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PHENOL ADSORPTION ONTO HIGH SURFACE AREA ACTIVATED CARBON PREPARED FROM AGRICULTURE WASTE FOX NUTSHELL BY CHEMICAL ACTIVATION WITH H_3PO_4: BATCH AND FIXED BED STUDIES

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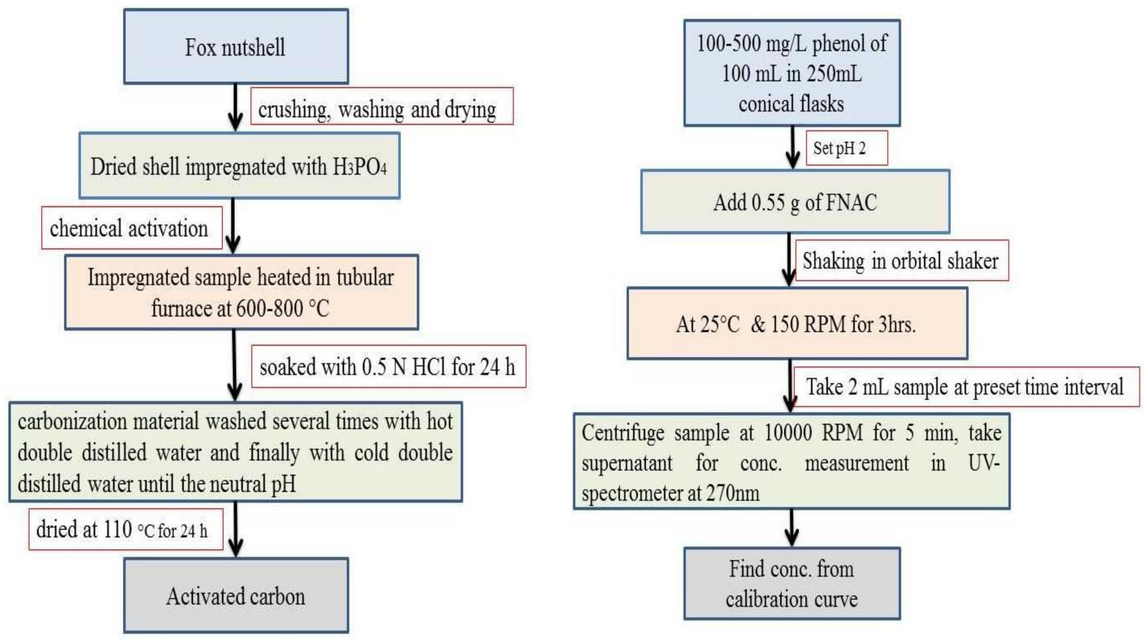
Abstract

High surface area activated carbon (FNAC) prepared from Fox nutshell with H_3PO_4 activating agent is utilized for removal of phenol from aqueous solution. The prepared FNAC has high surface area of 2636 $m^2\ g^{-1}$ and total pore volume of 1.53 $cm^3\ g^{-1}$ with 86.27 % micropores and average pore diameter of 2.32 nm. FNAC exhibited high adsorption capacity of 83.21 mg g^{-1} to phenol uptake. Pseudo second order kinetics and Freundlich isotherm model best fit to the experimental data. Fixed bed study resulted in highest capacity of 75.64 mg g^{-1} at 100 mg l^{-1} initial phenol conc., 4 cm bed height and 5 ml min^{-1} flowrate.

