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De-Risking Chemical Contamination In Non-Potable Reuse Water Applications

Source: Xylem Drinking Water Solutions

By Uwe Hübner, Achim Ried, and Andrew Dugan

As you walk through a grocery store's produce aisle, you're witnessing the fruits (and vegetables) of labor by farmers, their fields, and mother nature. We depend on these three to feed our world. But as prolonged drought conditions and changing weather patterns disrupt agricultural production, our produce shelves stand to be impacted.

So far in 2025, Germany has experienced its driest year in a century. The drought has put officials in the difficult position of deciding how to keep rivers flowing, irrigate crop fields, and quench cities' thirst. Looking ahead, European farmers are considering alternative water sources for their crops in anticipation of future dry spells and dwindling groundwater reserves.

Non-potable water reclamation offers a renewable, drought-proof water supply that holds tremendous potential for irrigating Europe's farmlands. More than forty billion cubic meters of wastewater are treated in the EU (European Union) every year, but only 2.4% is reused, around 1.1 billion cubic meters.

However, wastewater is contaminated by what we put down the drain, which challenges its reuse. Conventional wastewater treatment plants (WWTPs) were historically designed to remove biological hazards to human health, such as nutrients and pathogens (*E. coli*, nematodes). But the pharmaceuticals, industrial chemicals, and shampoos that make their way into our sewer systems are often unaffected by these traditional treatment processes.

In Europe, the adoption of water reuse for irrigation has been slow, as it is often perceived as potentially harmful to human health and the environment. This hesitation persists despite successful implementation and management worldwide that has established a pathway for countries across the continent to implement the practice safely.

Reuse Regulations

The EU established minimum requirements for non-potable water reuse for the first time in 2020, with Regulation (EU) 2020/741 which lists treatment requirements and water quality standards for crop irrigation, and the subsequent 2022/C 298/01 which provides guidance for the required risk management. However, while water quality and treatment requirements regarding microbial contaminants are clearly specified, these documents provide limited guidance on assessing chemical risks. Without specific guidance on how to identify and address the broad spectrum of chemicals in reclaimed water and their potential impact on health and environment, member states are unsure how to comply with the reuse regulations. This guidance gap delays their opportunity to tap into their wastewater as a water source.

In an effort to provide the German government with a chemical management framework for water reuse risk assessments, scientists at the Technical University of Munich (TUM) piloted a water reuse scenario at a water reclamation plant in Lower Franconia, Germany.

The Study

Along the Main River in Bavaria sits the city of Schweinfurt, Germany. The town of 55,000 annually treats 9.6 million cubic meters of residential and industrial wastewater at the Schweinfurt WWTP. The facility operates a conventional activated sludge (CAS) process, discharging to the Main River.

The plant is currently not designed to produce reclaimed water, so a portion of the plant's effluent was diverted to two pilot-scale treatment trains for this demo-scale study. Treatment Train A comprised of tertiary cartridge filters and Xylem's Wedeco brand ultraviolet (UV) irradiation, which represents the minimum treatment processes specified by EU water reuse regulations. Treatment Train B featured ceramic ultrafiltration, Wedeco ozonation, biological activated carbon (BAC) filtration, and Wedeco UV disinfection. Thirdly, tap water acted as the study's control, representing groundwater, which is currently commonly used in Germany for irrigation.

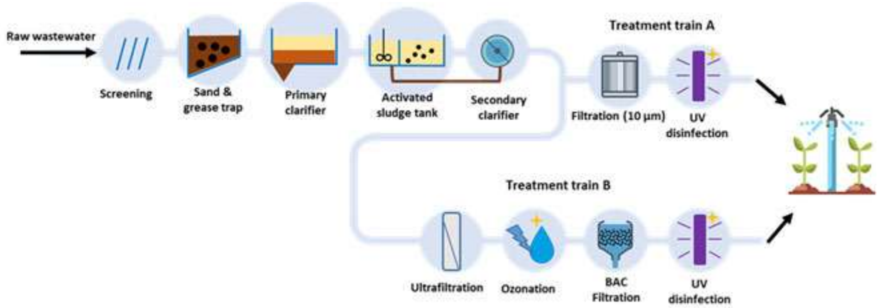


Figure 1. Schematic of the wastewater treatment plant Schweinfurt and the subsequent water reclamation trains A and B. Javad Ahmadi, Uwe Hübner, Benedikt M. Aumeier, Frederik Zumkeller, and Jörg E. Drewes ACS ES&T Water ©2025 5 (7), 3684-3699 DOI: 10.1021/acsestwater.4c01256

The three water sources were applied to crops in a greenhouse as a well as a nearby field to mimic common agricultural practices for edible crops in Germany. Upon identifying the most relevant trace organic chemicals in Schweinfurt's secondary effluent, the study tracked their removal from each treatment train and then irrigated melon, lamb's lettuce, oak leaf lettuce, and tomato in the greenhouse and onion and celery in the demonstration field.

Using a mass balance equation, the fruits and vegetables were analyzed for chemical uptake, and the demonstration field's soil was tested for contamination and groundwater leaching over nineteen months. Based on these results, the associated health risks were calculated using acceptable daily intake values and hazard quotients.

Xylem YSI sensors controlled the pilot systems' oxidation and disinfection processes, monitoring chemical oxygen demand, dissolved organic carbon, total suspended solids, and more.

