# Hybrid systems based on ultrafiltration membranes and powdered activated carbon for advanced waste water treatment

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## Introduction

Adaptation of membrane-based purification processes and/or combination with other treatment processes has been recently the focus of engineering research also in water reuse. In practice, ultrafiltration (UF) and microfiltration (MF) membranes are no longer a stand-alone process; instead, they become a part of a processing chain that is defined by the treatment objective. For instance, UF / MF membranes could be combined with powdered activated carbon (PAC) adsorption in order to achieve advanced water purification as required in water reuse, i.e. removal of organic micro-pollutants (via PAC adsorption) as well as separation of pollutants particles (besides PAC) and bacteria (via membrane filtration). Utilization of synergetic effects of such a hybrid process and scaling up from bench-scale experiments to the technical scale, taking into account the different boundary conditions, are the main objectives of this study.

## Bench-scale experiments

A laboratory scale out/in MF membrane unit (provided by PALL®) operated in dead-end mode) was employed. PAC was dosed into the feed of the membrane causing the generation of a PAC layer on top of the membrane surface. For each experiment the filtration time was set to 60 min and the specific dosage of PAC to 0.7 g per m² membrane independent on the PAC dosage time which was varied from 1 to 60 min. In each case the totally dosed PAC was equivalent to a continuous dosage of 5 mg/L. Depending on the dosage time, the PAC layer was established very fast (e.g. more or less one-time dosage in 1 min) or developed slowly (e.g. continuous dosage for 60 min). Synthetic model water containing 5 mg/L diclofenac (DFC) was used as feed solution. Besides the influence of different PAC dosage times, influences of further operating parameters, e.g., average particle size of PAC (conventional vs. finely-grinded), on the efficiency of the hybrid purification process were investigated. For example, the study revealed that higher loading of the PAC could be achieved with decreasing dosing time (cf. Figure 1).

This can be interpreted by two effects: firstly, as shorter the dosage time as higher the establishment of the equilibrium concentration of DFC in contact with the face of

the PAC layer on top of the membrane surface (so called filter-effect). Secondly, shorter dosage time due to longer average retention time of the PAC. Moreover, higher PAC concentrations were revealed to form agglomerates that are negatively influencing the purification process. This can be explained by de-accelerating the adsorption kinetics by longer diffusion paths within agglomerates and/or poor distribution of PAC near the membrane surface.