Methodology



Results

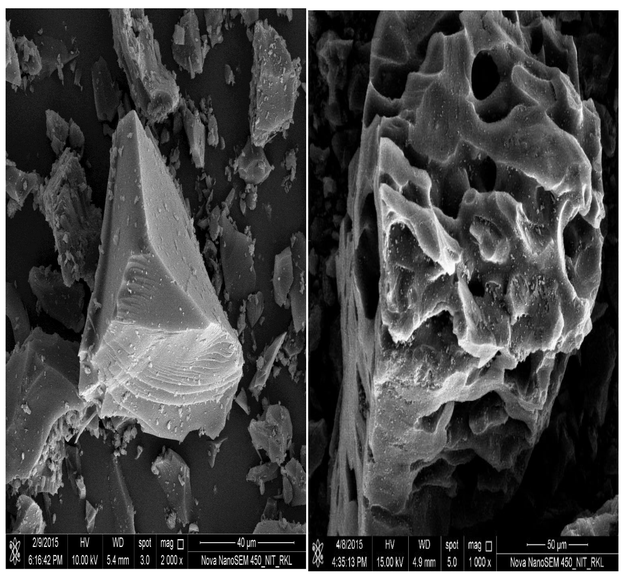
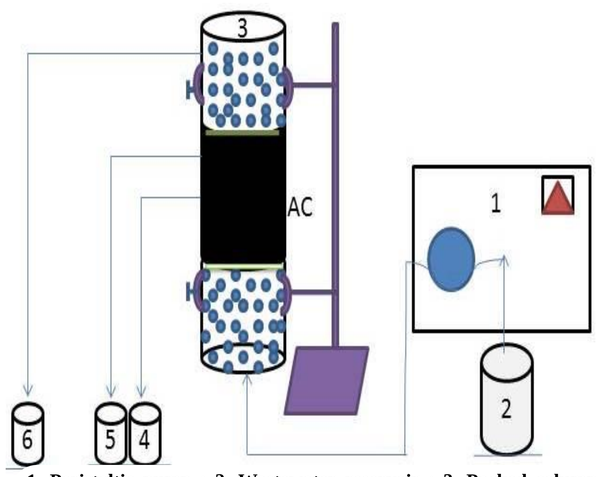


Fig.1. FESEM images of the Fox nutshell and FNAC



1. Peristaltic pump ; 2. Wastewater reservoir ; 3. Packed column (glass beads + cotton + activated carbon + cotton + glass beads) ; 4./5./6. Sample storing vial (at each 1 cm height of filled activated carbon)

Fig.2. Schematic diagram of a fixed bed adsorption column

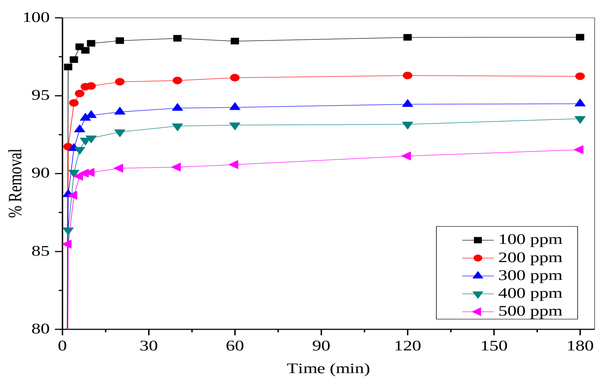


Fig.3. % removal of phenol at different initial concentrations. mass of adsorbent: 0.55 g, phenol conc.= 100mg/L, pH = 2.0, Temp.= 25 °C.

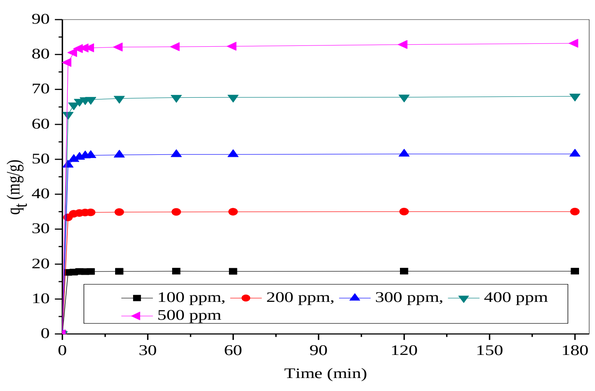


Fig. 4. Effects of contact time on the adsorption capacity at different initial concentrations. mass of adsorbent: 0.55 g phenol conc.= 100mg/L, pH = 2.0, Temp.= 25 °C.

