grow robustly. The bacteria were clearly important for the algae's nutrient supply.

But what was their precise role in this process? Further tests provided the answer. They showed that the bacteria excrete special enzymes known as phosphatases. These dissolve the phosphate from the organic compounds so that the algae can absorb the phosphorus. Having isolated the phosphatases in a pure form, the researchers put their discovery to the test. They added the enzymes to a bacteria-free algal solution: the algae thrived – even when the phosphorus was available only in compounds.

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»Lake Plußsee acts as a field laboratory for the inland waters researchers, and is the pet project of the head of the institute […] Out there in the forest, he [Overbeck] aims to put the credo on which his nature studies are based into action: "An ecosystem is a network, and it takes a network of scientists to research it."«

Hans Jürgen Overbeck succeeded in demonstrating that algal growth was not dependent on the currently quantifiable concentration of phosphorus in the water. What is far more important is the rapid transformation of the bound phosphorus. Even a body of water the size of Orangery pond is a highly dynamic system that is subject to a very rapid cycle. Overbeck and his colleague Hans-Dieter Babenzien later also proved that other enzymes – amylases and saccharases – control the decomposition of carbohydrates.

"It later emerged that this principle of the linking of the metabolisms of different organisms in ecosystems through free enzymes is a universal phenomenon that applies not only to aquatic ecosystems, but also to terrestrial ones," writes Overbeck in his novel. The studies on the grounds of Sanssouci Palace not only contributed to the explanation of the phosphorus cycle, but also brought a fundamental ecological principle to light.

After the success of his work on Orangery pond, Overbeck soon turned his attention again to a "real" body of water: Lake Plußsee near Plön, in the hilly area known as the Holstein Switzerland. At the time, he was troubled not only by the travel restrictions and lack of technical resources available to him in the GDR, but also by the lack of intellectual freedom there. Thus, he and his family moved to the West in 1961 – shortly before the construction of the Berlin Wall.

His new place of work was the Hydrobiological Institute of the Max Planck Society in Plön. He quickly made a name for himself internationally with his comprehensive studies on Lake Plußsee. In 1966 – the Hydrobiological Institute had since become the Max Planck Institute for Limnology – he became Director of a new department called the Department of General Limnology.

The aim of the Plußsee project was not only to explain the complicated metabolic cycles in the lake, but also to measure the plant, bacterial and animal production, study the population dynamics of the plankton, and clarify various climate effects. Scientists from very different disciplines were involved in the study. They came from fields as wide-ranging as hydrophysics, chemistry, biochemistry, microbiology, planktology, zoology, paleontology and mathematical modeling. Today, this small lake in its idyllic forest setting is one of the most studied lakes in the world.

Throughout his life, Overbeck's passion remained the bacteria found in bodies of water and the biochemical processes they control. For this reason, the scientist, who died in March 2013, shortly before his 90th birthday, is feted as the pioneer of "aquatic microbial ecology." The fact that he never neglected the environmental perspective was typical of his approach. For example, he and his colleagues investigated the microbiological processes behind the production and use of methane in water bodies. Their research provided an important basis for our understanding of the role of methane in climate change.

Overbeck's insights into the phosphorus cycle were used when solutions were being sought for overcoming the eutrophication of waters. In the 1970s, the Max Planck Institute built one of the first German pilot sites for a so-called third or chemical stage in water treatment in Lütjenburg, near Plön. It was so successful in eliminating the phosphate content of the water using iron salts, and functioned so well, that 90 percent of the phosphate was removed from the water from the outset. The process prevailed: today, a mechanical, biological and chemical treatment stage is standard at water treatment plants in Germany.