

Supplementary Materials

Text S1 Preparation of Zr-bentonite and PVC/Zr-BT

The Zr-modified-bentonite was synthesized using a simple ion exchange method. First, 25 g bentonite was added into 250 mL 2% Zr (IV) solution which was prepared by dissolving $\text{ZrOCl}_2 \cdot 8\text{H}_2\text{O}$. Then, the mixture was stirred with a magnetic rotor at 500 r/min for 3 h at room temperature. The pH of the suspension was then raised to 7–8 using a 1 mol/L NaOH solution, and it was continuously agitated for an additional 2 h. The solid was then dried within an oven at 60°C, rinsed three times with DI water, put through a 200-mesh filter, and labeled Zr-BT for further usage.

The PVC/Zr-BT was prepared by phase inversion method. First, 5 g of Zr-BT was added to 50 mL NMP solution. After 2 h of room temperature stirring at 500 r/min, 5 g of PVC powder was added to the mixture, and it was swirled again until all of the powder was dissolved. The mixed solution was subjected to ultrasonic treatment for 1 h and vacuum degassing for 0.5 h. Finally, the membrane was coated on an automatic film scraper, and the film was formed by soaking in water.



Fig. S1 (a) The automatic film applicator. (b) The triple high pressure flat membrane test equipment.

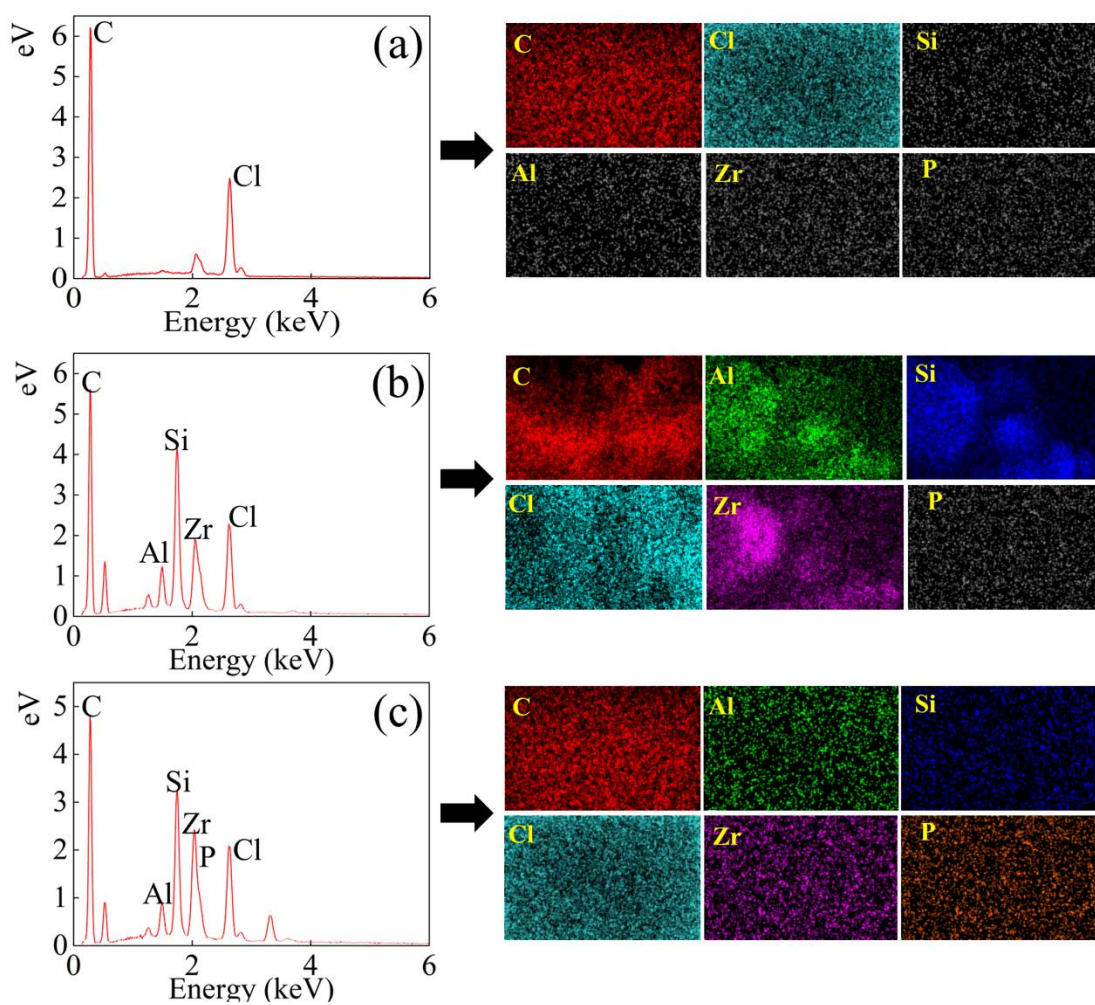


Fig. S2 EDS spectra of PVC membrane and PVC/Zr-BT: (a) EDS spectrum of PVC/Zr-BT membrane; (b) EDS spectrum of PVC/Zr-BT before phosphate adsorption; (c) EDS spectrum of PVC/Zr-BT after phosphate adsorption.

