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Characterisation of a new adsorbent (beta cyclodextrin modified hybrid hydrous iron-zirconium oxide) to remove fluoride from aqueous solution

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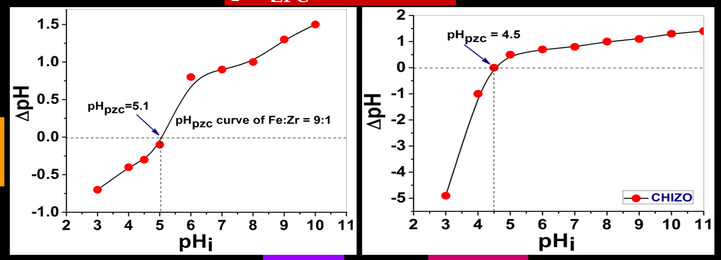
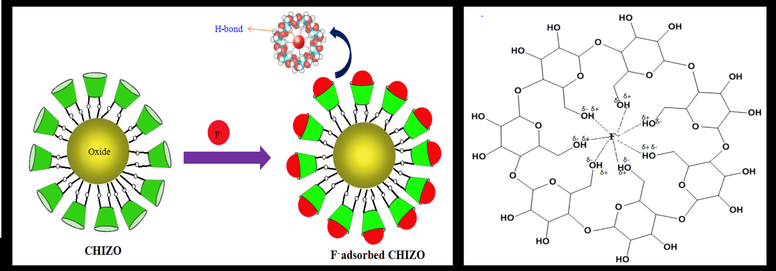
Synthesis of β-Cyclodextrin modified hydrous iron-zirconium hybrid oxide (CHIZO)

$FeCl_3 + ZrOCl_2$ in 0.1M HCl + β-cylodextrin (9:1 mol ratio) → Constant stirring → 0.01MNaOH, pH=7.0 → Brown precipitate → Washed, Filtered, Dried at 100°C → Solid mass → ground → Particle size 140-290 nm are used for experiment

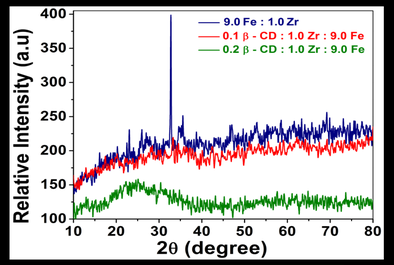
pH_{ZPC} estimation



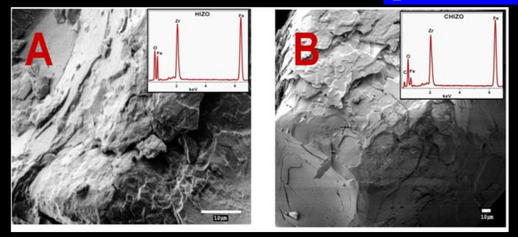
Mechanism of fluoride adsorption over CHIZO surface



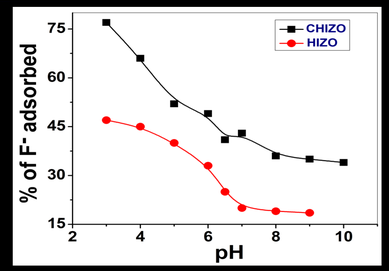
XRD pattern



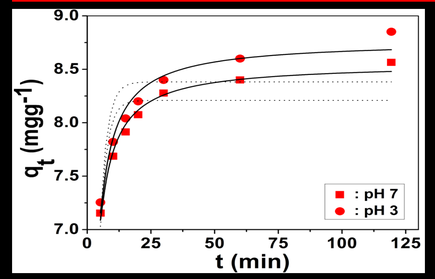
SEM image



pH effect of CHIZO and HIZO at 303K

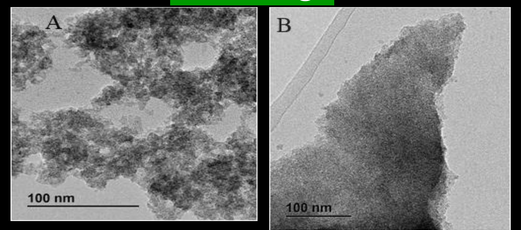


Defluoridation kinetics of CHIZO at T=303K, pH=7 and 3

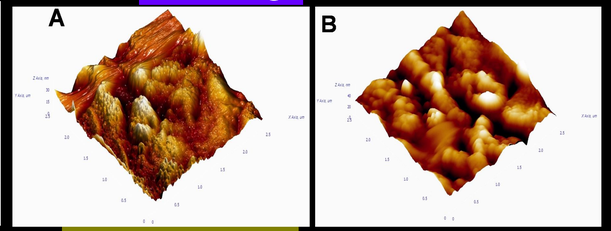


Concentration ([F_o], mg.L^{-1})	Adsorbent	Pseudo-first order $q_t = q_e\,[1-\exp(-k_1.t)]$				Pseudo-second order $q_t = t.k_2.q_e^2/(1+k_2q_e t)$			
		k_1	q_e	R^2	χ^2	k_2	q_e	R^2	χ^2
10	CHIZO (pH=3.0)	0.364	8.38	0.68	0.107	0.0977	8.768	0.97	0.0115
	CHIZO (pH=7.0)	0.374	8.21	0.72	0.077	0.1087	8.556	0.98	0.00423

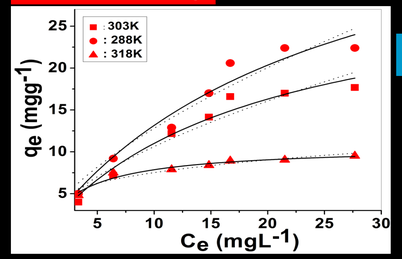
TEM image



AFM image



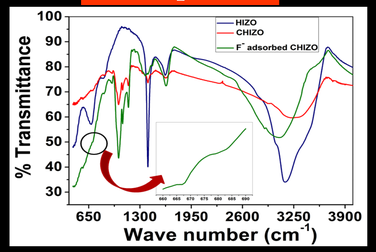
Isotherm study



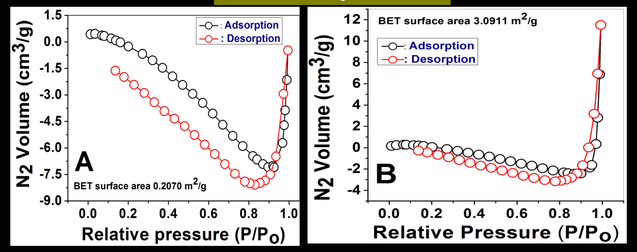
Thermodynamic parameters evaluated for fluoride adsorption on CHIZO

Species	$[F]_0$ (mgL^{-1})	ΔH^0 ($kJmol^{-1}$)	ΔS^0 ($Jmol^{-1}K^{-1}$)	ΔG^0($kJmol^{-1}$)		
				288K	303K	318K
CHIZO	25	59.89	-209.66	-0.81	0.015	1.126

FTIR spectra



BET analysis



- CHIZO used for fluoride adsorption is a composite of HIZO and β-CD. It is an amorphous functional material with irregular surface morphology and high surface site density. The particle size on average is 150 nm which is higher than pristine HIZO (~ 6-8 nm).
- Predominantly pseudo-second order kinetic model for adsorption of fluoride over CHIZO was found to be the best fit.
- Monolayer adsorption capacity of CHIZO was notably higher than commonly found adsorbents.
- Thermodynamic modeling envisages that the adsorption process over CHIZO was exothermic in nature.
- Fluoride adsorption over CHIZO occurs through the formation of H- bonding with surface –OH groups.

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