

Supplementary data

Ultrasound-assisted adsorptive removal of Cd, Cu, Ni and Mn from environmental samples using Fe₃O₄-ZrO₂@APS nanocomposite: Kinetic and equilibrium isotherm studies

Aphiwe Siyasanga Gugushe¹, Anele Mpupa^{1,2}, Tshimangadzo S. Munonde^{1,2}, Luthando Nyaba^{1,2}, Philiswa N. Nomngongo^{1,2,3*}

¹*Department of Chemical Sciences, University of Johannesburg, Doornfontein Campus, P.O. Box 17011, Johannesburg, 2028, South Africa*

²*DSI/NRF SARChI: Nanotechnology for Water, University of Johannesburg, Doornfontein 2028, South Africa*

³*DSI/Mintek Nanotechnology Innovation Centre, University of Johannesburg, Doornfontein, 2028, South Africa*

Table S1 Experimental range and levels of independent variables

Variables	Minimum (-)	Central point (0)	Maximum (+)
Sample pH	3	6	9
Mass of Adsorbent (MA)(mg)	50	75	100

Table S2 The central composite design for the two independent variables

Standard Run	Variables		%removal efficiency			
	pH	MA(mg)	Cd	Cu	Mn	Ni
1	3	50	61.7	41.5	39.1	61.7
2	3	100	70.1	55.7	57.3	55.9
3	9	50	75.9	95.0	99.4	87.0
4	9	100	92.9	93.4	94.5	91.8
5	1.8	75	38.4	33.1	46.9	41.1
6	10	75	88.0	88.0	89.0	89.9
7	6	40	50.8	39.2	35.4	42.2
8	6	110	94.4	93.3	91.5	93.2
9 (C)	6	75	92.0	92.9	95.0	93.3
10 (C)	6	75	92.0	92.4	94.1	94.3
11 (C)	6	75	92.0	93.4	95.0	92.7
12 (C)	6	75	92.0	92.4	94.9	93.6

