Supplementary Information for

A pilot study of hybrid biological activated carbon (BAC) filter-ultrafiltration process for water supply in rural areas: Role of BAC pretreatment in alleviating membrane fouling

Fangshu Qu, Zhongsen Yan, Hao Wang, Xiaobo Wang, Heng Liang, Huarong Yu*, Junguo He, Guibai Li

School of Municipal and Environmental Engineering, Harbin Institute of Technology, Harbin, 150090, P.R. China

*Corresponding author.

Tel.: +86 451 86282252; Fax: +86 451 86282252.

E-mail address: huarongyu@gmail.com (Huarong Yu)

1. Bench-scale ultrafiltration (UF) system

As shown in Fig. S1, the bench-scale UF system was comprised of feed tanks, water level regulators, membrane tanks, permeate tanks, membrane modules, values and pipes. The fee water was driven through the membrane by a constant pressure provided by the water level difference between the water level regulator and the permeate tank. A mini membrane module was used with an effective membrane area of 0.05 m^2.

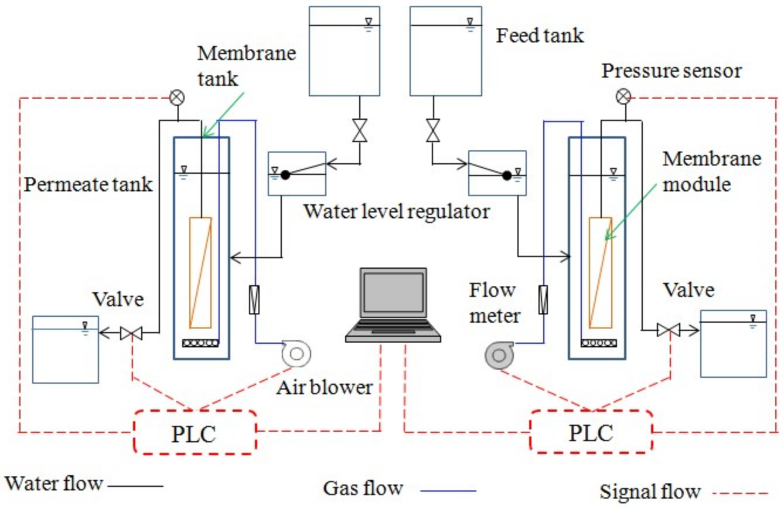

Fig. S1 Schematic diagram of bench-scale filtration system

2. Fouling mechanisms

The classic filtration models include complete blocking, standard blocking, intermediate blocking and cake filtration (Shen et al. 2010). Their schematic diagrams are presented in Fig.S4. In terms of complete blocking, each particle completely blocks a certain pore, lead to the formation of single fouling layer and the linear relationship between membrane permeability and foulant amounts; For standard blocking, it is assumed that a decrease in pore volume is proportional to permeate volume on the basis of particle depositing on the pore walls; Intermediate blocking is similar to completely blocking, but the restriction on single-layer deposition was relaxed. With regards to cake filtration, particles are assumed to be stacked onto early arrivals on the membrane surface forming a cake layer.

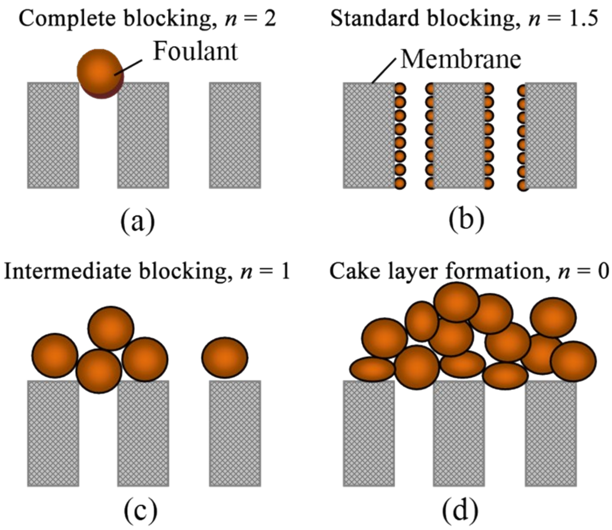

Fig. S2 Schematic diagrams of four filtration models: (a) complete blocking, (b) standard blocking, (c) intermediate blocking, and (d) cake filtration (Shen et al. 2010).

