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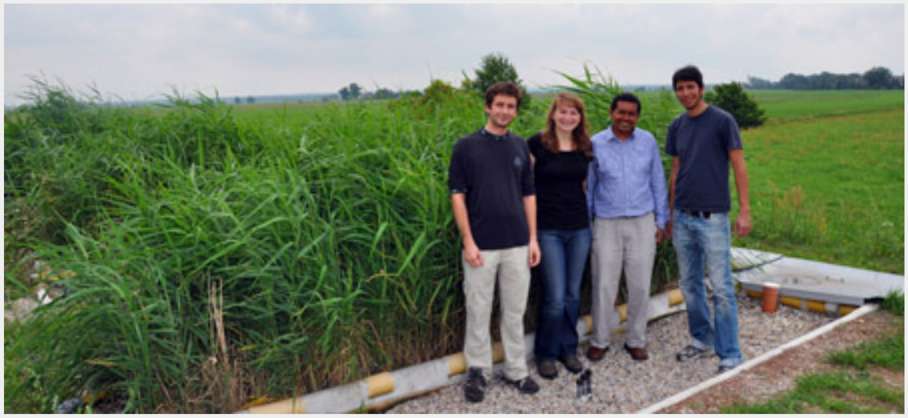
Designing treatment wetlands for the 21st century

GERMAN RESEARCH CENTER EVALUATES DIVERSE TECHNOLOGIES FOR DIFFERENT APPLICATIONS.

By Scott Wallace, P.E., Jaime Nivala, E.I.T.

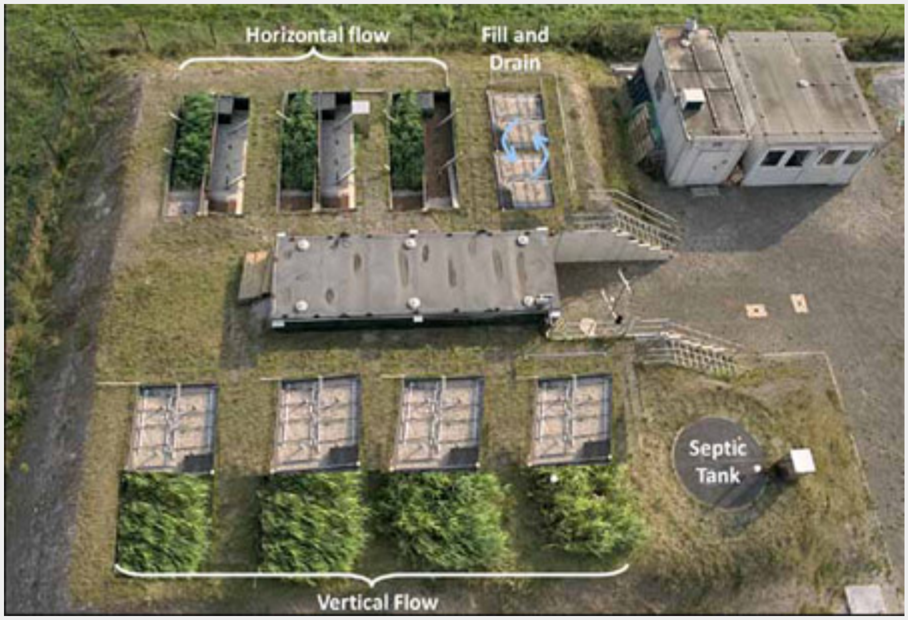


One of the research teams at the Langenreichenbach treatment wetland research facility includes (from left) Thomas Aubron, Jaime Nivala, Kinfe Kassa, and Otoniel Carranza Diaz.

"Wetland technology has a great potential, because it is so versatile"
–Roland Müller, Ph.D., director of UFZ's Environmental and Biotechnology Center.

The Langenreichenbach treatment wetland research facility at the Helmholtz Center for Environmental Research in Langenreichenbach, Germany, is inventing a new generation of treatment wetlands for the 21st century. Combining the best of the old (passive wetland technologies traditionally favored in Europe) and the new (intensified wetland technologies developed in North America), researchers now have the ability to evaluate different types of treatment wetlands under controlled conditions.

The Helmholtz Association contributes to solving major environmental challenges facing society, science, and the economy with top scientific achievements in six research areas: Energy, Earth and Environment, Health, Key Technologies, Structure of Matter, Transport, and Space. With 28,000 employees in 16 research centers and an annual budget of approximately 2.8 billion euros, the Helmholtz Association is Germany's largest scientific organization. The Helmholtz Center for Environmental Research (Helmholtz-Zentrum für Umweltforschung – UFZ) was established in 1991 and today has approximately 900 employees. More than two-thirds of its scientific staff is located at its research campus in Leipzig, Germany.



The Langenreichenbach research facility contains 15 standalone treatment wetlands of seven different designs.

