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Pilot-scale advanced wastewater treatment for direct potable reuse: achieving safe water for the beverage industry

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Potable reuse can provide a realistic and practical source of drinking water under severe water scarcity, uncertain/unreliable supply or emergency situations and pilot demonstration projects are essential for developing future guidelines and best practices. To demonstrate the safety and feasibility of direct potable reuse (DPR) in the beverage industry, a pilot-scale study was conducted at the Beirolas Water Resource Recovery Facility (WRRF) in Lisbon, Portugal, with tertiary treatment and sand filtration.

The study tested four advanced treatment schemes, comprising different combinations of ultrafiltration (UF), ozonation (O_3), biologically active granular activated carbon (BAC), and reverse osmosis (RO), evaluated in continuous operation (24/7):

1. UF+RO,
2. UF+O_3+RO,
3. UF+O_3+BAC+RO,
4. O_3+BAC+RO.

The containerised automated pilot unit, with photovoltaic energy production, produced water complying with EU and Portuguese drinking water standards. The water quality monitoring included parameters such as total organic carbon (TOC), nutrients, trace compounds (pharmaceuticals, PFAS, disinfection by-products), and pathogen indicators (bacteria, viruses, and protozoa). Regular operational monitoring assessed normalised permeate fluxes, pressures, and permeate quality to compare the performance of the four configurations.

Key results indicated that all treatment schemes achieved water quality suitable for the beverage industry. Contaminants of emerging concern, including PFAS, pharmaceuticals, and disinfection by-products, were consistently below detection limits. PFAS (<2 ng/L), THMs (<2 µg/L), 5 HAAs (<1 µg/L), bromate (<3 ng/L), NDMA (<8 ng/L), and pharmaceuticals (<0.3 µg/L). Pathogen indicators were below quantifiable levels, ensuring microbiological safety.

Operational monitoring results indicated lower normalized net driving pressure, i.e. lower energy demand, for the UF (+ low-dose Cl_2, whenever needed for RO biofouling control) + RO scheme.

Considering the results obtained and since downstream safety barriers are provided by the beverage production steps for controlling pathogens and volatile dissolved chemicals, this scheme proves adequate for this specific application. In cases where additional safety barriers should be accounted for, BAC/O_3 could be considered.

These findings validate the capability of advanced treatment systems to meet stringent potable water standards, ensuring the safety and reliability of DPR for industrial applications. By demonstrating the production of safe, high-quality water in a real-world context,

the study builds trust in water reuse practices and highlights their role in addressing water scarcity challenges while advancing sustainable industrial processes.

Notably, 1,000 litres of craft beer were brewed using the treated water, showcasing its potential for real-world applications.

Keywords: Direct potable reuse; Beverage industry; Reverse osmosis; Contaminants of emerging concern

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