Supplementary Material

Aluminum-loaded bifunctional resins for efficient fluoride removal from aqueous solution

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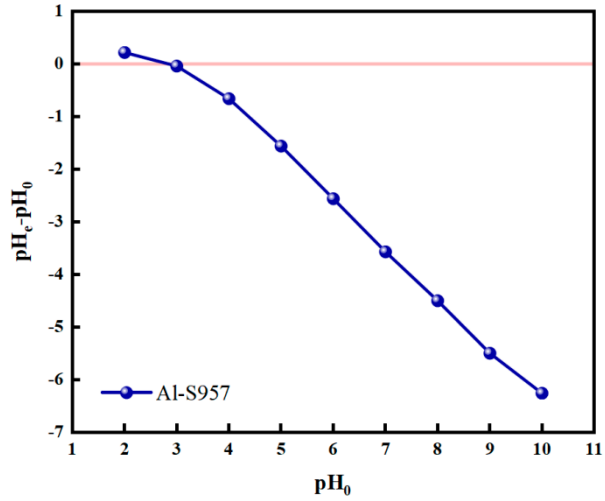


Figure S1. The pH_{pzc} of Al-S957.

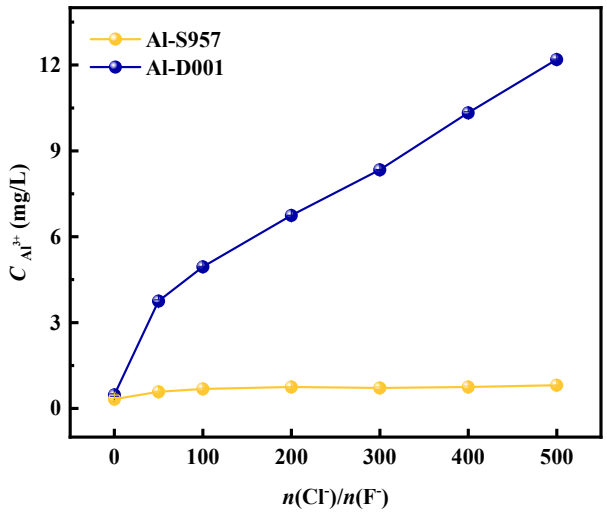


Figure S2. Leakage of aluminum in the presence of chloride ions in different molar.

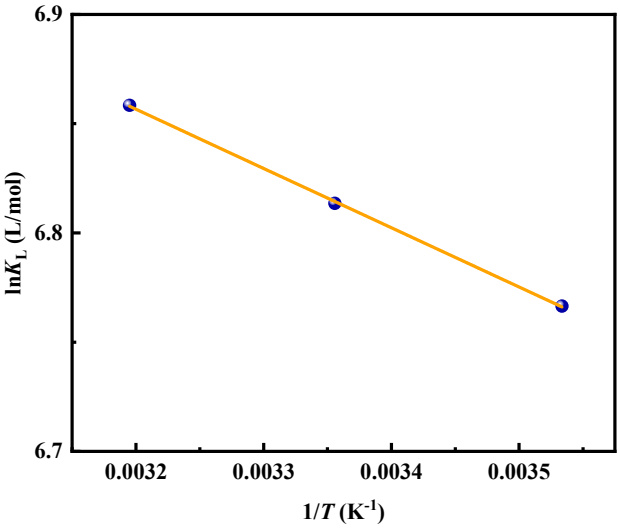


Figure S3. The linear relationship between lnK_L and $1/T(K^{-1})$ for the adsorption of fluoride by Al-S957 at different temperatures.