Old perspectives and new potentials

Still considered innovative by many engineers, the origins of constructed wetlands stretch back almost 50 years, when the technology was invented in Germany. Since then, manmade treatment wetlands have spread worldwide in different forms, including surface flow wetlands (similar to natural marshes) and subsurface flow wetlands (gravel-based systems where the water is not exposed during the treatment process).

While the original application for constructed wetlands was for treating domestic wastewater, treatment wetlands today are being tailor-engineered for many special applications, including animal wastes, food processing wastewaters, landfill leachate, and contaminated groundwater. Moreover, treatment wetland technology is now considered a "go-to" technology for the oil and gas industry, and is also a widely accepted treatment solution for airports dealing with deicing fluid runoff.

"Wetland technology has a great potential, because it is so versatile," said Roland Müller, Ph.D., director of UFZ's Environmental and Biotechnology Center. "The technology can be optimized for extremely specific applications. In addition to our wetland research facility at Langenerichenbach, we have a pilot facility in Jordan that compares treatment wetlands against the latest onsite wastewater treatment technologies. In addition to these facilities, we have pilot- and full-scale treatment wetlands for hydrocarbon-contaminated groundwater remediation here in Germany, as well as decentralized wastewater projects in developing regions such as Mongolia."

The Langenreichenbach treatment wetland research facility is actually a "reboot" of an existing site constructed in 1999. Redeveloping the site included complete reconstruction of the existing wetland cells to reflect the diversification of wetland technology that has occurred during the last decade. The resulting design and construction effort was an international collaboration, involving engineers from Germany, the United States, and Australia.

The Langenreichenbach facility has been up and running for longer than a year now, resulting in groundbreaking insight into the comparative benefits of different wetland configurations for different applications. For example, a wetland treatment system in central Europe will function very differently than a system in North Africa. The current research team reflects this, drawing from talent in Germany, the United States, Australia, Brazil, Ethiopia, France, Mexico, Spain, Sweden, and Sudan. The independent, third-party data being developed by UFZ interests and benefits the international design community because it allows side-by-side comparison of intensified and passive wetland systems.

Wetland technologies

One of the unique aspects of the Langenreichenbach research program is the ability to compare wetland technologies in a side-by-side, controlled environment (see Table 1). The research facility contains 15 standalone treatment wetlands of seven different designs. Traditional designs were included at the site in order to determine "baseline" treatment performance. The rest of the designs incorporate improvements and innovations to overcome the limitation of the traditional designs: subsurface oxygen availability. The availability of subsurface oxygen has a direct impact on a wetland system's ability to degrade ammonia, nitrogen, and organic matter.

System Type	Saturation Status	Depth of Main Media	Size of Main Media	Area (m^2)	Hydraulic Loading Rate (L/m^2-d)
HF (25 cm depth)	Saturated	25 cm	8 – 16 mm gravel	5.6	17
HF (50 cm depth)	Saturated	50 cm	8 – 16 mm gravel	5.6	34
VF Sand (bi-hourly dosing)	Unsaturated	85 cm	1 – 3 mm sand	6.2	97
VF Sand (hourly dosing)	Unsaturated	85 cm	1 – 3 mm sand	6.2	97
VF Gravel (hourly dosing)	Unsaturated	85 cm	4 – 8 mm gravel	6.2	97
VF with Forced Bed Aeration™	Saturated	85 cm	8 – 16 mm gravel	6.2	97
HF with Forced Bed Aeration™	Saturated	100 cm	8 – 16 mm gravel	5.6	128
Fill-and-Drain (FAD)	Alternating	85 cm	8 – 16 mm gravel	12.4	172

Table 1: Comparison of technologies at the Langenreichenbach treatment wetland research facility

To address the often-asked engineering question, "What role do plants play in wetland treatment processes?" all treatment options (except the fill-and-drain, or reciprocating, design) are replicated with planted (Phragmites australis) and unplanted controls. Furthermore, each wetland has been constructed with the capability to sample water as it is passing through the system, which allows researchers at UFZ to break into what has been commonly known to date as a "black box" technology.

Other research topics at the facility include nutrient cycling, hydraulic efficiency, evapotransiration, and energy consumption (per amount of pollutant degraded). Scientists and engineers working at Langenreichenbach also hope to develop further the latest design methodologies presented in "Treatment Wetlands, Second Edition," authored by Robert Kadlec and Scott Wallace in 2009.

"We can see there is a definite correlation between the degree of treatment and the level of intensification through mechanical aeration or fill-and-drain pumping", said Tom Headley, one of the engineers responsible for redevelopment of the Langenreichenbach facility. "This is especially of interest in a space-limited situation or where water loss due to evapotranspiration is an issue, because an intensified wetland will be much smaller (but dependent on external energy inputs), compared to a passive wetland alternative (Figure 1). With our work in Mongolia and Jordan, we are trying to optimize the U.S. technology to match the land area versus energy input (Figure 2) to meet the demands of decentralized wastewater treatment in these very diverse climates."

