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Make-up water production from laboratory-scale experiments and industrial-scale design

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Growing global energy demand and the water-quality requirements for thermal power plant operations necessitate a reliable, scalable method for producing pure water as make-up. Two stages were investigated during this work for the Danube River water treatment. First, a pretreatment comparison of different methods for the removal of organic carbon and suspended solids, followed by a pressure-driven membrane filtration sequence with the goal of choosing appropriate flux and flow rates, for different working pressures.

In the pretreatment study, a hybrid process of coagulation followed by microfiltration, using jar tests, was followed by dead-end filtration through a 0.45 µm membrane. Prior to coagulation, the disinfection effect was tested. Ferric chloride ($FeCl_3$) and poly-aluminium chloride (PACl) were tested across a range of concentrations. $FeCl_3$ consistently outperformed PACl, achieving up to 78% total suspended solids removal and approximately 62% reduction in total organic carbon content at a concentration of 33.3 mg/L without pre-disinfection. Disinfection proved counterproductive, decreasing TOC removal efficiency, as the formation of disinfection byproducts (DBPs) reduced organic carbon removal efficiency by up to 27%.

Using a pressure-driven filtration sequence comprising ultrafiltration, nanofiltration, and reverse osmosis, the analysis of varying transmembrane pressure was conducted for each membrane. The constant-pressure operation confirmed a linear operating regime for each membrane, enabling the estimation of a resistance factor suitable for pump sizing and system design. The parameters derived from the bench experiments were then scaled up to an industrial system to produce 26.1 m^3/h of pure water suitable as make-up water for a thermal power plant.

The findings demonstrate that combining hybrid methods, using a coagulation-assisted pretreatment step based on $FeCl_3$, shows that minimal chemical use, coupled with microfiltration, provides a good starting point for the following membrane sequence and an industrial-scale blueprint for make-up water production in thermal power plants.