Supplementary information

Conductive MXene ultrafiltration membrane for enhanced antifouling ability and water quality under electrochemical assistance

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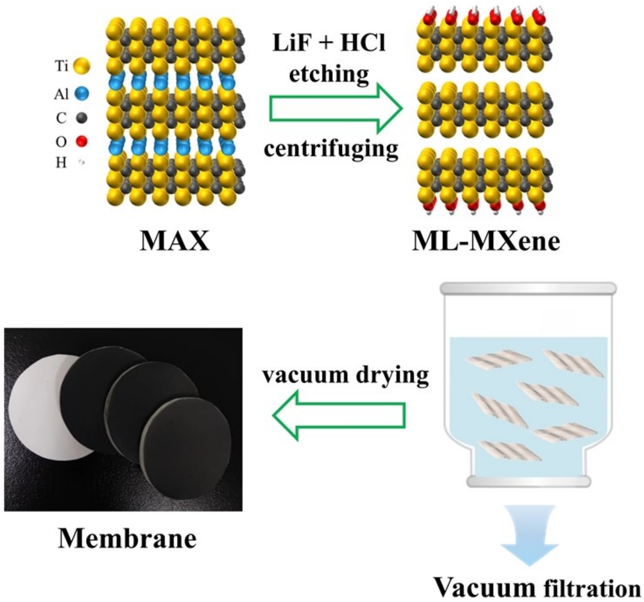

Figure S1. Illustration for membrane fabrications.

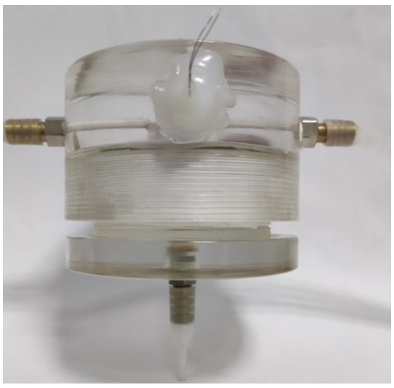

Figure S2. The photo image of the membrane module.

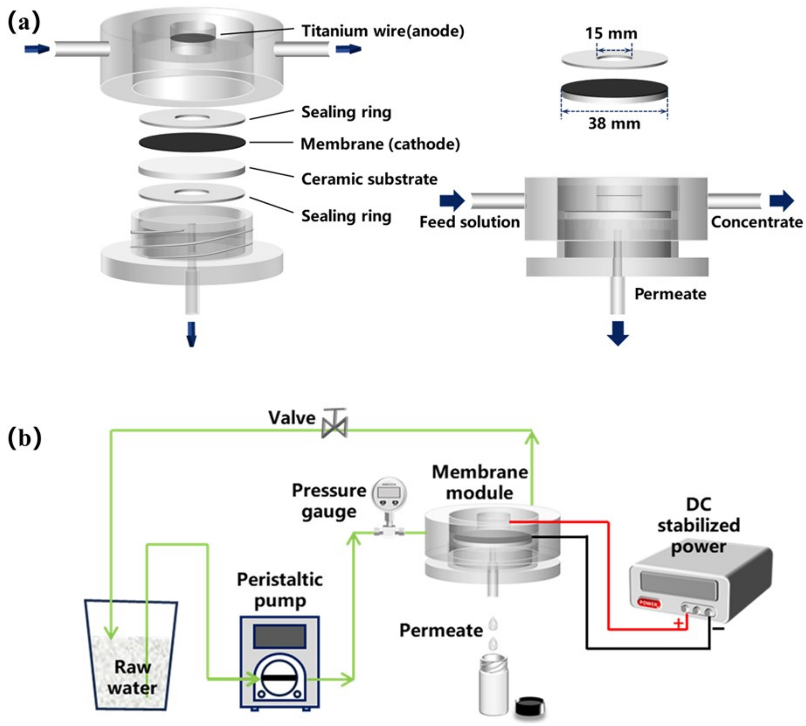

Figure S3. Diagrams of (a) the home-made membrane module and (b) electrically-assisted membrane filtration setup.