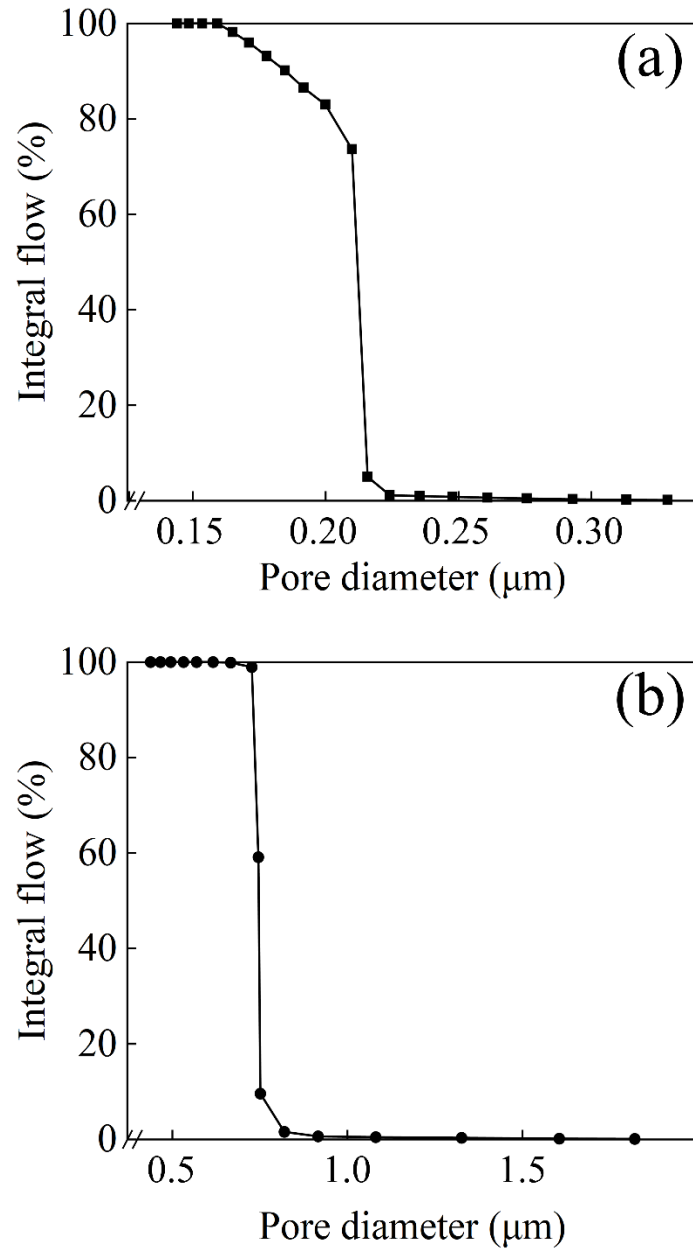


Fig. S3 Integral flow Pore Diameter Distribution of (a) PVC membrane and (b) PVC/Zr-BT.

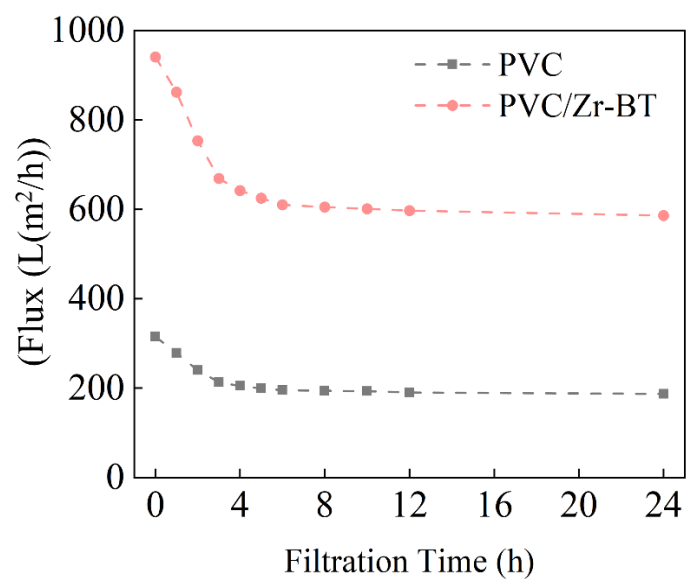


Fig. S4 Water flux for the PVC membrane and PVC/Zr-BT.

