Aquatic Pollutants

Potential of Decentralized Wastewater Treatment for Preventing the Spread of Antibiotic Resistance, Organic Micropollutants, Pathogens and Viruses (PRESAGE)

PRESAGE: Pioneering Decentralized Wastewater Treatment

Innovating Decentralized Wastewater Treatment to Safeguard Health and Environment

We PRESAGE a Snowball Effect

The presence of contaminants of emerging concern (CECs), often xenobiotic (any chemical foreign to an organism), in different wastewaters (WW) is an emerging issue. Reducing these CEC emissions requires new approaches. Hospitals and industrial manufacturing are major contributors, prompting PRESAGE to focus on innovative decentralized wastewater treatment (WWT) using anaerobic and aerobic compact systems (Figure 1).

Can We Separate on Good Terms?

Some WW streams contribute more to the spread of such contaminants. As an example, in separated domestic WW collection systems, grey water (GW), water coming from kitchens and showers, accounts for up to 75% of the total flow but contains a lower concentration of CECs compared to black water (BW), which is water coming from toilets.

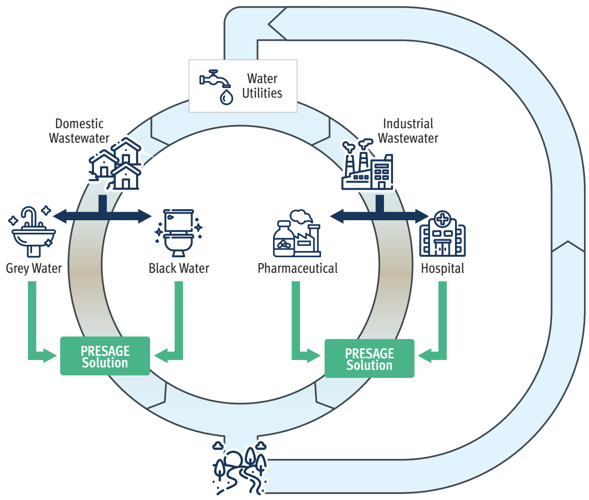

Figure 1. PRESAGE develops decentralized solutions to treat contaminated wastewaters coming from hospitals, industry, and municipalities.

A Burden Shared is Halved

PRESAGE implemented innovative decentralized WWT strategies targeting key CEC sources using advanced secondary treatment and disinfection in compact systems. Detailed data on the fate and removal of selected CECs and pathogens were obtained under various conditions. We focused on examining antimicrobial resistance (AMR) generation and transfer in biological systems, biomass concentration, composition, solids retention time (SRT), and temperature. Comprehensive assessments measured AMR/ARGs (ARGs: antibiotic resistant genes) in effluents and the impact of CECs on AMR/ARGs in sludge. Treated WW effects on aquatic ecosystems were also evaluated through ecotoxicity studies.

Gonna Try with a Little Help from my Friends

We validated our decentralized treatment technologies at pilot scales across four sites. Demo 1: An office building located in Vigo (NW Spain) where BW is treated in a membrane anaerobic reactor, and its effluent is mixed with GW in a hybrid anoxic/aerobic membrane bioreactor (MBR; Fig. 2A/B). Demo 2 and Demo 3: Hospital effluent and fermentation-based antibiotics production WW, respectively, both in Copenhagen, were treated either by an integrated fixed film activated sludge (IFAS)-MBR (Fig. 2C) or MBR followed by a moving bed biofilm reactor (MBBR; Fig. 2D). Demo 4: Anaerobic biofilm reactors for hospital WW from the General Hospital of the Ribeirão Preto School of Medicine (USP). Two lab-scale anaerobic biofilm reactors studied the influence of flow patterns on CEC degradation: plug flow in an anaerobic structured-bed reactor (PF-AnFBR) and completely mixed in a stirred tank anaerobic sequencing batch reactor (STAR) (Fig. 2E/F).