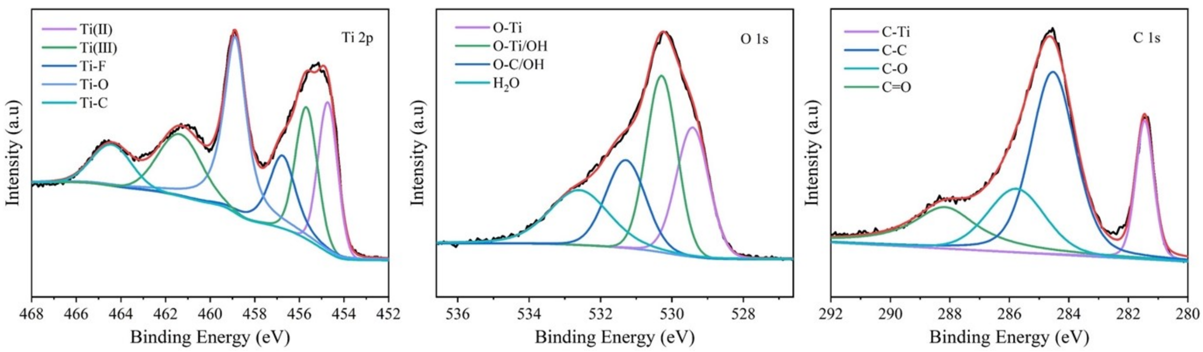

Figure S4. High-resolution XPS spectra of multi-layered $Ti_3C_2T_X$ MXene for Ti, O, C, respectively.

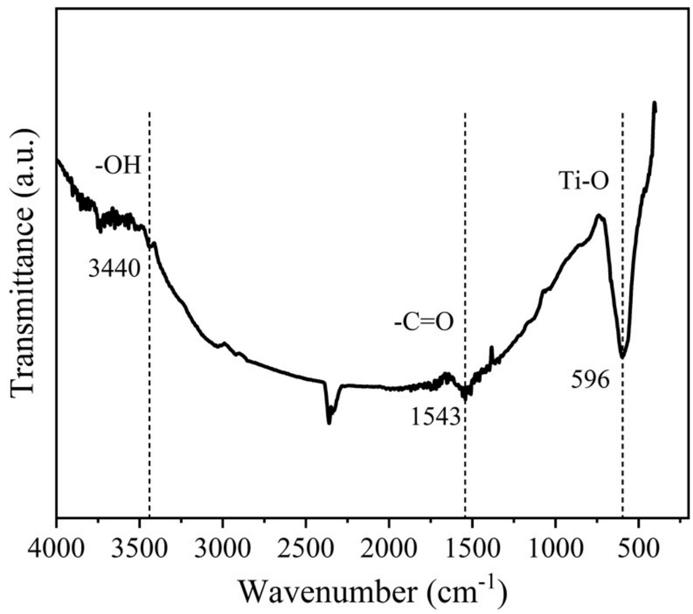

Figure S5. FTIR spectrum of multi-layered $Ti_3C_2T_X$ nanosheets.

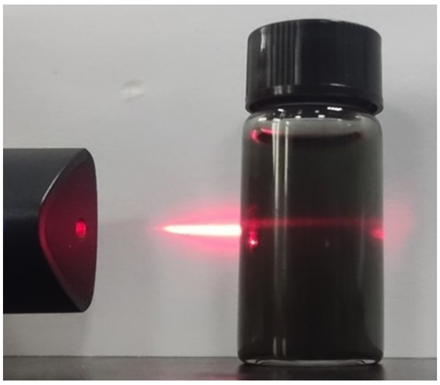

Figure S6. Tyndall phenomenon of multi-layered $Ti_3C_2T_X$ MXene dispersion.