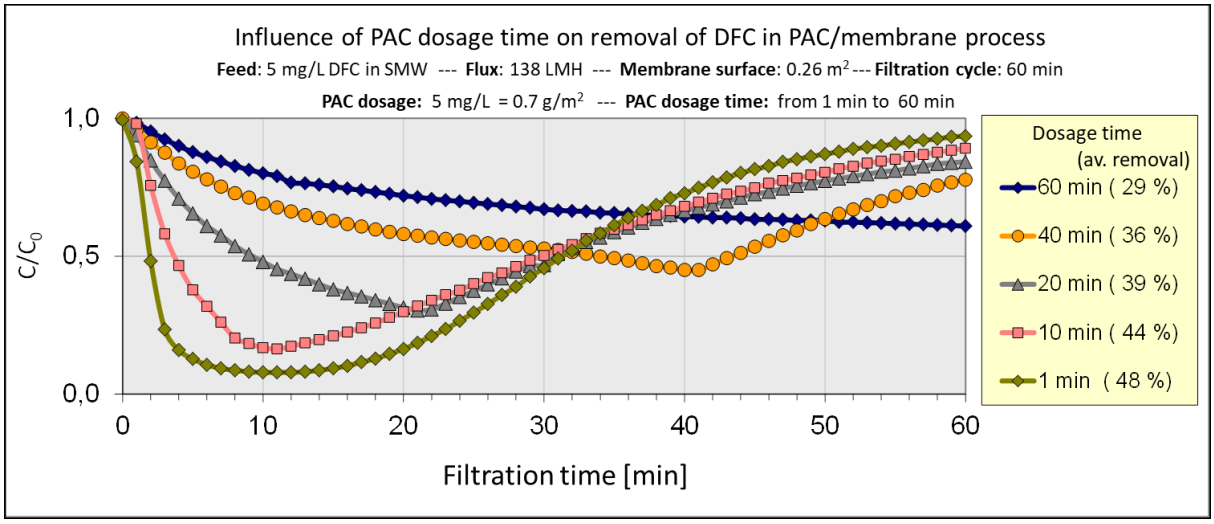


Figure 1: Removal of DFC at different PAC dosing times in PAC/membrane system

**Pilot-scale experiments**

The pilot study with hybrid PAC-UF system has been conducted in a technical center located at a wastewater treatment plant of the Emschergenossenschaft, Germany. Knowledge gained at the bench-scale experiments was transferred to technical scale aiming to achieve optimum removal of micro-pollutants and stable performance. The pilot unit provided by inge watertechnologies GmbH and equipped with a 80 $m^2$ module containing inside-out Multibore® polyethersulfone fibers has been fed with secondary effluent. The system has been operated at a flux of 60 L/($m^2$.h), a filtration time of 45 min, and besides PAC dosage, with a prior coagulation step using polyaluminumchloride (4 mg Al/L). Removal of UV active matter ($UV_{254}$) was measured employing an online UV probe. A one-time PAC dosing was again compared with continuous dosing (see Figure 2). Generally, the commonly used equivalent PAC dosage of 10 mg/L showed a relatively low removal of $UV_{254}$, which might be related to the low adsorption of UV active matter. However, it can clearly be seen that no significant benefits of shorter dosing times of PAC originate under the experimental conditions. This might be attributed to the formation of agglomerates caused by dosing of PAC from a highly concentrated stock solution. Furthermore, at cycles 1 – 3, the adsorption of $UV_{254}$ was found only during PAC addition time,

thereafter no removal of $UV_{254}$ was seen, which was not the case in bench-scale experiments. Another reason could be the additional coagulation step which was not conducted in bench scale and might influence the adsorption process negatively. Therefore, further research will be devoted towards a more efficient and optimized hybrid water purification system.

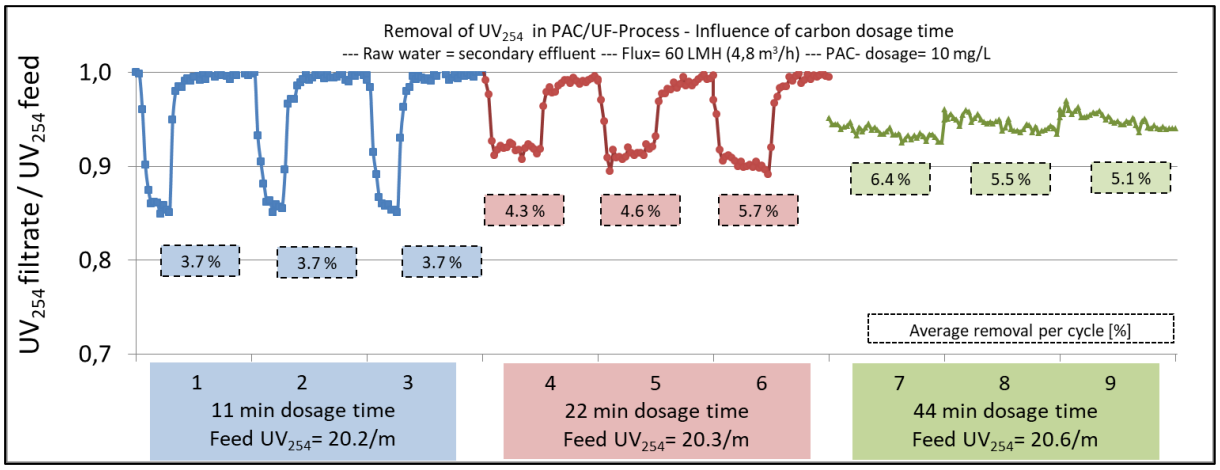


Figure 2: Removal of $UV_{254}$ in PAC/membrane hybrid system at pilot scale

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