3. Pollutants removal in BAC-UF and UF alone processes

Turbidity, COD_{Mn}, UV_{254}, NH_3-N in raw water, the effluent of BAC-UF process, and the effluent of UF alone process are shown in Fig. S3. In terms of turbidity removal, both processes showed similar performance (0.061±0.010 NTU in BAC-UF effluent, 0.068±0.012 NTU in UF effluent). For COD_{Mn} and UV_{254} removal, BAC-UF process (1.45±0.15 mg/L COD_{Mn} and 0.012±0.002 cm^{-1} UV_{254} in effluent) performed better than UF alone (1.77±0.20 mg/L COD_{Mn} and 0.017±0.002 cm^{-1} UV_{254} in effluent). UF alone removed almost no ammonia during the operation (1.17±0.30 mg/L in influent and 0.98±0.34 mg/L in effluent), while ammonia removal in BAC-UF was very efficient (0.05±0.12 mg/L in effluent). This could be attributed to the biological nitrification in BAC process.

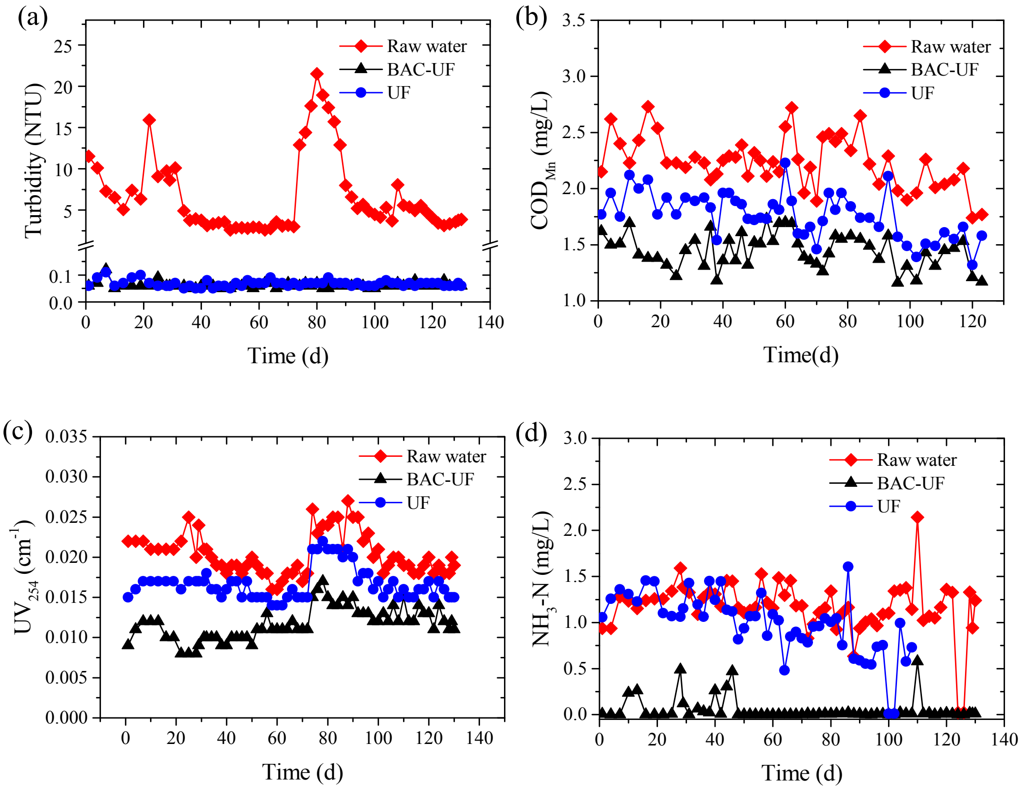

Fig. S3 Performance of BAC-UF and UF alone in removing pollutants in mountain reservoir water: (a) Turbidity, (b) COD_{Mn}, (c) UV_{254} and (d) NH_3-N

4. Accumulation of Nitrite nitrogen in BAC filter treating mountain reservoir water

Concentrations of nitrite in raw water and BAC effluent were continuously measured with results shown in Fig. S3. The apparent increase in the concentration of nitrite was observed within 0-40 d, revealing the accumulation in the initial phase of the experiment.

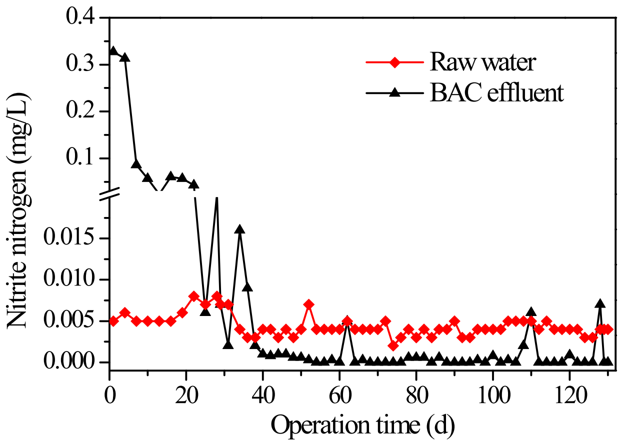

Fig. S4 Concentrations of Nitrite nitrogen in raw mountain reservoir water and BAC effluent

5. Organics extracted from the fouled membranes

The DOC concentrations and UV_{254} of chemical cleaning wastewater were measured to evaluate the amounts of organics irreversibly deposited on membrane surface. The results are shown in Table S1.