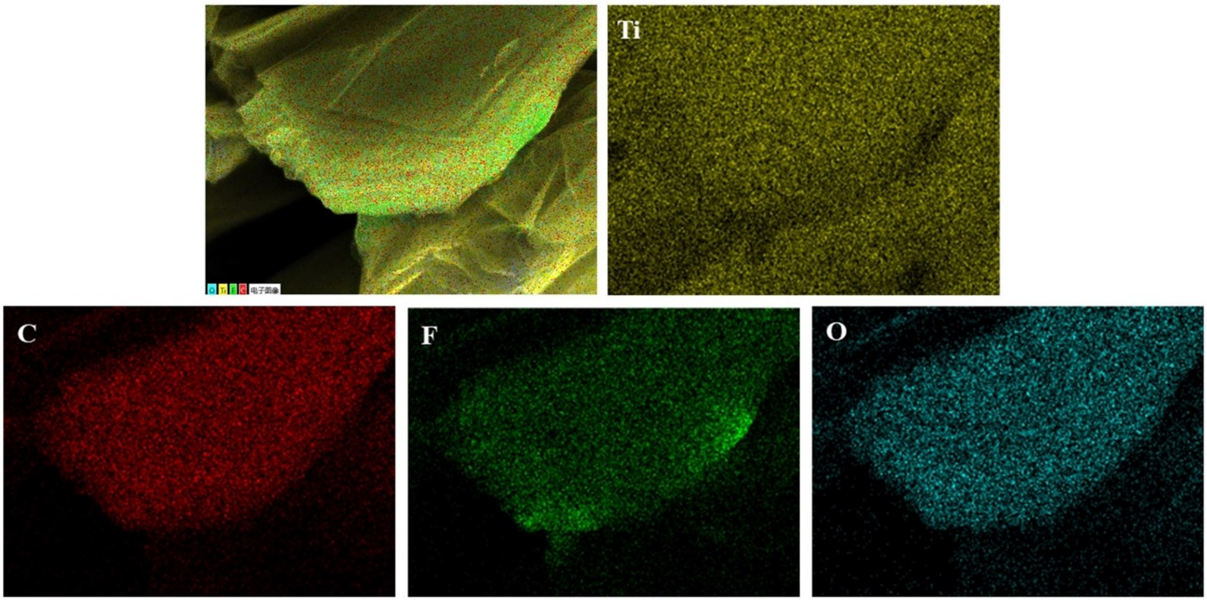

Figure S7. Distribution of elements on the surface of MXene materials.

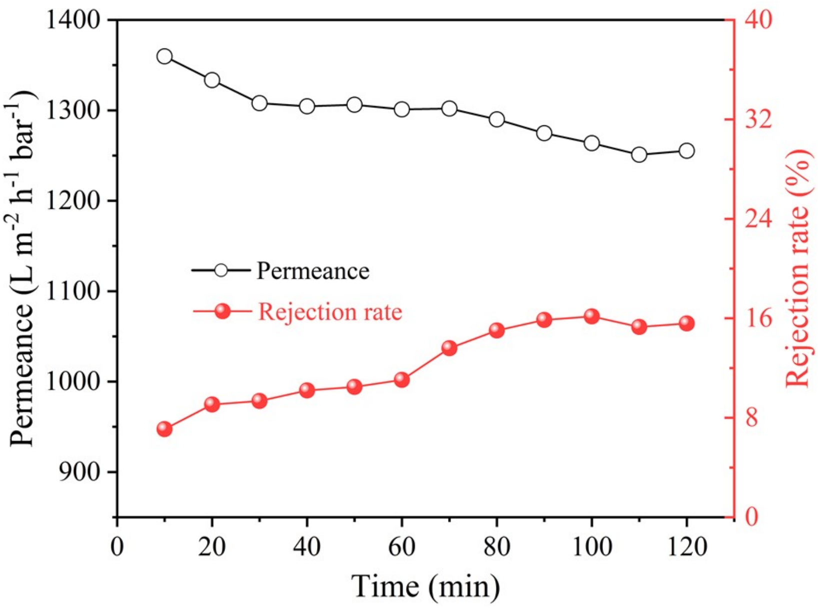

Figure S8. Permeation and HA rejection of unmodified ceramic substrate during operation of 120 min.