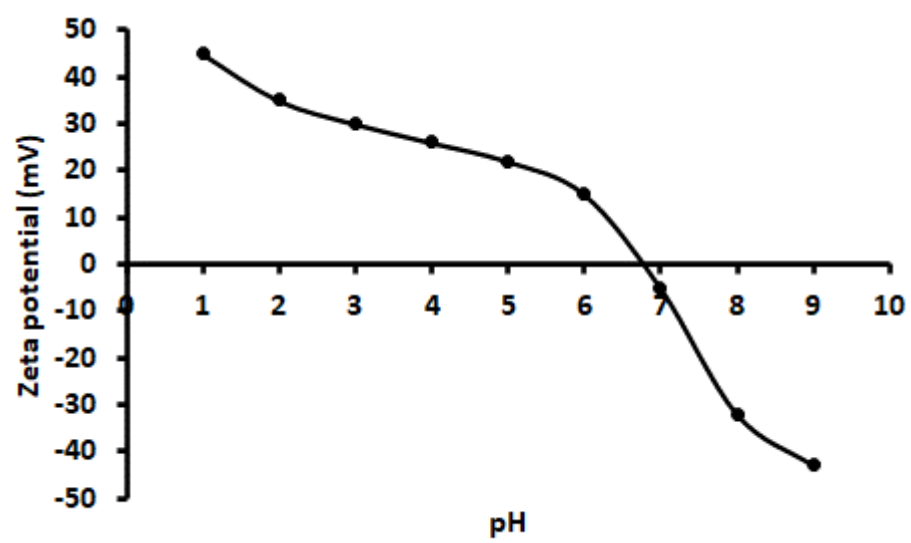


Fig. S1 Determination of point of zero charge

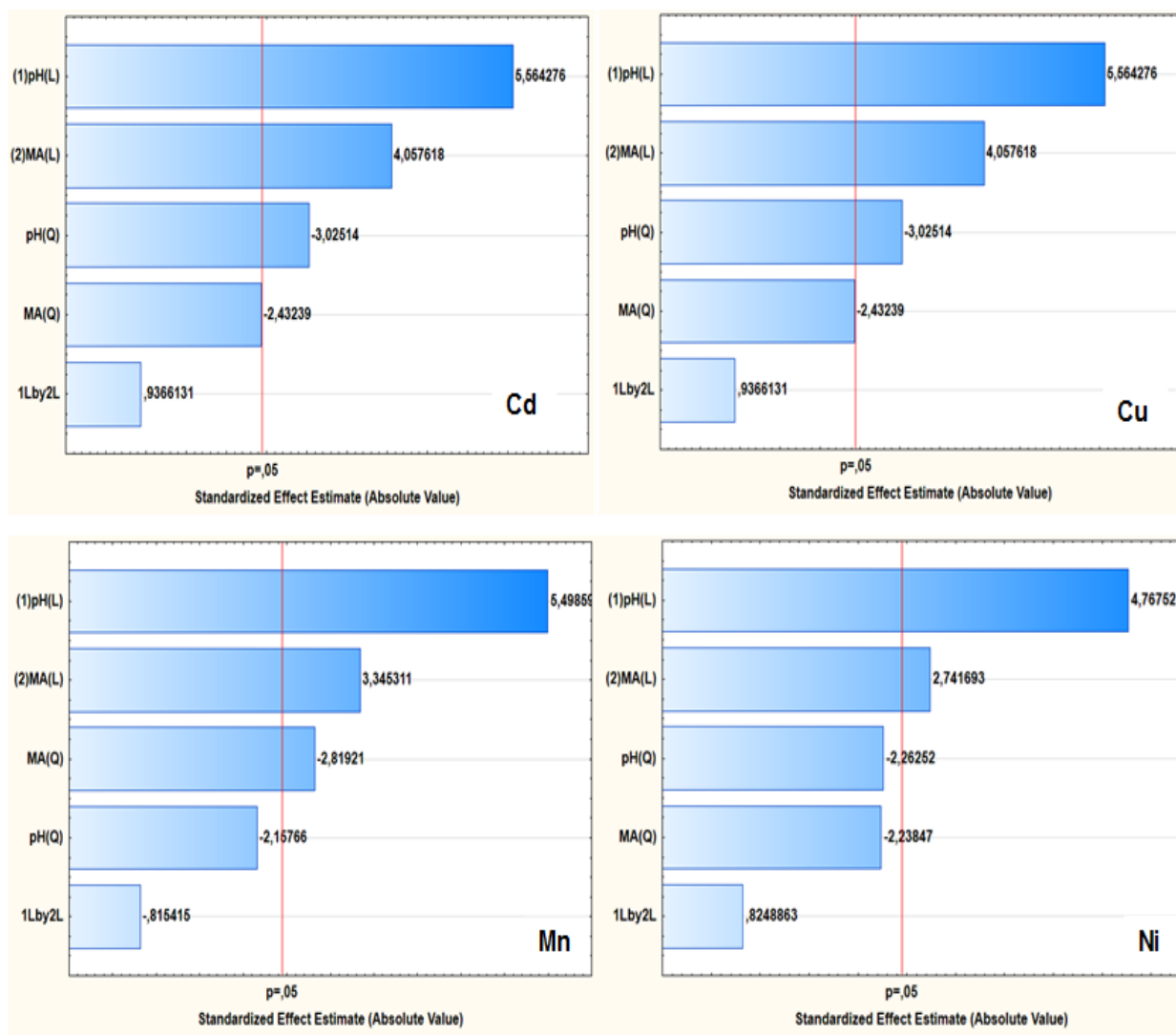


Fig. S2Pareto Chart for Cadmium(Cd), Copper(Cu), Manganese(Mn) and Nickel(Ni)