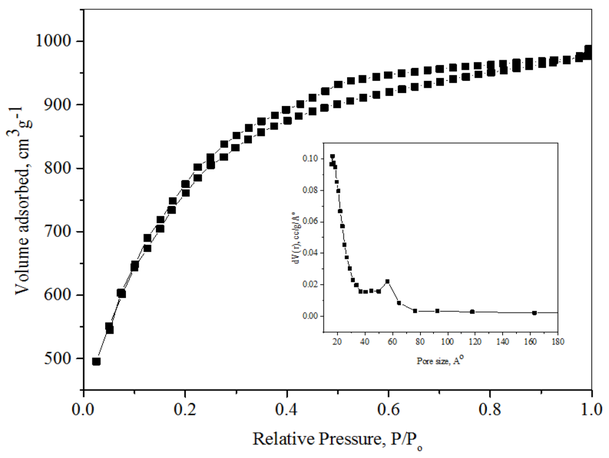


Fig.5. Nitrogen adsorption–desorption isotherms FNAC

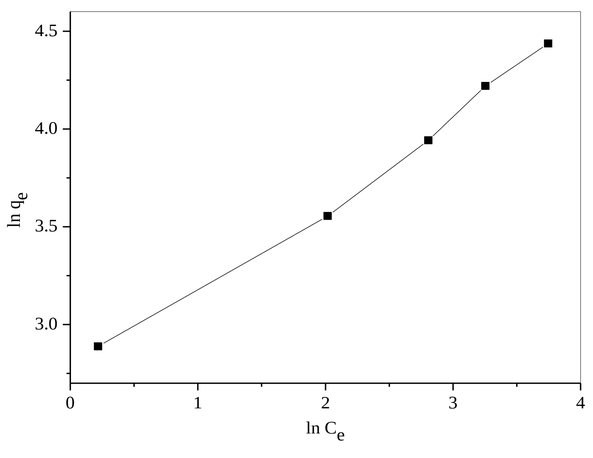


Fig.6. Freundlich isotherms for the adsorption of phenol onto the FNAC

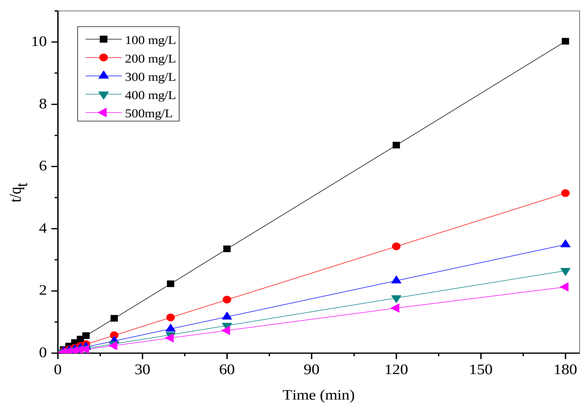


Fig. 7. Pseudo-second order kinetic plot for the phenol adsorption by FNAC at different concentrations. Experimental conditions: pH 2.0; 25 °C; adsorbent weight, 0.55 g.

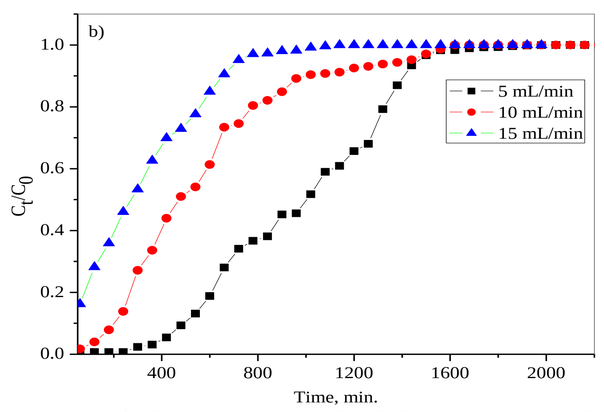


Fig.8. Breakthrough curves of phenol adsorption on prepared activated carbon (FNAC) at different flow rates (initial adsorbates concentration = 100 mg/L, bed height = 4 cm)

Table 1. Proximate, ultimate analysis, Product yields, and Pore structure characterization of prepared activated carbon FNAC.

Prepared activated carbon (FNAC)					
Proximate analysis	(wt%)	Ultimate analysis	(wt%)	Pore structure characteristics	
Moisture	3.12	C	84.85	S_{BET} (m^2/g)	2636
Volatile matter	21.05	H	3.52	V_T (cm^3/g)	1.53
Ash	2.12	N	1.24	V_μ (cm^3/g)	1.32
Fixed carbon[a]	73.71	S	0.15	Vm (cm^3/g)	0.23
Yield (%)	30.35	O [a]	10.24	V_μ/V_T (%)	86.27
[a] by difference				D_p (nm)	2.32

S_{BET}: BET surface area, V_T: total pore volume, V_μ: micropore volume, V_m: mesopore volume, $V_\mu\% = (V_\mu/V_T) \times 100$, D_p: average diameter.