The additional experiments were conducted using two types of commercial membranes (Figure R3) for the filtration of humic acid (HA) solution under identical operating conditions as MXene membrane. The results are shown in Figure S9. After 120 minutes of operation, the flux of 100 nm PVDF membrane decreased to 80.9% of its pure water flux, and the rejection rate for HA was only 8.0%. The flux of 100 nm CA-CN membrane decreased to 15.9% of pure water flux, and the rejection rate for HA was 26.9%. In contrast, although the flux of MXene membrane was reduced to 26.7%

of pure water flux, its rejection rate for HA was as high as 86.5%. To further demonstrate the superior antifouling performance of prepared MXene membrane, the hydrophilicity of the above three membranes were characterized by optical contact angle meter. The water contact angles of PVDF, CA-CN and MXene membranes were 55°, 77° and 23°, respectively (Figure S10). These results indicate that MXene membrane has much higher hydrophilicity than the commercial membranes, which contributes to its good antifouling performance.

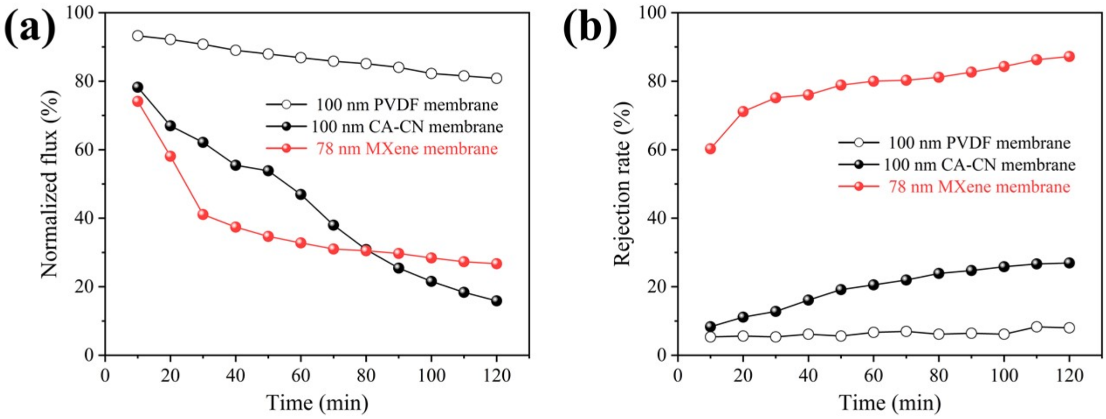

Figure S9. The variation of (a) flux and (b) rejection rate with time when PVDF membrane, CA-CN membrane and prepared MXene membrane filtered HA solution, respectively.

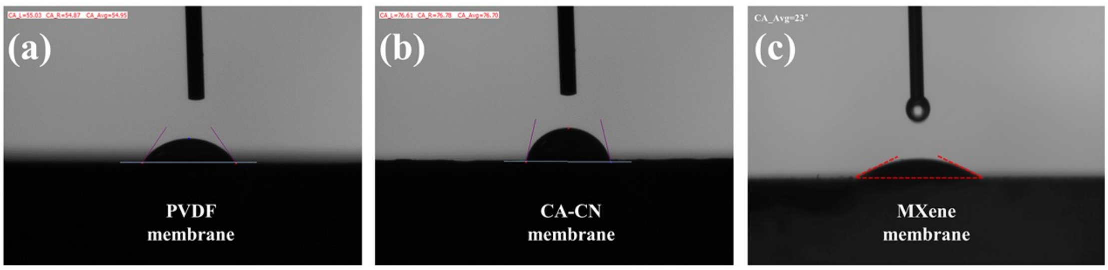

Figure S10. The water contact angles of (a) PVDF, (b) CA-CN and (c) MXene membrane.