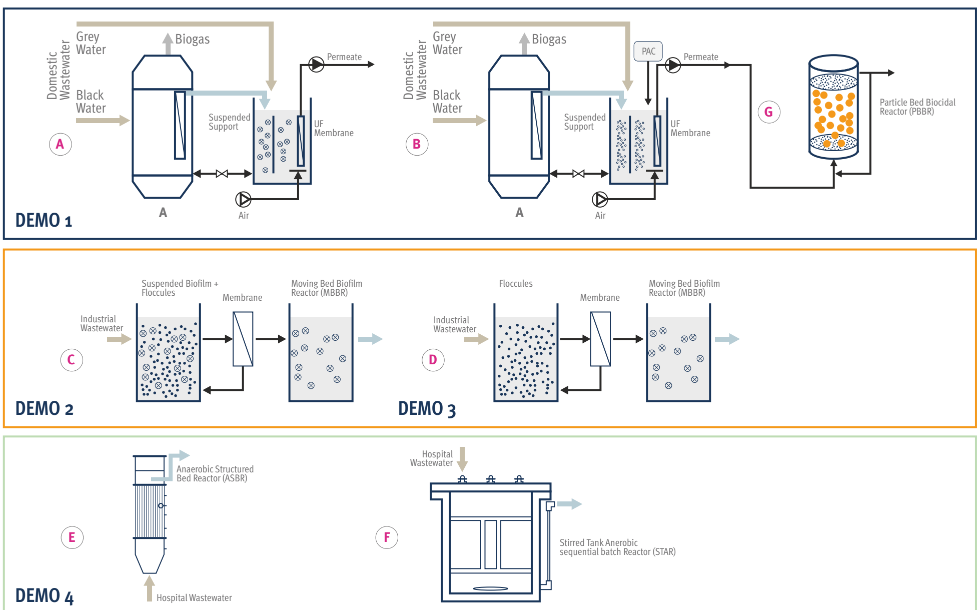

Figure 2: Treatment configurations and methodologies applied in PRESAGE. A) An ultrafiltration membrane was used for retention of biomass. B) Besides mobile plastic support, powdered activated carbon (PAC) was added to promote CEC removal through sorption and enhanced biotransformation. C) IFAS-MBR combines suspended carriers for biofilm development with suspended activated sludge in one single reactor. D) The membrane completely separates the biomasses in each reactor and prevents bacteria contained in the WW from reaching the biofilm in the second tank. E) Lab-scale anaerobic biofilm reactors studied plug-flow in an anaerobic structured-bed reactor (PF-AnFBR) and F) stirred tank anaerobic sequencing batch reactor (STAR). G) The PBBR consist of 3-4 mm particles “functionalized” with an immobilized biocide, used for disinfection, packed together inside a column reactor.

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Wastewater and Separation Anxiety

Compact solutions for biological wastewater treatment have shown to be effective for the removal of CECs. Anaerobic conditions applied in Demos 1 and 4 have led to very high removals of antibiotics (>70%), but also in aerobic reactors used in Demos 2 and 3 a partial removal was achieved. Very high removals of ARGs were observed in all demo plants at the optimum operational and technological conditions. Membrane filtration was especially important for the removal of pathogenic bacteria and reduction of viral load (Figure 3).

In order to produce water suitable for reuse, a further disinfection step is needed. For this purpose, PRESAGE offers a new approach based on immobilizing biocides on small particles contained in a continuous flow bed reactor. Apart from demonstrating a high biocidal activity with no significant biocide release, such wastewater post-treatment further increased the removal of antibiotics and pathogenic bacteria and viruses.

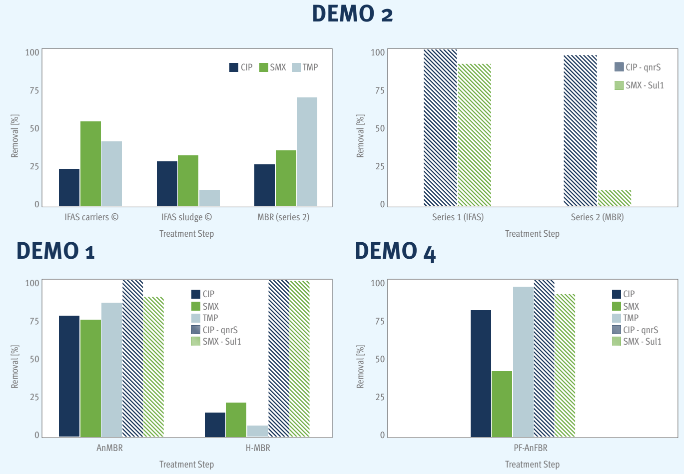


Figure 3: Removal of antibiotics (sulfamethoxazole, SMX; trimethoprim, TMP and ciprofloxacin, CIP) and some of their related ARGs in the demosites.

