

**Enhanced fluoride removal by loading Al/Zr onto carboxymethyl
starch sodium: synergistic interactions between Al and Zr**

Table S1 Calculated R_L values based on the Langmuir isotherm model.

C_0 (mg/L)	R_L		
	CMS–Al	CMS–Zr	CMS–Al–Zr
5	0.9074	0.8946	0.9114
10	0.8305	0.8093	0.8372
20	0.7101	0.6797	0.7200
30	0.6202	0.5859	0.6316
40	0.5505	0.5148	0.5626
60	0.4495	0.4143	0.4616
80	0.3798	0.3466	0.3914
100	0.3288	0.2980	0.3397
150	0.2462	0.2206	0.2554
200	0.1968	0.1751	0.2046

Table S2 Comparison of fluoride adsorption capacity determined in this study with those reported for other carbohydrate polymer-based adsorbents.

Adsorbent	q ⁰ (mg/g)	pH	Contact time	Reference
Zr loaded cross-linked chitosan composite	48.26	6	40 min	1
Linked-CMC-La	42.66	3	24 h	2
Carboxymethyl cellulose loaded with Zr	38.46	4	4 h	3
Porous zirconium alginate beads	32.80	2	20 h	4
Al-doping chitosan-Fe(III) hydrogel	31.16	5	30 min	5
Chitosan/MMT/ZrO ₂ nanocomposite	23	4	60 min	6
Fe-impregnated chitosan	20.75	–	24 h	
β-Cyclodextrin modified zirconium oxide	20.6	7	60 min	7
Alginate based anion exchanger from <i>Ulva japonica</i>	18.1	5	24 h	8
Dendrimer like chitosan beads	17.47	7	80 min	9
Titanium hydrate based on chitosan template	16.12	4-9	3 h	10
Alginate-zirconium biopolymeric complex	9.57	3	25 min	11
Hydrous ferric oxide dropped alginate beads	8.9	7	4 h	12
Zr enabled in carboxylated alginic acid	6.58	3	30 min	13
Zirconium impregnated cellulose	4.95	4.5-5.5	50 min	14
Chitosan/bentonite composite	2.95	7	–	15
Alginate bioencapsulated nano-hydroxyapatite composite	0.123	3	30 min	16
Cerium loaded cellulose nanocomposite bead	0.095	3	1 h	17
CMS-Zr	40.23	3	60 min	This work
CMS-Al	51.44	5-10	60 min	This work
CMS-Al-Zr	60.61	4-10	60 min	This work

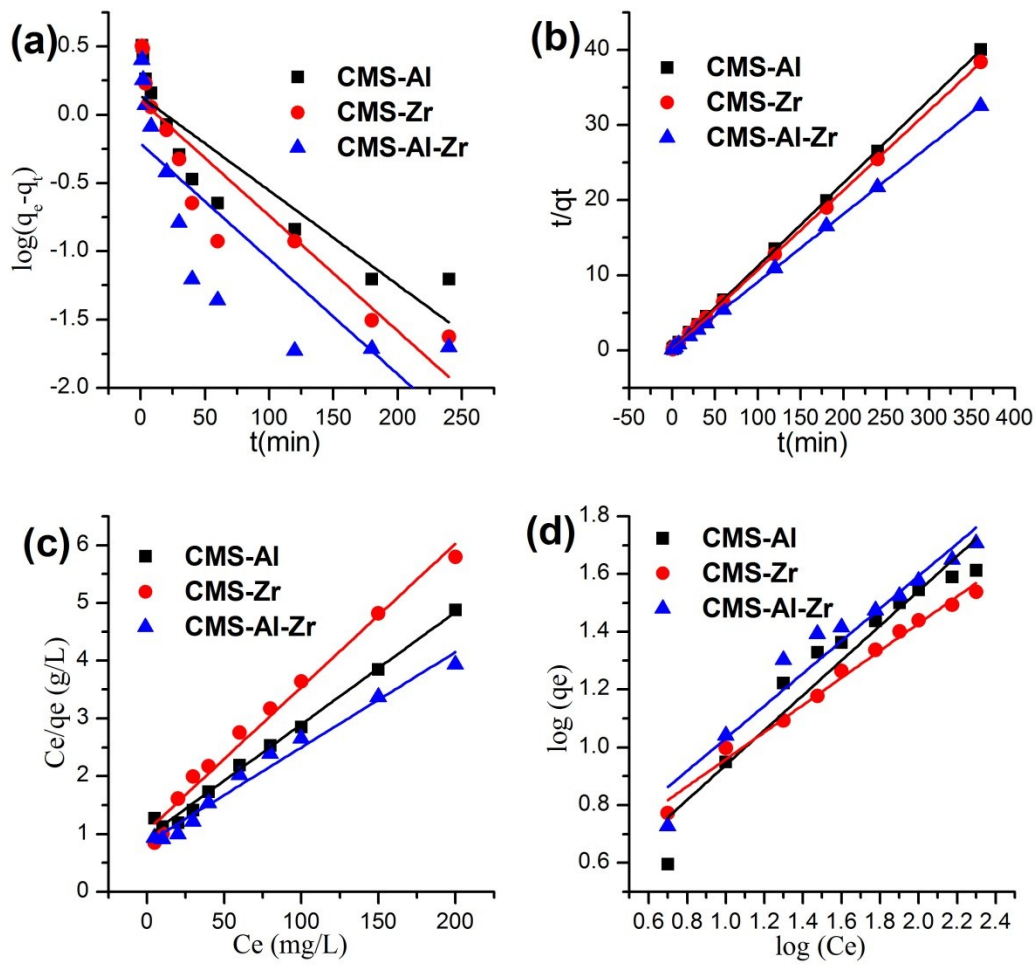


Fig. S1. The pseudo-first-order kinetic model (a), the pseudo-second-order kinetic model (b), the Langmuir isotherm (c) and the Freundlich isotherm (d) for fluoride adsorption on adsorbents.