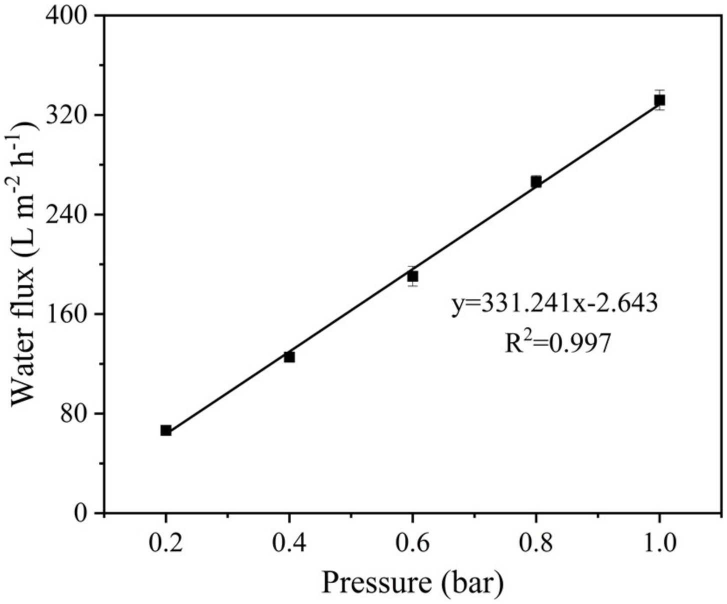

Figure S11. Pure water flux of membrane with MXene loading of 2.33 mg cm^{-2} at different pressures.