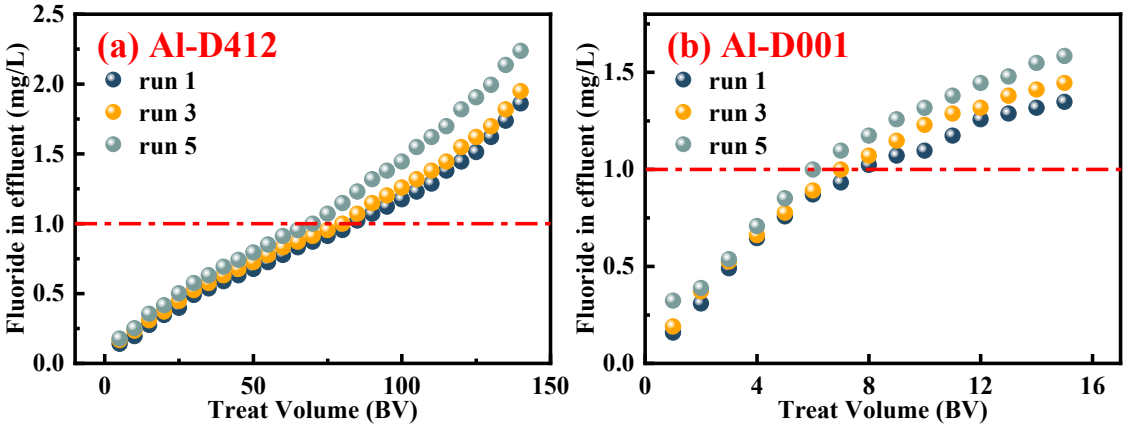


Figure S4. Column adsorption of Al-D412 and Al-D001 with photovoltaic wastewater.

Table S1 Basic information about S957, D412, and D001.

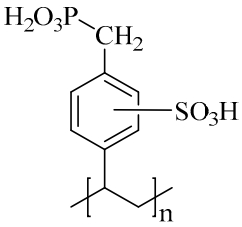
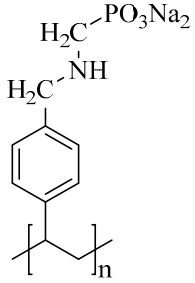
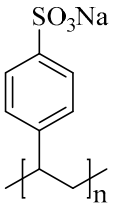
Resin	Functional group	Total exchange capacity (mmol/g)	Chemical structure
S957	phosphoric-sulfonic acid difunctional group	3.35	
D412	phosphoric acid group	5.5	
D001	sulfonic acid group	4.5	

Table S2. Adsorption kinetics fitting parameters of Al-S957.

n(Cl)/*n*(F)	$Q_{e,\ exp}$ (mg g^{-1})	Pseudo-first-order kinetic			Pseudo- second-order kinetic		
		$Q_{e,\ cal}$ (mg g^{-1})	k_1 (min^{-1})	R^2	$Q_{e,\ cal}$ (mg g^{-1})	k_2 (g mg^{-1} min^{-1})	R^2
0:1	1.7593	1.5963	0.01968	0.9262	1.7945	0.01456	0.9988
250:1	1.7820	1.6247	0.01054	0.9536	1.8259	0.00644	0.9985
500:1	1.7820	1.5729	0.00948	0.9270	1.7727	0.00596	0.9978

Table S3. Adsorption isotherm fitting parameters of Al-S957.

Adsorbent	T (k)	Langmuir			Freundlich		
		Q_m (mg g^{-1})	K_L (L mg^{-1})	R^2	1/n	K_F (L mg^{-1})	R^2
Al-S957	283	13.54	0.0457	0.9993	0.6583	0.9103	0.9870
	298	15.49	0.0479	0.9994	0.6613	0.9986	0.9830
	313	16.61	0.0501	0.9994	0.6702	1.1608	0.9712

Table S4. Adsorption thermodynamic fitting parameters of Al-S957.

Adsorbent	T (k)	$\triangle H$ (kJ/mol)	$\triangle S$ (J/mol·k)	$\triangle G$ (kJ/mol)	R^2
Al-S957	283	2.2555	64.2237	-15.9207	0.9998
	298			-16.8811	
	313			-17.8476	

Table S5. Cost of preparing Al-S957 for treating 1 L of actual photovoltaic wastewater.

NO	Materials	Unit Cost	Quantity used	Net Price ($)
1	S957 resin	610 $/Kg	0.55 g	0.34
2	Aluminum chloride	1.12 $/Kg	3.40 g	0.004
3	Drying	0.09 $/kWh	0.5kWh for 12h (50℃)	0.13
4	Net Cost			0.474
5	Overhead Cost (10% of the Net Cost)			0.0474
6	Total Cost			0.52

Note: All chemical prices were obtained from publicly available industrial procurement platforms.