

Supporting Information

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Title: Birnessite-coated sand filled vertical flow constructed wetlands improved nutrients removal in cold climate

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Method

Chemicals

The birnessite-coated sand is artificially synthesized. Specifically, 2 mol of potassium permanganate (158 g) was first dissolved in 2.5 L of water, and then 300 g of hydrochloric acid washed sand was added and heated to boiling. Next, 2 mol of concentrated hydrochloric acid (167 ml) was added dropwise to the solution and stirred all the time. After the addition, the boiling was continued for ten minutes. After cooling, the resulting precipitate was filtered and rinsed with deionized water. After drying, the synthesized birnessite-coated sand was obtained. Repeat the operation 10 times to get a sufficient amount to be used.

Table S1 Influent and effluent concentrations of NH₄-N, NO₃-N, TP, COD in Mn-CWs and Control during the winter

Systems	Temperature (°C)	PH	Conductivity	NH ₄ -N (mg/L)	NO ₃ -N (mg/L)	TN (mg/L)	TP (mg/L)	COD (mg/L)
Influent	5.50 ± 1.70	7.85 ± 0.27	1327 ± 68	7.98 ± 0.39	11.67 ± 0.97	19.65 ± 0.65	0.95 ± 0.07	65.79 ± 7.35
Mn-CWs	5.70 ± 2.20	8.17 ± 0.16	1395 ± 84	2.09 ± 1.43 ^b	1.09 ± 0.60 ^a	3.45 ± 1.61 ^b	0.40 ± 0.29 ^b	28.42 ± 6.68 ^b
				73.81	90.66	82.44	57.89	56.80
Control	5.70 ± 1.80	8.36 ± 0.09	1311 ± 52	5.66 ± 0.61 ^a	1.12 ± 0.66 ^a	7.31 ± 1.16 ^a	1.20 ± 0.71 ^a	39.37 ± 7.35 ^a
				29.07	90.40	62.80	-26.32	40.16

^{a and b} means significant difference (P<0.05).

Table S2 Comparison of microbial community abundance and diversity at 20 cm height of Mn-CWs and Control

Samples	OTUs	ACE	Chao	Shannon	Coverage(%)
Control-20	1199	1303.7005	1321.9179	5.1988	99.56
Mn-20	1041	1139.5042	1153.1287	5.1298	99.64

Table S3 The relative abundance of nitrifying and denitrifying bacteria at at 20 cm height of Mn-CWs and Control

reabundance (%)	Control-20	Mn-20
Nitrifying bacteria	19.87	37.07
Denitrifying bacteria	33.76	42.47

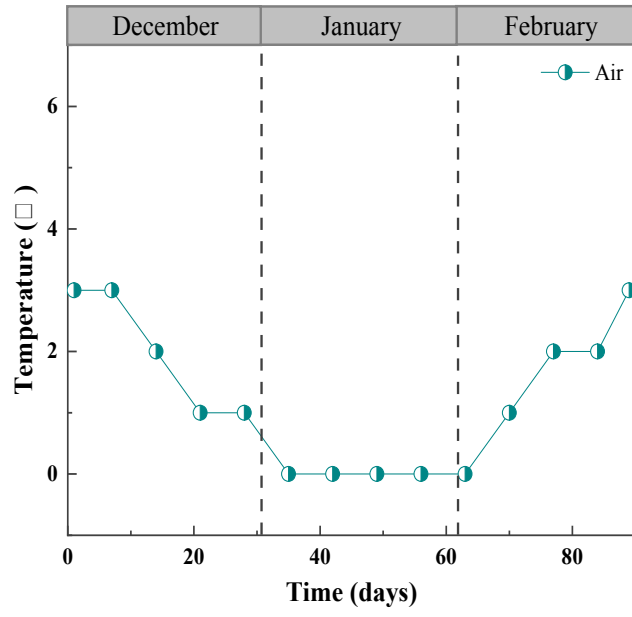


Fig. S1 Air temperature in winter.