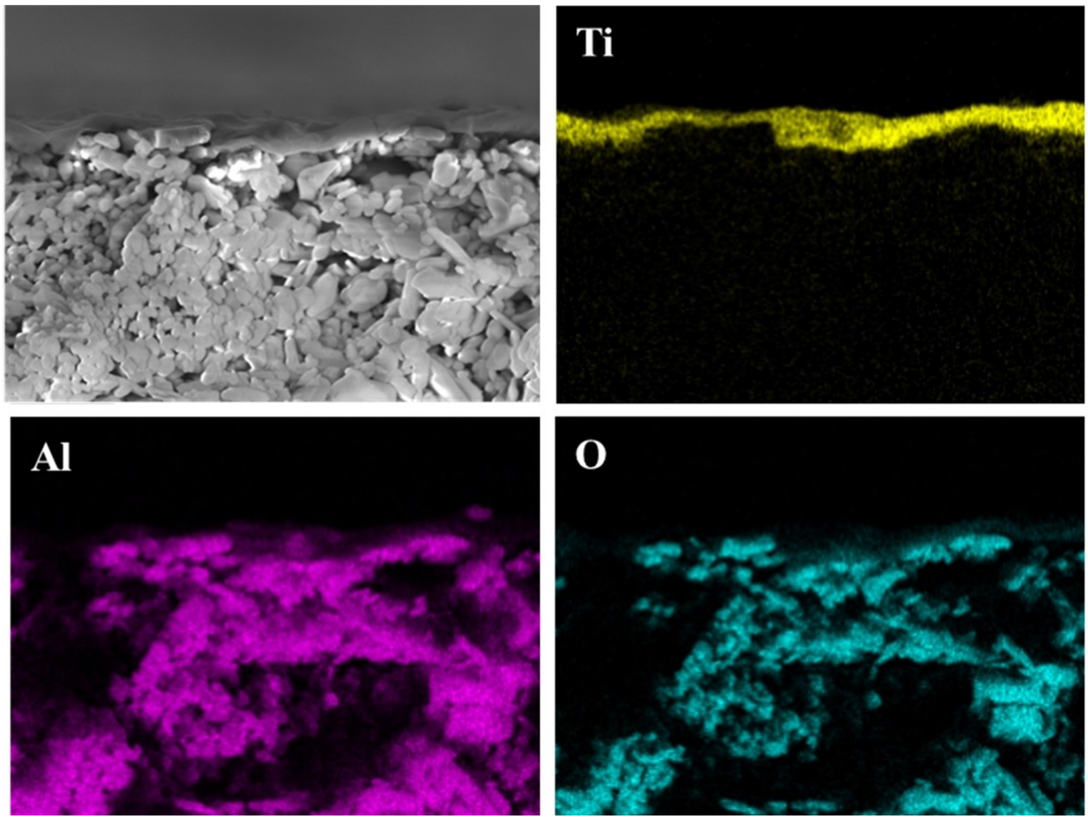

Figure S12. EDS mapping images of the cross-section of MXene membrane.

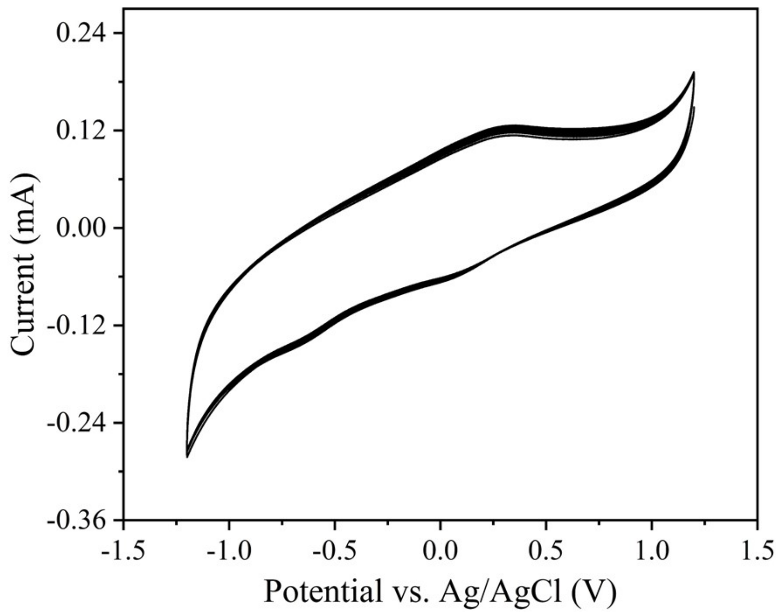

Figure S13. CV scans of a MXene membrane as a working electrode in 5 mM Na_2SO_4 solution (20 cycles). A titanium mesh was served as a counter electrode. Scanning range was between 0 V and -1.2 V vs. SCE, and the scaning rate was 10 mV s^{-1}.