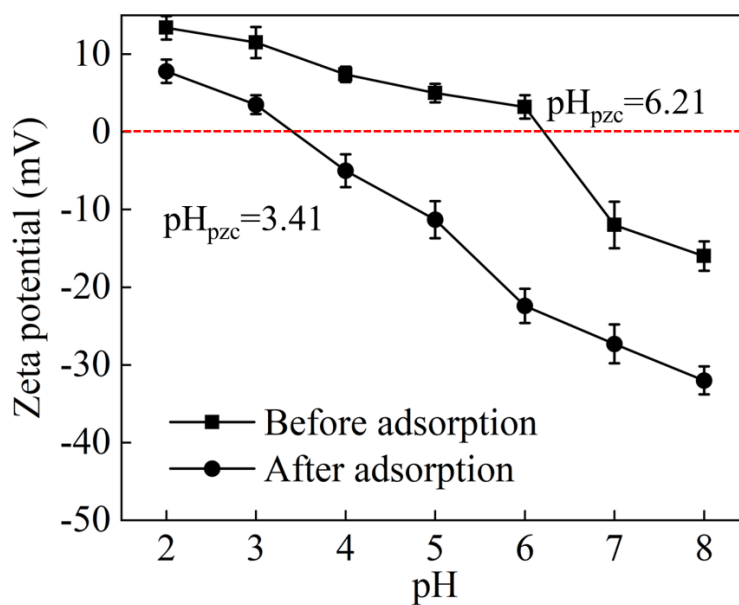


Fig. S5 The zeta potential of PVC/Zr-BT membrane before and after phosphate adsorption.

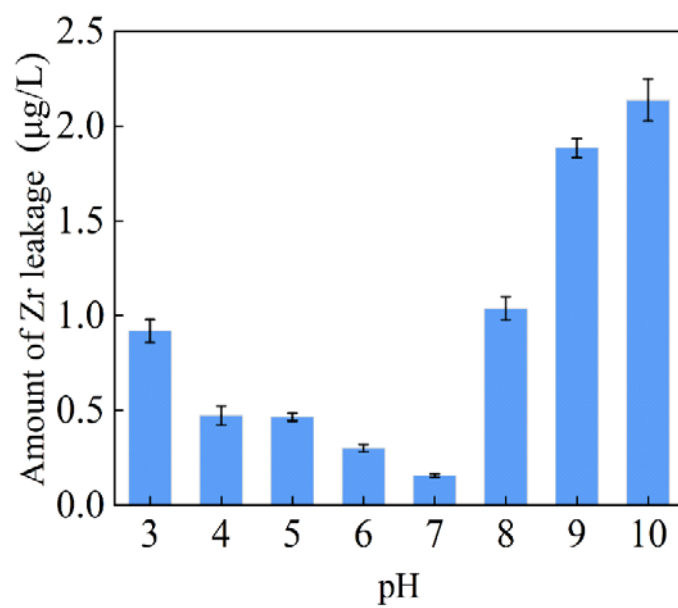


Fig. S6 The effect of pH on the leakage of Zr ions in the membrane.

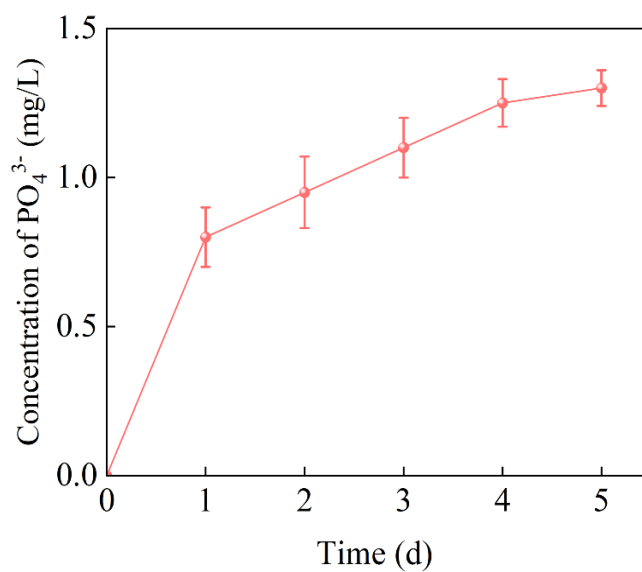


Fig. S7 Elution of phosphate from PVC/Zr-BT containing P, which was directly added to into P-free f/2 medium. Solid-liquid ratios were 1:1000. Error bars indicate standard deviations ($n = 3$).