Table 2. Pseudo-first-order and pseudo-second-order constants for the phenol adsorption on FNAC at 25 °C.

Parameters	C_0 (mg/L) Phenol				
	100	200	300	400	500
$q_{e,exp}$ (mg g^{-1})	17.95	34.99	51.53	68.02	83.21
Pseudo first order					
$q_{e,cal}$ (mg g^{-1})	0.442	1.80	1.32	6.58	7.02
h_0 (mg g−1 min−1)	8.11	26.76	14.43	35.00	35.90
K_1(min^{-1})	0.0811	0.1338	0.0481	0.0875	0.0718
R^2	0.797	0.889	0.940	0.694	0.694
Δq (%)	32.51	31.62	32.48	30.12	30.52
Pseudo second order					
$q_{e,cal}$ (mg g^{-1})	17.96	35.01	50.15	68.03	84.17
k_2 (g (mg min)$^{-1}$)	0.939	0.349	0.171	0.084	0.024
h_0 (mg g^{-1} min^{-1})	302.88	427.77	430.07	388.76	170.03
R^2	1	1	1	1	1
Δq (%)	0.0186	0.019	0.893	0.0049	0.384

Table 3. Langmuir, Freundlich and Tempkin parameters for the phenol adsorption of on FNAC at 25 °C temperature.

C_0 (mg L^{-1})	Freundlich			Langmuir			Tempkin		
	k_F (mg/g(L/mg)$^{1/n}$)	n	R^2	q_m (mg/g)	k_L (L/mg)	R^2	b	A (L/g)	R^2
Phenol	15.58	2.27	0.988	101.83	0.086	0.914	136.58	1.53	0.876

Table 4. Thermodynamic parameters for the adsorption of Phenol onto activated carbon.

T(K)	ΔG (kJ/mol)	ΔH (kJ/mol)	ΔS (J/molK)
298	-1.2	-18.33	-57.83
303	-0.75		
308	-0.39		
313	-0.24		
318	-0.013		

Table.5 Column data parameters obtained at different bed heights and flow rates

Phenol Initial concentration (100 mg/L)					
Bed height (cm)	Flow rate (mL/min)	Breakthrough time (min)	exhaustion time (min)	Bed capacity, q_{eq} (mg/g)	% Removal
4	5	420	1500	75.64	44.49
3	5	150	1140	65.05	42.43
2	5	40	780	47.0	27.65
4	10	135	1440	82.81	32.06
4	15	30	720	61.86	22.91

Conclusion

High surface area activated carbon (FNAC) prepared from Fox nutshell with H_3PO_4 activating agent is found to be an extremely promising material for the successful removal of contaminant such as phenol from the wastewater. The phenol adsorption is physical one and exothermic in nature.

Selected References

1. Damjanović, L., Rakić, V., Rac, V., Stošić, D., Auroux, A., 2010. The investigation of phenol removal from aqueous solutions by zeolites as solid adsorbents. J. Hazard. Mater. 184(1–3), 477–484.
2. Ahmaruzzaman, M., Sharma, D.K., 2005. Adsorption of phenols from wastewater. J. Colloid Interface Sci. 287, 14–24.
3. Lin, S.H., Juang, R.S., 2009. Adsorption of phenol and its derivatives from water using synthetic resins and low-cost natural adsorbents: a review. J. Environ. Manage. 90(3), 1336–1349.

Related publications

1. Kumar, Arvind, **Jena, H.M.**, 2017. Adsorption of Cr(VI) from aqueous solution by prepared high surface area activated carbon from Fox nutshell by chemical activation with H_3PO_4. Journal of Environmental Chemical Engineering 5, 2032–2041.
2. Kumar, Arvind, **Jena, H.M.**, 2016. Preparation and characterization of high surface area activated carbon from Fox nut (Euryale ferox) shell by chemical activation with H_3PO_4. Results in Physics 6 (2016), 651-658.
3. Kumar, Arvind, **Jena, H.M.**, 2016. Removal of methylene blue and phenol onto prepared activated carbon from Fox nutshell by chemical activation in batch and fixed-bed column. Journal of Cleaner Production 137, 1246-1259.\
4. Kumar, Arvind, **Jena, H.M.,** 2015. High surface area microporous activated carbons prepared from Foxnut (Euryale ferox) shell by zinc chloride activation. Applied Surface Science 356, 753-761.