Rethinking water treatment

Professors from the University of Birmingham explore how dormant water fleas – dating back to pre-industrial times – possess greater efficiency in purifying water from chemical contaminants than their modern counterparts.

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According to World Health Organization figures, pollution kills around 12.6 million people a year – nearly one in four or 23% of all deaths. Water pollution is a major contributor to these figures. The utilization of treated wastewater in various sectors introduces harmful chemical pollutants into our water bodies, posing risks to both human health and the environment. These pollutants can accumulate in animal tissue and eventually find their way into our food chain, causing cancer and autoimmune diseases, even when they occur at very low concentrations. With this pressing challenge in mind, how can we revolutionize water treatment to ensure sustainability and human safety?

Daphne Water Solutions (DWS) has pioneered an innovative solution to tackle persistent chemical pollution in surface and wastewater. The DWS team has harnessed the water flea Daphnia, a tiny crustacean the size of a grain of rice, to remove persistent chemicals from wastewater, enabling water reuse. Daphnia are small planktonic crustaceans typically found in freshwater environments, including lakes and ponds. Traditionally recognized as a sentinel species for detecting toxic chemicals in water, Daphnia plays a crucial role in freshwater ecosystems as filter feeders, consuming algae and microbes and being the preferred food for small fish and other invertebrates.

DWS's technology exploits the unique characteristics of Daphnia, including their filtering abilities, long dormancy, and evolutionary resilience, to combat chemical pollution in water. The adoption of DWS technology highlights a significant shift toward more eco-friendly and cost-effective water treatment solutions, harnessing the power of nature to address the critical need for clean water.

Sustainable water treatment solutions are urgently needed to respond to increasing environmental degradation, population growth, and the escalating water crisis. Traditional water treatment methods are often energy-intensive and impactful on the environment, emphasizing the necessity for innovative, sustainable alternatives. The growing demand for reclaimed water and sustainability underly the urgency to develop and adopt technologies like DWS, which offer eco-friendly, efficient, and cost-effective solutions for water decontamination, aligning with global efforts to ensure environmental sustainability and resource reuse.

NATURE AND ENGINEERING'S INGENUITY

The DWS technology has elevated the role of the tiny crustacean Daphnia to new heights, utilizing it as a natural filter of chemical pollutants from wastewater. As they filter the water to feed, they also remove nasty chemical pollutants and other contaminants, effectively cleaning the water. Remarkably, DWS employs Daphnia strains revived from pre-industrial era lake deposits which have proven more effective at removing persistent chemicals than their modern counterparts.

Left: *Microscopic image of zooplankton water flea Daphnia*

Capitalizing on the natural feeding behavior of Daphnia, DWS created an eco-friendly way to reduce harmful substances in wastewater, making the DWS technology a beacon of hope in water treatment. Once revived from lake deposits, Daphnia reproduces clonally, allowing for rapid population growth and self-sustaining populations. This rapid reproduction is vital to their resilience, ensuring a steady population even in changing environmental conditions.

SELF-SUSTAINING DWS

The engineering of the DWS technology involves a primary "live" environment with modular filtration vessels containing live Daphnia for effluent treatment. A backup environment comprising tandem bioreactors ensures a continuous supply of proprietary Daphnia strains, tailored to specific effluents. The live environment allows Daphnia to thrive and filter water, without being released in the environment. The backup system is used to seed the live environment and to replenish the extant population in case of shock events.

The setup is designed for efficiency, with interconnected vessels and a "Daphnia sludge" collection and treatment mechanism. The system's effectiveness is maintained by

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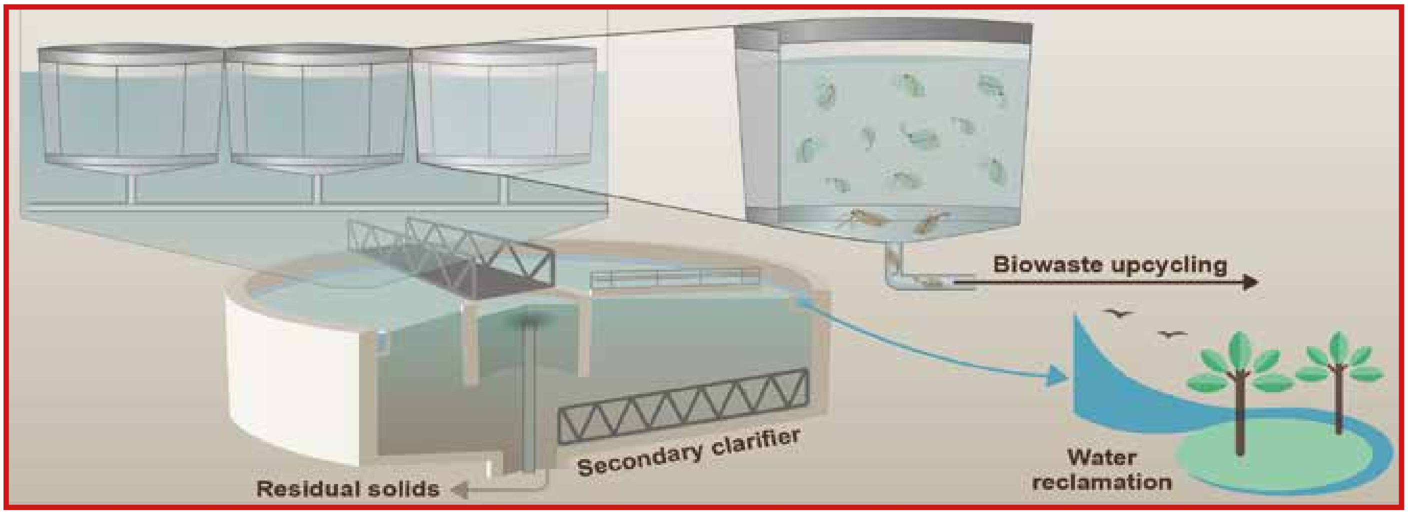

Figure 1: *The modular, interconnected devices are placed into clarifying tanks to sustain the daphnia population and remove chemical pollutants. Daphnia carcasses are removed and reclaimed after further treatment.*

monitoring Daphnia populations and their impact on pollutant removal. The ideal Daphnia population density was defined by mathematical modelling to understand population dynamics under various environmental conditions. Whereas this ideal density is naturally maintained in standard conditions, DWS has also envisioned a top-up system in particularly challenging conditions.