Findings

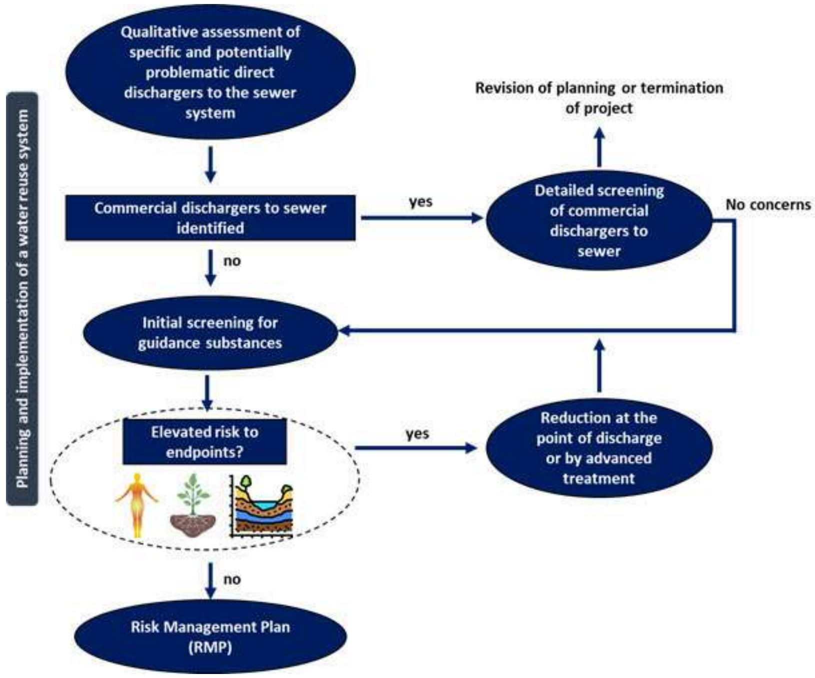
Unsurprisingly, the advanced Treatment Train B removed higher concentrations of the twenty-nine target chemicals than Treatment Train A, achieving over 99% removal of 17 target chemicals. These lower chemical concentrations precipitated lower levels of crop uptake, soil accumulation, and groundwater percolation as a result.

Inversely, Train A exhibited target compound concentrations similar to the secondary effluent from the WWTP, meaning this process couldn't effectively remove them. Edible crops and soil tests irrigated by Train A showed slightly higher levels of these compounds as compared to Train B effluent.

Regardless of which Treatment Train irrigated the crops, none of the six crops contained chemical levels that would indicate harm to human health. Eleven of the 29 substances were not detected in crops whatsoever, due to individual plant uptake capacity, chemical and soil characteristics, and degradability, among other reasons. Tests indicated minimal groundwater contamination risk as well, which is attributed to the soil acting as a barrier.

This study also highlights that every situation is unique. For example, Schweinfurt WWTP receives elevated concentrations of corrosion inhibitors from nearby metal industries that discharge to the public sewer system. While it may not be a common concern for other WWTPs, each site will likely have its own set of dischargers that it will need to manage and communicate with to ensure the quality of its reclaimed water. The study advised, "For those with higher risk due to chemical concentrations, an advanced multibarrier treatment such as tertiary filtration + ozonation + BAC is recommended."

From the study's data, the researchers created a chemical risk assessment framework for non-potable water reuse. The framework defines select chemicals based on plant influent and secondary effluent concentrations and reclaimed water's key endpoints to enable WWTPs interested in irrigating with non-potable reuse water a more accurate assessment of chemical contamination risk caused by crop irrigation. This chemical risk framework helps bridge the EU's non-potable water reuse standards gap.



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Reusing water to irrigate fields could be a critical water resource strategy across Europe as water scarcity threatens food security. The billions of cubic meters of reclaimed water available have the potential to offer relief from the uncertainty caused by irregular weather patterns and drought.

Citing the results and framework from the TUM study funded by the German Federal Ministry of Research, Technology and Space Exploration (BMFTR) and others like it, the German federal government is now considering how to best leverage this water source for agriculture while ensuring the safety of the people it's aimed to help. The German Water Association (DWA) drafted a series of technical guideline documents further specifying requirements for agricultural and urban reuse practices, which adopted the proposed framework for chemical risk assessment. These guideline documents are currently under public consultation. As an EU leader, Germany's roll out of water reuse in irrigation will likely be studied and mirrored by other member states wishing to do the same.

Readers interested in diving deeper into the results of this study and the development of the chemical assessment framework can find the study here as an open access publication.

Author bios

Achim Ried works at Xylem as a Distinguished Engineer in Disinfection and Oxidation. He has held various roles in his thirty years in the Water Industry: Manager R&D, Technical Director, Environmental-Safety-Health and Quality Manager, Manager Pilot Application and Laboratory.

Uwe Hübner is a senior process engineer at Xylem responsible for treatment solutions in Water Reuse & Advanced Oxidation. Uwe holds a master and Ph.D. from the Technical University of Berlin and served as Associate Professor at the Technical University of Munich.

Andrew Dugan runs WaterWrites, a utility-focused copywriting and creative agency. He helps technology companies, engineering firms, and utilities communicate their work.

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