Table S1 Amounts of organics irreversible deposited on membrane surface

	UF	BAC-UF
DOC (mg L^{-1})	104.9	51.2
UV_{254} (cm^{-1})	1.688	0.924

Table S2 Details of the capital cost of the BAC-UF process in the pilot plant.

Capital cost				
	Items	**Quantity**	**Price**	**Description**
BAC-UF	Frame and installation	1	¥4,600	Stainless steel
	Feed pump	1	¥800	Nanfang CDL1-2, Height 11.5m；Q: 1m^3/h; Powder: 0.55 kWh
	Granular activated carbon	0.03 m^3	¥600	8×16 mesh cocoanut granular activated carbon, reactor height 1.5 m, reactor radius: 200 mm
	Backwash pump	2	¥1,960	Nanfang CDL2-4, Height 30m；Q: 2m^3/h; Powder: 0.55 kWh
	Pipes and valves (a set)		¥3,400	PE pipes, float flowmeters, plastic valves and installation services
	Membrane module	1	¥5,000	PVC UF membrane (LW3-700-PV2, Litree, China), 10 m^2
	Air compressor	1	¥900	750-30L (Panda, China); Pressure<0.7MPa, Flow<135L/min;Powder:78Kw
	Automatic control system	1	¥6,000	Siemens PLC (S7-200), LED screen, programming and installation services
	Total		¥23,260	

Table S3 Details of the capital cost of the UF process in the pilot plant.

Capital cost				
	Items	**Quantity**	**Price**	**Description**
UF	Frame and installation	1	¥2,500	Stainless steel
	Membrane module	1	¥5,000	PVC UF membrane (LW3-700-PV2, Litree, China), 10 m^2
	Backwash pump	1	¥980	Nanfang CDL2-4, Height 30m；Q: 2m^3/h; Powder: 0.55 kWh
	Pipes and vavels (a set)	1	¥2,000	PE pipes, float flowmeters, plastic valves and installation services
	Air compressor	1	¥900	750-30L (Panda, China); Pressure<0.7MPa, Flow<135L/min;Powder:78Kw
	Automatic control system	1	¥6,000	Siemens PLC (S7-200), LED screen, programming and installation services
	Total		¥17,380	

Table S4 Details of the operation and maintenance cost of the BAC-UF process in the pilot plant.

Operation and maintenance cost					
		Category		**Price**	**Description**
BAC-UF (Capacity: 2.5 ton/d*)	BAC	Electricity	Feed	¥1.0700	Powder: 0.185kW, work for 24h/day, electricity price ¥0.6 per kWh
			Backwash	¥0.0048	Powder: 0.55 kW, 16 min per 7 d;
			Aeration	¥0.0004	Powder: 0.78 kW, Aeration time: 1 min per 7 d，
		Water	Backwash	¥0.0289	Only every week, hydraulic backwashing intensity:14L/m^2·s; backwashing time: 16 min; water price ¥1.2 per ton
		Chemicals		¥0.0000	
	UF	Electricity	Feed	¥0.0000	Gravity driven
			Backwash	¥0.0088	Power 0.55 kW; 2min per 12h; electricity price ¥0.6 per kWh
		Water	Backwash	¥0.0192	60L/m^{2}h, 2min
		Membrane depreciation		¥1.0960	Life span of UF membrane: 5 year
		Chemicals		¥0.0000	
	Total			¥2.2281	

* The capacity of the BAC-UF process is calculated using the steady flux of the UF, i.e. 10.4 L/m^2·h, and factored by the membrane area (10 m^2).

Table S5 Details of the operation and maintenance cost of the UF process in the pilot plant.

Operation and maintenance cost				
	Category		**Price**	**Description**
UF (Capacity: 1.7 ton/d*)	Electricity	Feed	¥1.5735	Powder: 0.185kW, work for 24h/day, electricity price ¥0.6 per degree
		Backwash	¥0.0129	Powder: 0.55 kW; backwashing time: 2min per 12h;
	Water	Backwash	¥0.0282	60L/ m^2·h, 2min
	Membrane depreciation		¥1.6117	Life span of UF membrane: 5 year
	Chemicals		¥0.0000	
	Total		¥3.2263	

* The capacity of the UF process is calculated using the steady flux of the UF, i.e. 7.0 L/m^2·h, and factored by the membrane area (10 m^2).

Reference

Shen, Y., Zhao, W., Xiao, K. and Huang, X. (2010) A systematic insight into fouling propensity of soluble microbial products in membrane bioreactors based on hydrophobic interaction and size exclusion. J. Membr. Sci. 346(1), 187-193.