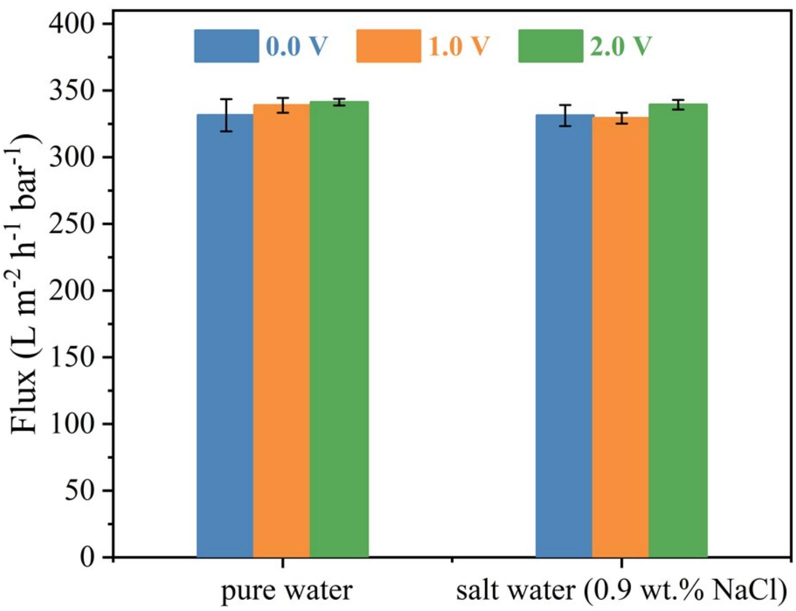

Figure S14. Permeances of MXene membrane under different voltages.

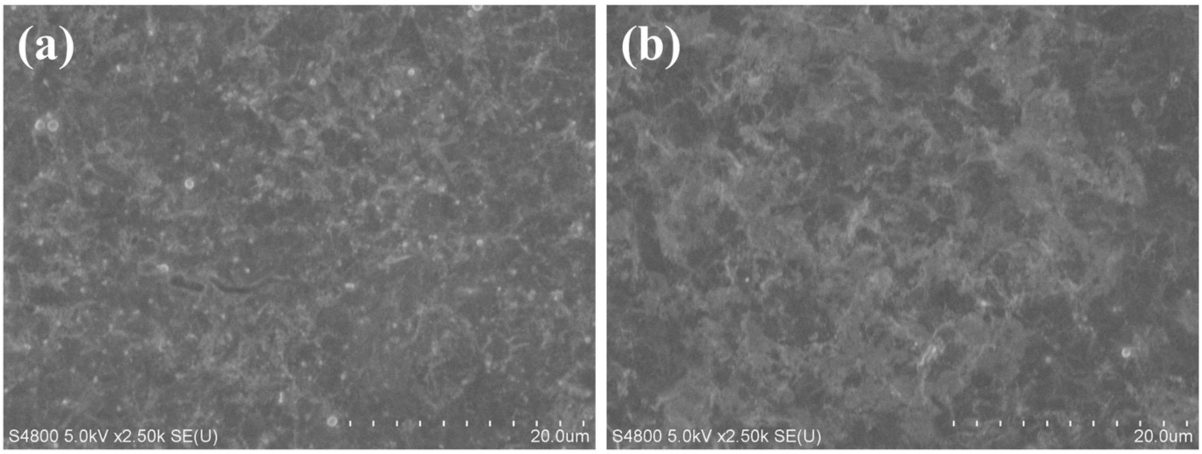

Figure S15. SEM images of MXene membranes after NOM filtration for 120 min (a) in the absence of a potential and (b) at the cell voltage of 2.0 V.

Table S1. Performance comparison of MXene membrane under electrochemical assistance

Membrane	Conductivity ($S\cdot m^{-1}$)	Feed solution ($mg\ L^{-1}$)	Applied voltage (V)	Rejection (%)	References
CNTs/Al_2O_3	1615	10, HA	1.5 V, membrane as cathode	~88%	1
Nanocarbon-based membrane	1900	10, HA	1.0 V, membrane as cathode	~71%	2
			1.0 V, membrane as anode	~62%	
CNTs/ceramic	765	10, HA	3.0 V, membrane as cathode	~65%	3
			3.0 V, membrane as anode	~75%	
MXene	2×10^5	10, HA	2.0 V, membrane as cathode	~95%	This work

Table S2. Parameters of surface water

Item	TOC ($mg\ L^{-1}$)	UV_{254} (cm^{-1})	pH	Turbidity (NTU)
Data	36.55	0.155	7.28	2.35