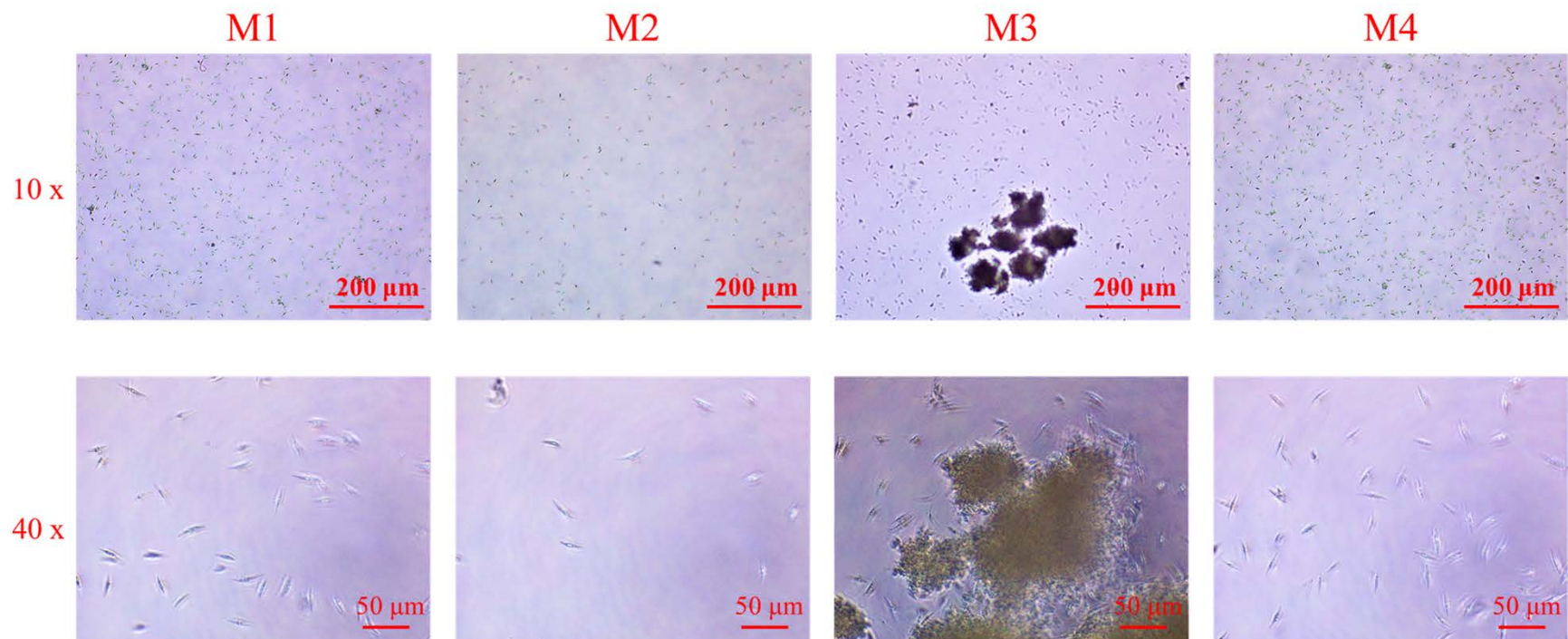


Fig. S8 Microscopic photographs of microalgae under different media after 16 days of incubation.

Table S1 Specific surface area (BET) and pore volume of the PVC, PVC/BT and PVC/Zr-BT membrane.

Membrane	BET (m ² /g)	Total pore volume (cm ³ /g)	Average pore size (nm)
PVC	11.54	0.031	9.77
PVC/BT	16.28	0.051	14.18
PVC/Zr-BT	16.12	0.053	13.65

Table S2 Composition of Zr-BT and PVC in the casting solution for flat membrane and thickness of the prepared membranes.

Membrane number	Adsorbent (wt%)	PVC (wt%)	Membrane thickness before phase inversion(μm)	Membrane real thickness (μm)
1	0	10.0	200	95 ± 3
2	10 BT	10.0	200	105 ± 5
3	5 Zr-BT	10.0	200	102 ± 3
4	10 Zr-BT	10.0	200	111 ± 6
5	15 Zr-BT	10.0	200	117 ± 5
6	20 Zr-BT	10.0	200	127 ± 4
7	10 Zr-BT	10.0	100	54 ± 2
8	10 Zr-BT	10.0	300	179 ± 6
9	10 Zr-BT	10.0	500	296 ± 11