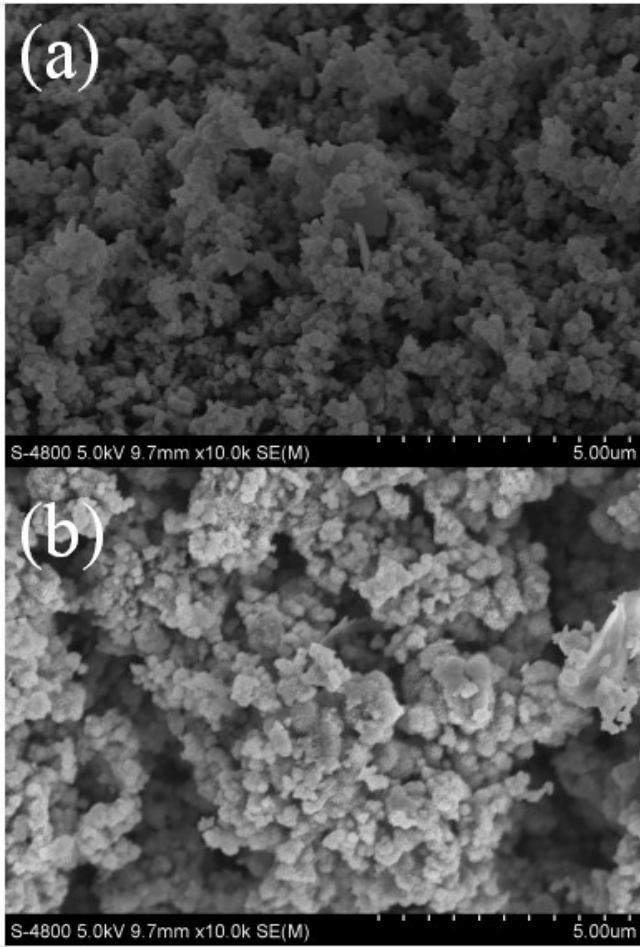


Fig. S2 The before (a) and after (b) SEM comparative figure of birnessite-coated sand.

Scale bar in all images represents 5 μm .

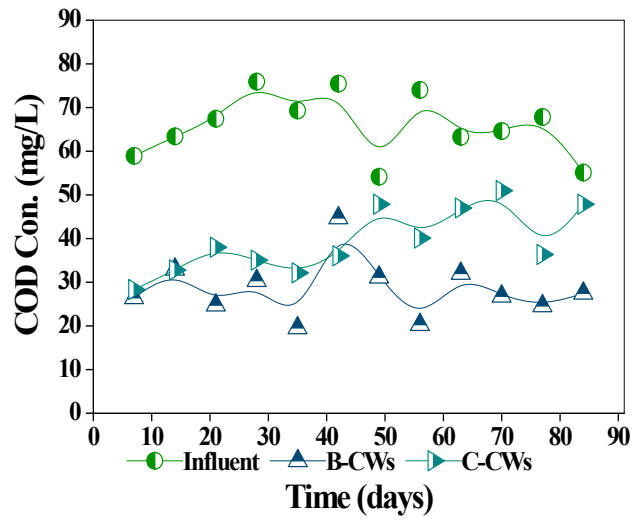
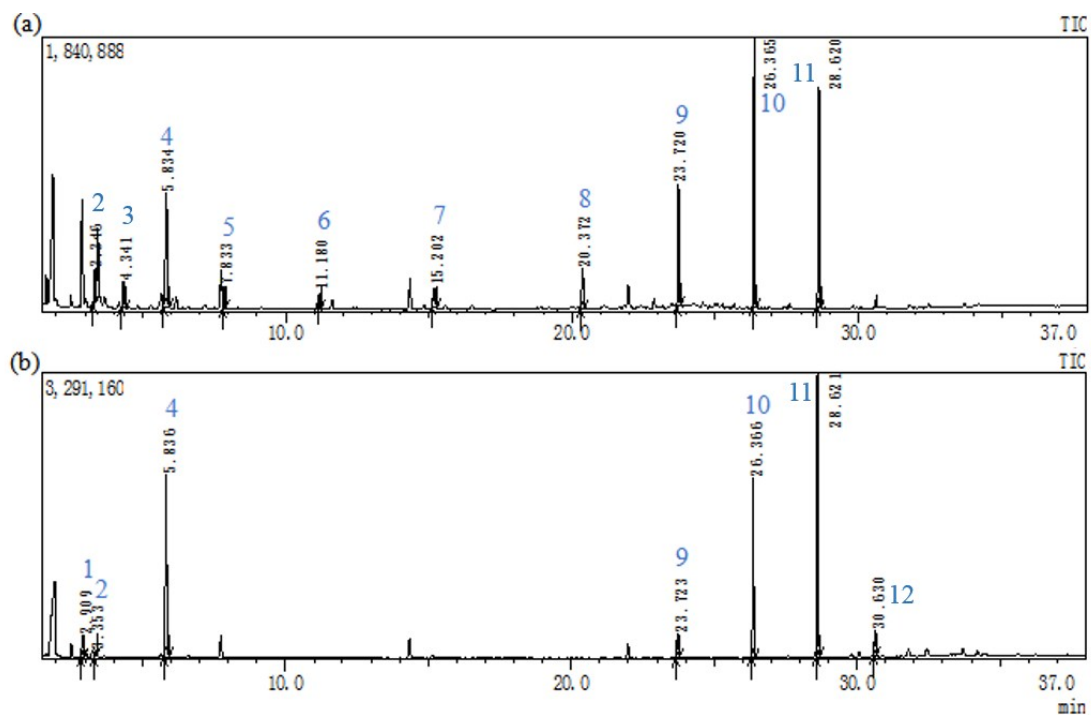


Fig. S3 Effluent concentrations of COD removal efficiency in the two CWs throughout the experiment period.



1. Acetoxy-2-methoxyethane; 2. Methyl acetate; 3. n-hexane; 4. Ethyl acetate; 5. Heptane; 6. Toluene; 7. o-xylene; 8. Decane; 9. Undecane; 10. Dodecane; 11. Tridecane; 12. Pentadecane

Fig. S4 TIC chromatograms of volatile organic compounds (VOC) in sediment: (a) and (b) Chromatographic profiles of Mn-CWs and Control.