Performance, Operational Optimization and Technical Evaluation of the HIPPOCRATES Demonstration Unit under Real Operating Conditions

E. Maragkaki[1], F. Galliou[1], A. Papadaki[1], C. Bouki[1], E. Viskadouraki[1], S. Dokianakis[1], M. Dragasaki[1], I. Daliakopoulos[1], G. Markakis[1], N. Katsarakis[1], N. Vidakis[1], T. Manios[1]

[1]Department of Agriculture, Hellenic Mediterranean University, Heraklion, Crete, Greece

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Presenting author email: tmanios@hmu.gr

The HIPPOCRATES demonstration unit was developed within the framework of the LIFE22-ENV-EL-HIPPOCRATES project, aiming to evaluate the treatment efficiency and operational stability of an on-site integrated hospital wastewater treatment system under real operating conditions. The system was specifically designed for the treatment of hospital effluents containing organic pollutants, nutrients, pathogens, pharmaceutical compounds, and contaminants of emerging concern (CECs), prior to their discharge into municipal sewer networks or potential water reuse applications. The optimized treatment train consists of an anoxic Moving Bed Biofilm Reactor (Anox-MBBR), followed by an aerobic Membrane Bioreactor (Aer-MBR) equipped with submerged ultrafiltration membranes. A core component of the HIPPOCRATES treatment scheme is the Advanced Oxidation Process (AOP), based on UV/H_2O_2 technology, which was integrated to maximize the removal of pharmaceutical residues and other micropollutants, thereby enhancing the overall quality and reuse potential of the treated wastewater.

This study presents and evaluates the results obtained during the first complete operational period of the HIPPOCRATES demonstration unit. This initial operational phase was structured into four consecutive operational periods, aiming at system stabilization, process optimization, performance assessment, and long-term validation. Period A comprised the start-up and stabilization phase, during which biological activity, instrumentation reliability, remote monitoring systems, and automation functions were evaluated and calibrated. Period B focused on operational optimization through adjustments to hydraulic retention times, aeration conditions, membrane operation, sludge recirculation, and chemical dosing strategies. Period C involved the implementation of process improvements and technical modifications identified during the optimization stage, with the objective of enhancing overall treatment efficiency and operational stability. Finally, Period D focused on long-term validation and environmental performance assessment under continuous real hospital wastewater loading conditions. The systematic evaluation of these operational periods provided valuable insights into the treatment performance, reliability, and robustness of the HIPPOCRATES system under real-scale operating conditions.

To ensure targeted and effective monitoring of the biological and polishing treatment stages, four critical sampling points were established throughout the treatment process, corresponding to the influent wastewater, mixed liquor within the biological reactors, membrane bioreactor effluent, and final AOP-treated effluent. A comprehensive analytical framework was applied throughout all operational periods, including physicochemical and operational parameters such as pH, EC, COD, BOD_5, TOC, TSS, turbidity, ammonium, nitrate, total nitrogen, phosphorus, dissolved oxygen, and temperature, together with specific microbiological indicators.

Preliminary results from this first operational year confirm that the HIPPOCRATES system operates effectively and reliably under real hospital wastewater conditions. A substantial organic load was developed and biologically treated within the anoxic and aerobic treatment zones, while the membrane bioreactor achieved nearly complete removal of suspended solids and produced a final effluent with high visual clarity and excellent pollutant removal performance. Excellent treatment performance was achieved throughout the monitoring period, with BOD_5

removal exceeding 95% and average COD and TSS reductions reaching 87% and 97%, respectively. Stable nitrification performance and satisfactory nutrient removal were also observed following operational optimization of the biological stages and membrane operation. In addition, the AOP polishing stage further improved final effluent quality and disinfection efficiency, while microbial indicators were almost eliminated at the outlet, highlighting the potential suitability of the treated effluent for water reuse applications.

The obtained results demonstrate that the HIPPOCRATES integrated treatment approach can achieve stable and efficient hospital wastewater treatment under continuous real-life operating conditions. The operational optimization strategy applied during the four operational periods significantly improved system reliability, treatment efficiency, and environmental performance, highlighting the potential applicability of the technology for decentralized hospital wastewater management and water reuse schemes. The demonstration unit is now fully operational and ready for evaluation during the second operational period, focusing on the removal of selected pharmaceutical compounds as well as antibiotic-resistant bacteria (ARB) and antibiotic resistance genes (ARGs).

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