The biological characteristics of Daphnia and the engineering to support them into a wastewater ecosystem are ingenuously harnessed in the DWS technology for efficient pollutant removal, as evidenced by a recent field trial in the UK. The prototype, holding real wastewater equivalent to eight households, has successfully run at Severn Trent's Resource Recovery and Innovation Centre in Spernal for the past 10 months.

Preliminary results confirm laboratory scale findings showing removal of pharmaceuticals, pesticides, and industrial chemicals. A second trial is planned with Umgeni Water Amanzi in Durban, South Africa. This trial is expected to start in summer 2024 in a commercial scale environment serving the city of Durban.

EFFICIENCY AND EFFECTIVENESS

Deployment of the technology in field trial in the UK presents significant findings on pollutant removal rates using the DWS system. Laboratory tests and field trials demonstrate that Daphnia can effectively reduce various pollutants from wastewater, including pharmaceuticals, industrial chemicals (e.g. PFOS and PFAS), pesticides and heavy metals.

DWS's remarkable efficiency in removing a wide range of chemical pollutants far exceeds the capacity of traditional water treatment methods. For example, DWS was notably effective in reducing concentrations of abundant pharmaceutical compounds in wastewater, including painkillers, antibiotics, and antidepressants, as well as pesticides globally used on crops, such as Roundup and Atrazine. These findings underscore the effectiveness of DWS in managing a variety of pollutants, highlighting its potential for broader applications in water treatment and filtration processes.

DWS technology has also shown effectiveness in managing other environmental pollutants in wastewater. These include organic pollutants, such as pathogenic bacteria and algae, and other inorganics, such as phosphorus, which causes the eutrophication of rivers.

By removing chemical pollutants that cause environmental degradation before they enter our rivers, DWS preserves the integrity of water and of biodiversity. Importantly, by preventing chemical pollutants from entering waterways and food resources, DWS contributes to improving environmental health. Furthermore, the low-cost, low-environmental impact and circular nature of the DWS technology provide notable economic advantages, underpinning its sustainability.

ECONOMIC AND ENVIRONMENTAL ADVANTAGES

The DWS technology is characterized by its low operational and maintenance costs. Unlike traditional water treatment methods, which often require significant energy input and expensive infrastructure, DWS operates with minimal energy and infrastructure requirements. Daphnia naturally filter water and reduce the need for costly chemical treatments and complex mechanical processes. This results in a more cost-effective and environmentally sustainable approach to water treatment.

Adopting the DWS technology in water treatment facilities can bring significant long-term economic benefits. Lower operational and maintenance costs and reduced energy requirements mean facilities can operate more efficiently and sustainably. Over time, this could result in substantial cost savings, making water treatment more economically viable.

Furthermore, the potential for less environmental impact aligns with the net-zero goals. Removing so-called "forever chemicals" from wastewater, the DWS technology meets current and upcoming regulatory needs favoring sustainable practices, leading to incentives or reduced compliance costs. In the long run, DWS could redefine the economic landscape of water treatment, making it both financially and environmentally sustainable.

CHALLENGES AND FUTURE DIRECTIONS

While the DWS technology offers numerous benefits, it is currently in the process of industrial scalability. Scaling the system to treat large volumes of wastewater in a real-world environment is an exciting challenge that DWS is facing with the support of the national and international water industry, providing insights and expertise to retrofit the technology within their wastewater treatment process.

Further research and testing are ongoing to optimize DWS for microplastics removal. Future development in DWS involves automated condition monitoring for Daphnia populations and more efficient systems for integrating DWS into existing wastewater treatment settings. DWS's potential broader applications are vast, including its use in industrial and municipal wastewater treatment, as well as bioremediation of natural waters.

A SUSTAINABLE FUTURE

The transformative potential of DWS technology presents a sustainable approach to tackling the global water crisis. Its adaptability to low- and middle-income countries, coupled with its modest infrastructure requirements, aligns with the United Nations' development objectives, solidifying its significance on the world stage.

The DWS technology aligns strongly with sustainable development goals, particularly those related to clean water and sanitation, sustainable cities, and responsible use of natural resources. By providing an eco-friendly, efficient solution for water treatment, DWS contributes to the broader agenda of environmental sustainability and resource conservation. This approach addresses the immediate need for clean water and promotes long-term environmental health, showcasing how innovative technologies can lead to a more sustainable future.

The promising potential of DWS technology in water treatment calls for increased attention from researchers, environmentalists, and industry professionals. Further research is essential to address its scalability and integration into existing systems.

The adoption of DWS represents a step toward achieving sustainable water management, aligning with global environmental goals. Stakeholders in the water treatment industry are encouraged to adopt and invest in the DWS technology, contributing to a future where sustainable water reuse is not just an aspiration but a reality.

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Top: *The DWS prototype, holding real wastewater equivalent to eight households*

Above inset: *Daphnia is a genus of small planktonic crustaceans, typically 0.2–6.0mm in length*

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