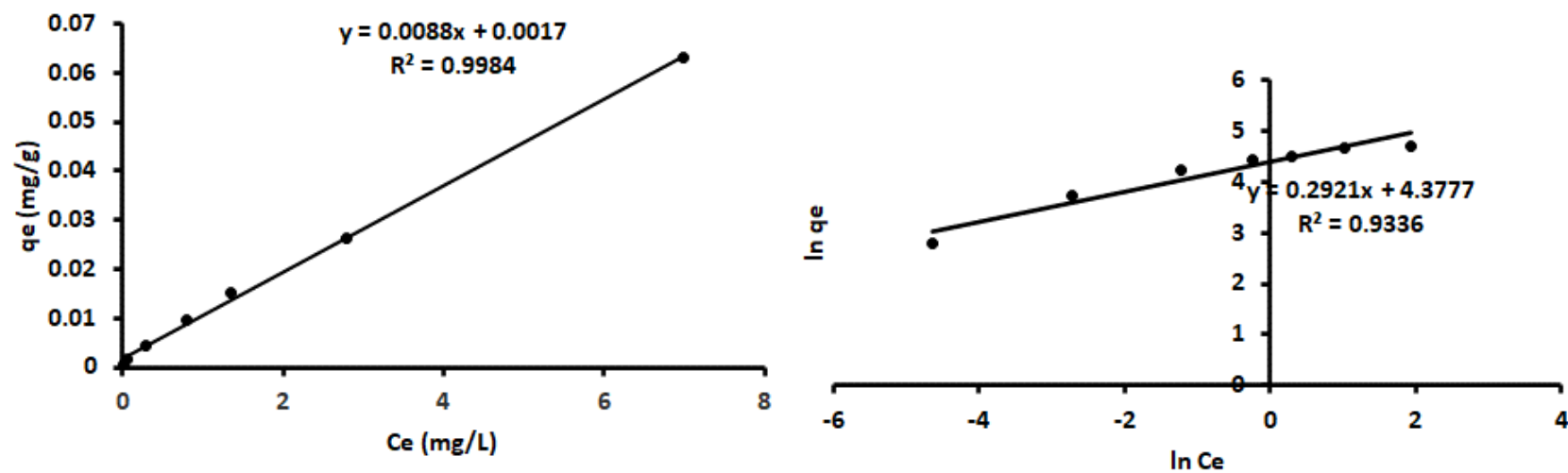


Fig S3 Application of isotherm models to experimental adsorption data of Cd by Fe₃O₄-ZrO₂@APS nanocomposite (a) Langmuir and (b) Freundlich

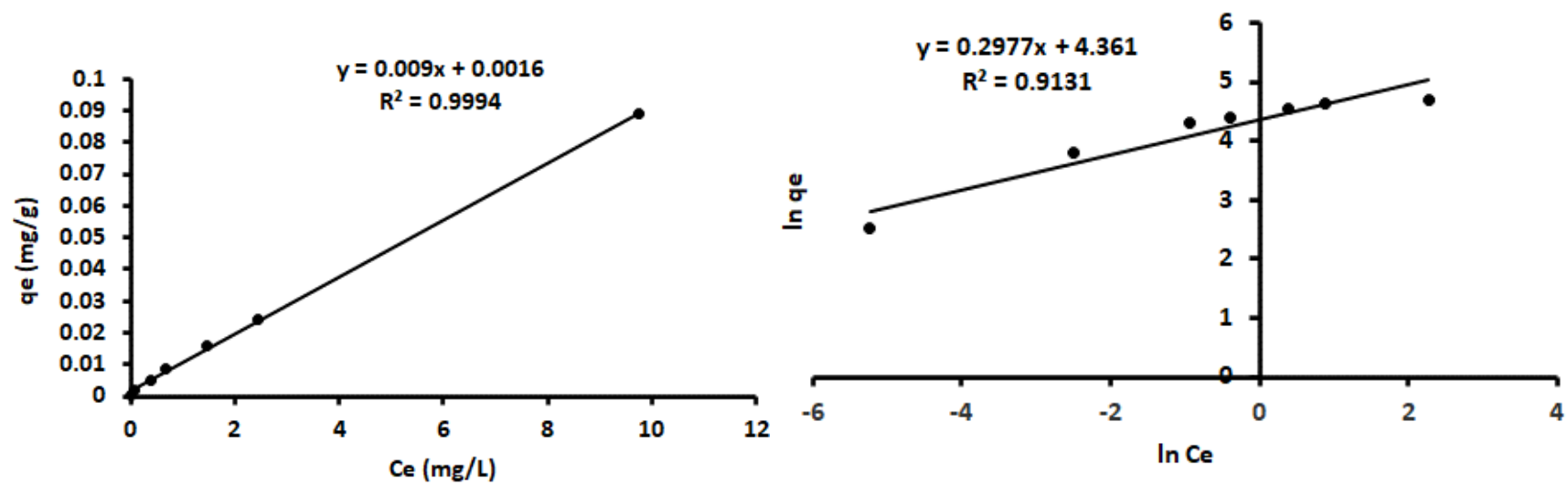


Fig S4 Application of isotherm models to experimental adsorption data of Cu by Fe₃O₄-ZrO₂@APS nanocomposite (a) Langmuir and (b) Freundlich