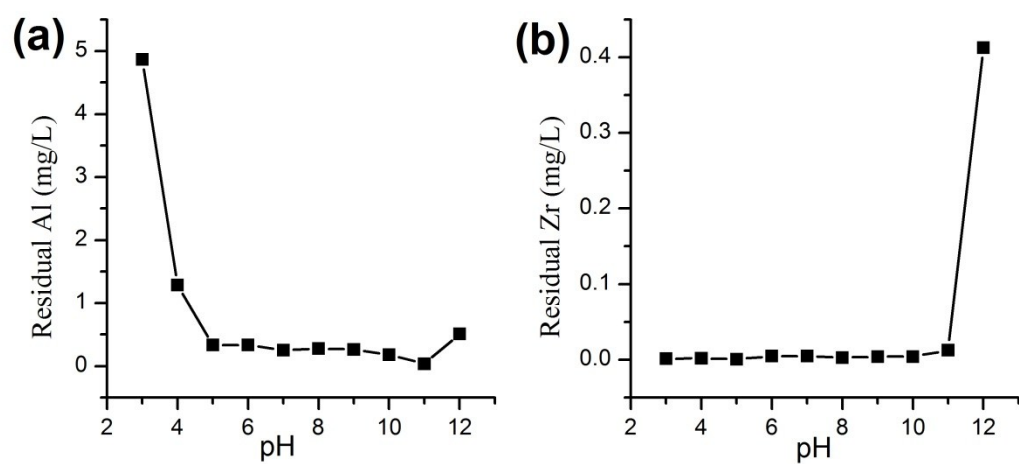


Fig. S2. Residual concentration of Al (a) and Zr (b) in solution with pH after adsorption by CMS-Al-Zr.

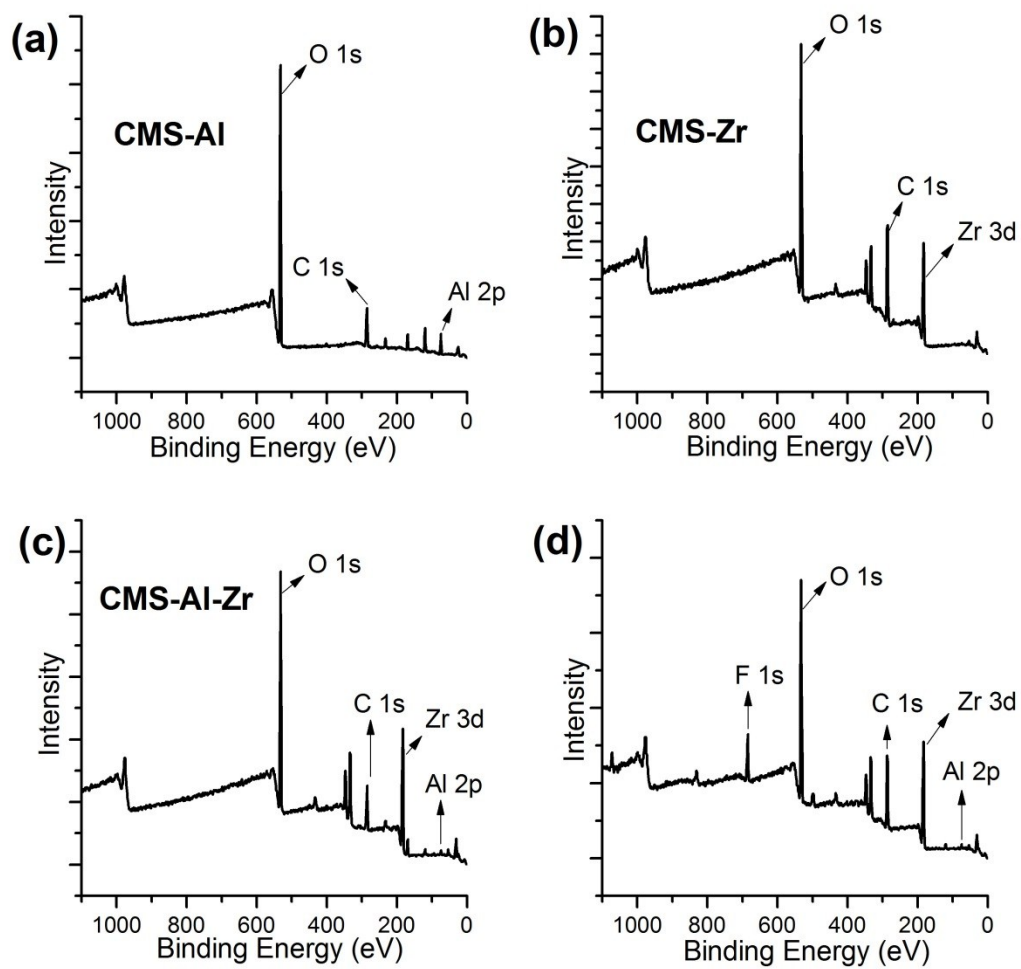


Fig. S3. XPS wide scan spectra of the adsorbents (a) CMS-Al, (b) CMS-Zr, (c) CMS-Al-Zr and (d) CMS-Al-Zr-F.

References

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