Pharmaceutical Cocktails, Stir Not Shaken

Organisms were exposed to different concentrations of PRESAGE effluents in short-term periods to test the ecotoxicity of the developed treatments. The *Xenopus laevis* biotest evaluates chronic toxicity by measuring growth inhibition and integrative parameters such as height, weight and morphometric characteristics. No acute toxicity was reported from demo 1 (Figure 4A). In contrast, demo 2 showed acute toxicity in *X. laevis* from the MBR process at high dilutions (Figure 4B). But, on the other hand, *Daphnia magna* acute toxicity was completely removed from inlet WW and no genotoxicity was reported in the treated effluent. In conclusion, PRESAGE processes achieve a significant reduction in terms of ecotoxicity compared to inlet WW.

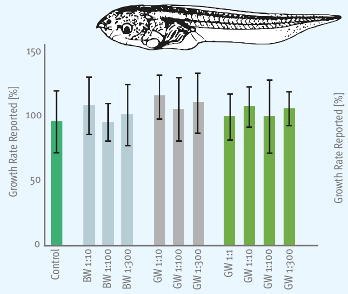


Figure 4A: Growth rate after 12 days of *X. laevis* larvae exposed to Demo 1 AnMBR + HmBR (75% BW, 25% GW) + Powder activated carbon.

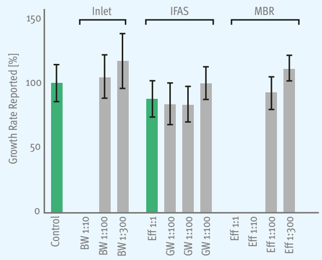


Figure 4B: Growth rate after 12 days of *X. laevis* larvae exposed to Demo 2 IFAS + MBR or MBR effluents

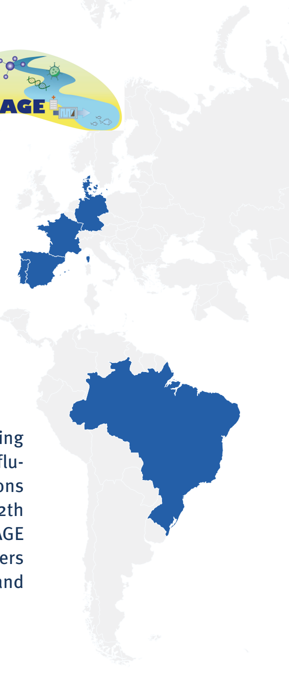
The Proof is IN the Pudding

Ecotoxicity strictly means toxicity to environmental relevant organisms, while the term "bioassay" implies that toxicity or stress caused by a compound has been measured in an environmental matrix pertinent to the habitats where the organism lives in nature.

Sharing is Caring

We offer an original research perspective in which environmental and microbiological know-how are integrated to develop sustainable decentralized treatment processes delivering high quality final effluents, facing important societal, economic and policy challenges. The Water JPI and JPIAMR highlight the importance of understanding the fate of CECs in water bodies of developing consistent environmental monitoring systems for AMR to support the implementation of specific policies. They also identify disinfection is a societal primary need and highlight the European water sector as a potential economic driver.

Figure 5. PRESAGE impacts society and economy, boosting the water industry and protecting the environment from effluent discharges containing CECs. As part of our contributions to science and academia, we organized and hosted the 12th MICROPOL & ECOHAZARD CONFERENCE 2022 and the PRESAGE Training School 2024 for early-stage scientists. Our partners are located in Spain, Portugal, France, Germany, Denmark, and Brazil.



Collaboration

This factsheet was developed by AquaticPollutantsTransNet in collaboration with the PRESAGE project as part of the AquaticPollutants Cross-Cutting Issue #3 on "Mitigation Technologies for CECs and AMR".

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PRESAGE

PRESAGE Partners

1. University of Santiago de Compostela, Spain (coordinator)
2. University of São Paulo – Brazil
3. Technical University of Denmark – Denmark
4. University of Porto – Portugal
5. CNRS/Institut National Polytechnique de Toulouse (INP Toulouse), Ecole Nationale Supérieure Agronomique de Toulouse – France
6. TU Dresden – Germany

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