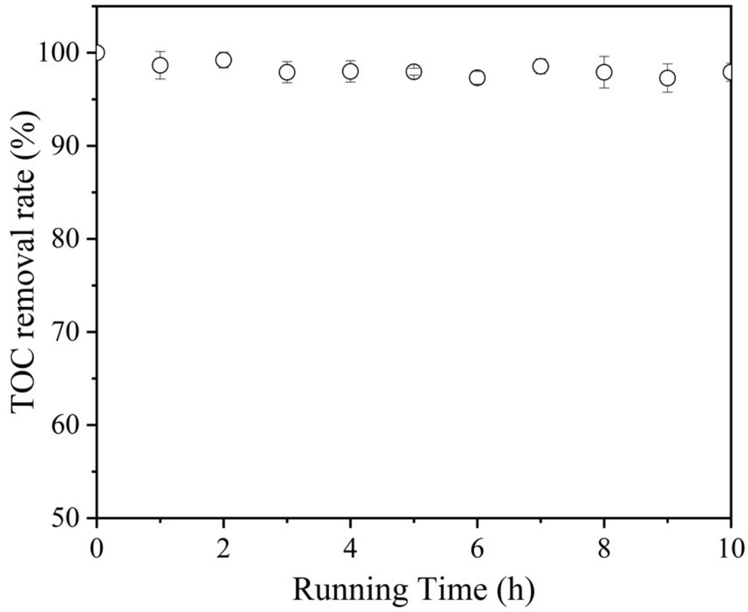

Figure S16. The normalized TOC removal rate of MXene membranes static adsorption experiment.

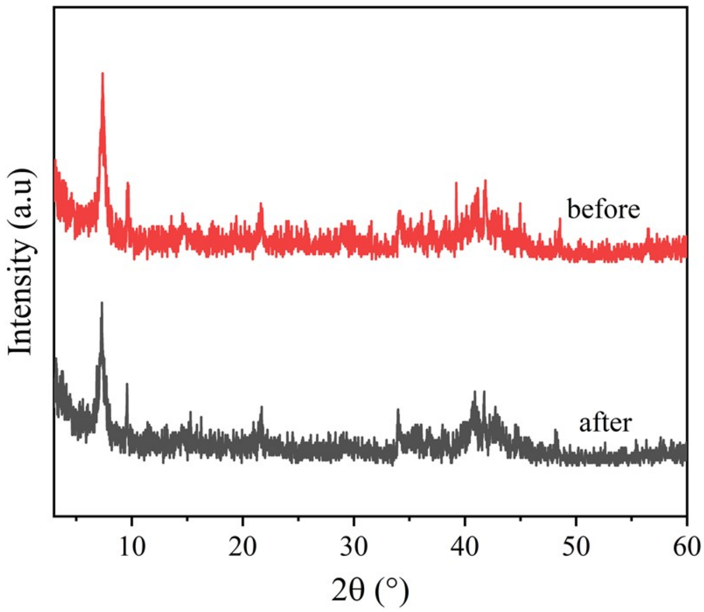

Figure S17. XRD patterns of MXene membrane before/after 300 min treatment with external voltage at 2.0 V.

Table S3. Effluent quality index after membrane filtration

Index	TOC (mg L^{-1})	Colony forming unit (CFU L^{-1})	Conductivity (μS cm^{-1})	Turbidity (NTU)	UV_{254}
Raw water	36.55	10^4	1655	2.35	0.155
MXene membrane filtration	14.36	None	1035	0.07	0.104
MXene membrane filtration under electrochemical assistance (2.0 V, membrane as cathode)	10.53	None	782	0.01	0.079

References

1 X. F. Fan, H. M. Zhao, Y. M. Liu, X. Quan, H. T. Yu and S. Chen, *Environ Sci Technol*, 2015, **49**, 2293-2300.

2 X. F. Fan, H. M. Zhao, X. Quan, Y. M. Liu and S. Chen, *Water Res*, 2016, **88**, 285-292.

3 S. Wei, L. Du, S. Chen, H. T. Yu and X. Quan, *Front Env Sci Eng*, 2021, **15**, 11.