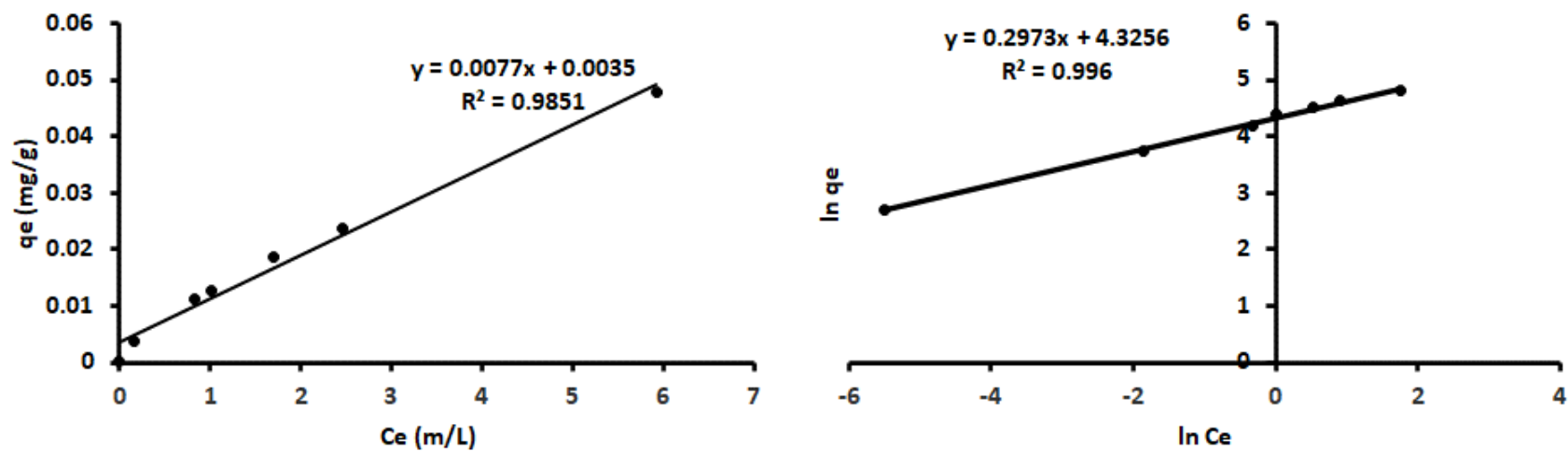


Fig S5 Application of isotherm models to experimental adsorption data of Ni by Fe₃O₄-ZrO₂@APS nanocomposite (a) Langmuir and (b) Freundlich

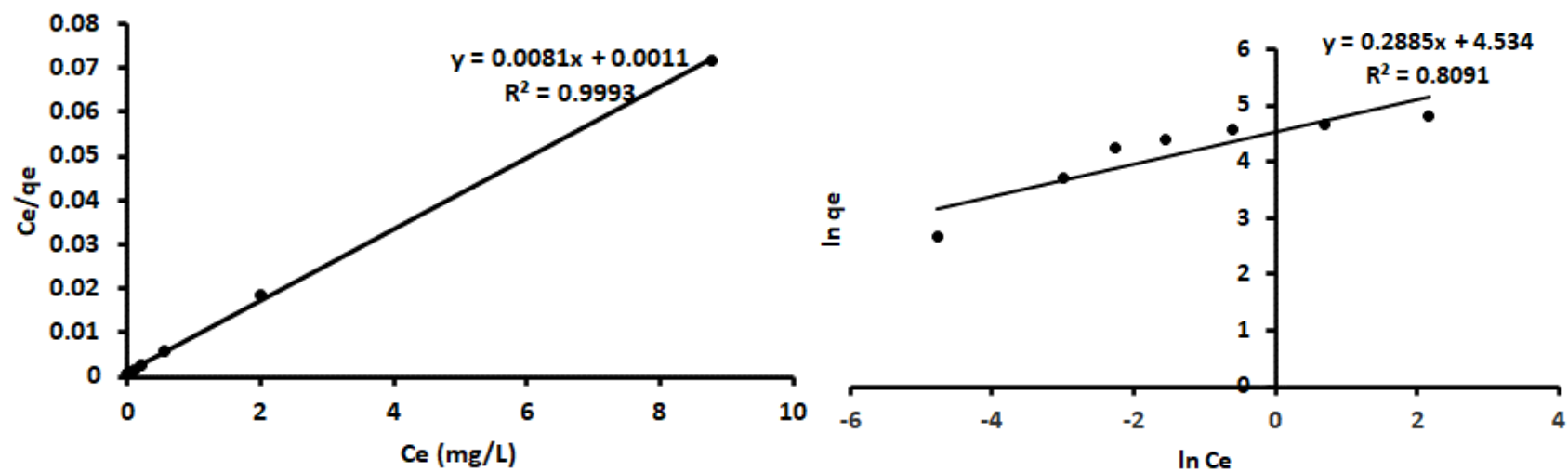


Fig S6 Application of isotherm models to experimental adsorption data of Mn by $\text{Fe}_3\text{O}_4\text{-ZrO}_2\text{@APS}$ nanocomposite (a) Langmuir and (b) Freundlich