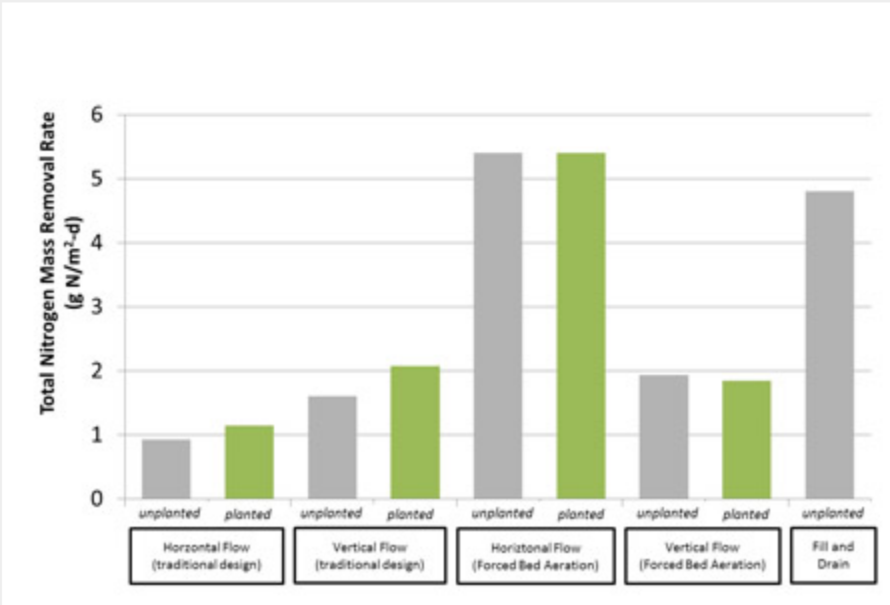


Figure 1: Total Nitrogen mass removal rates for five treatment wetland designs at Langenreichenbach

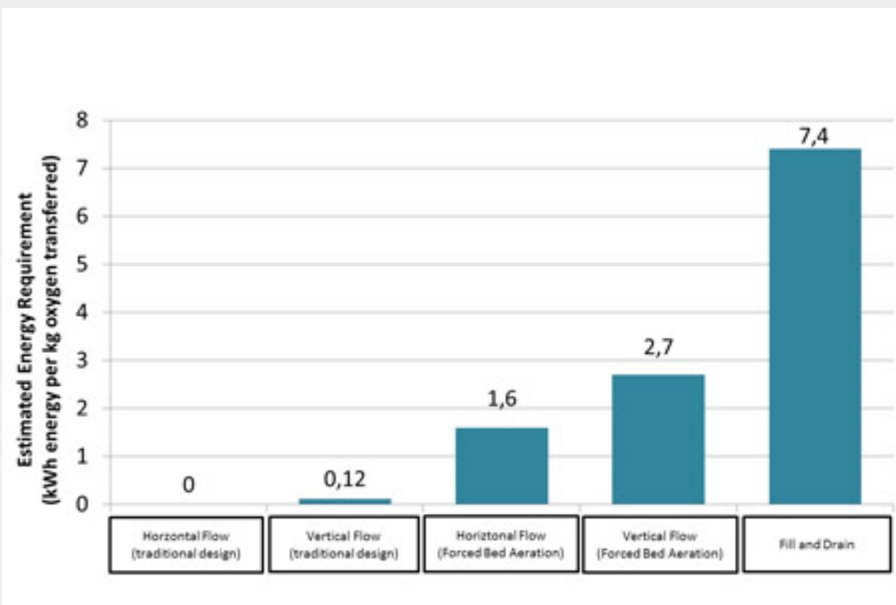


Figure 2: Estimated energy requirement for various treatment wetland designs

Conclusions

Although the research is based in Germany, the results have global implications. The research facility at Langenreichenbach allows international wetland designers and engineers to intelligently map out the solution space between passive wetlands (at one end of the land-requirement spectrum), intensified wetlands (an intermediate solution), and mechanical treatment alternatives (the most energy and operations-intensive solution).

Planted and unplanted vertical flow wetlands at Langenreichenbach

Scott Wallace P.E., *is president, Naturally Wallace Consulting LLC, Stillwater, Minn. Wallace and his team were awarded the 2009 Diamond Award for Engineering Excellence in Water Resources from the American Council of Engineering Companies (ACEC) for design of a natural treatment system to treat spent deicing fluid at Buffalo International Airport in Buffalo, N.Y., and the 2005 Grand Award for Engineering Excellence from ACEC for design of a hydrocarbon remediation wetland for British Petroleum in Casper, Wyo. He can be contacted at* scott.wallace@naturallywallace.com. ***Jaime Nivala, E.I.T.,*** *is a PhD student at the Helmholtz Center for Environmental Research in Leipzig, Germany. She can be contacted at* jaime.nivala@ufz.de.