Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Electronic supplementary information (ESI):

Fig. S1

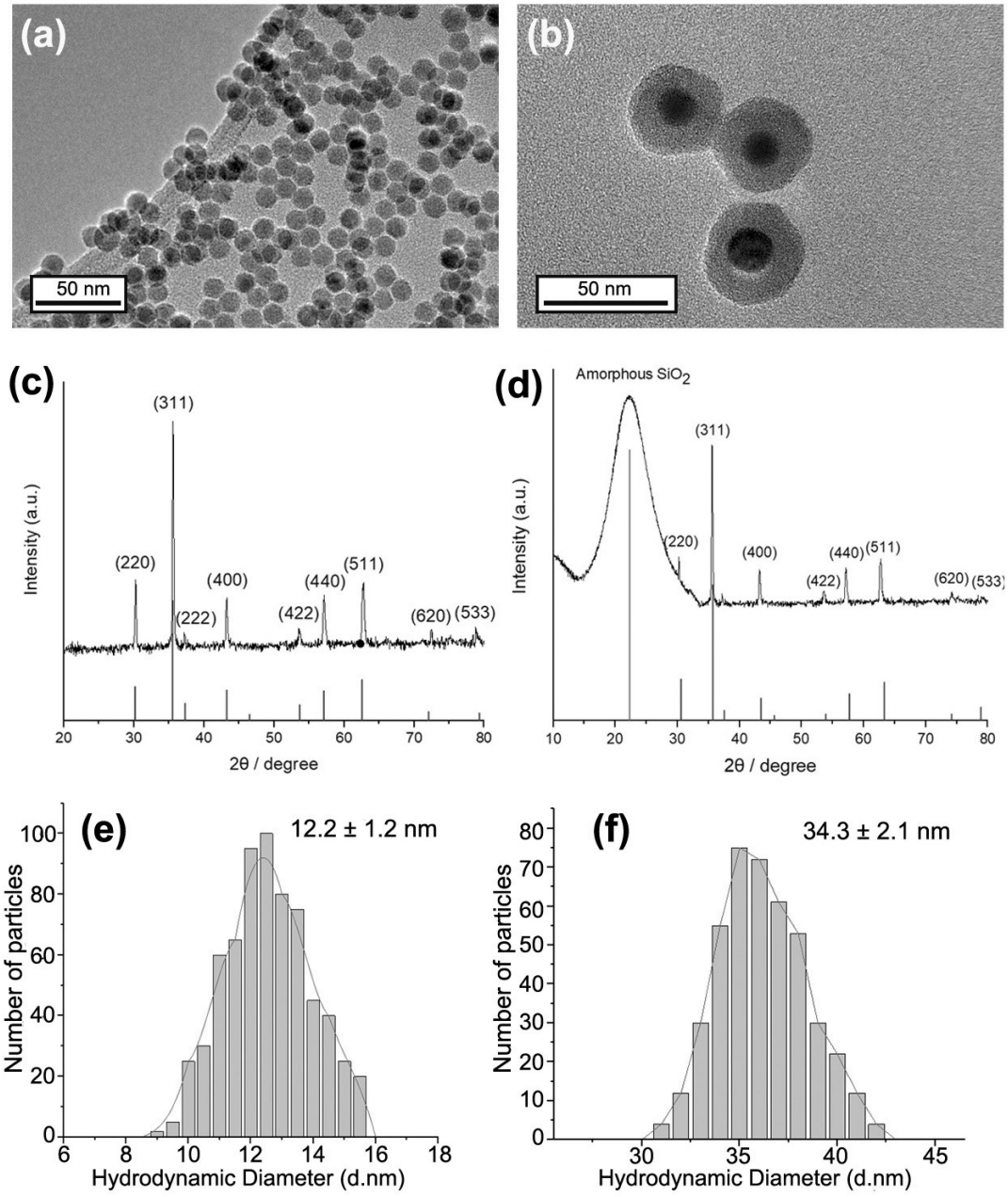
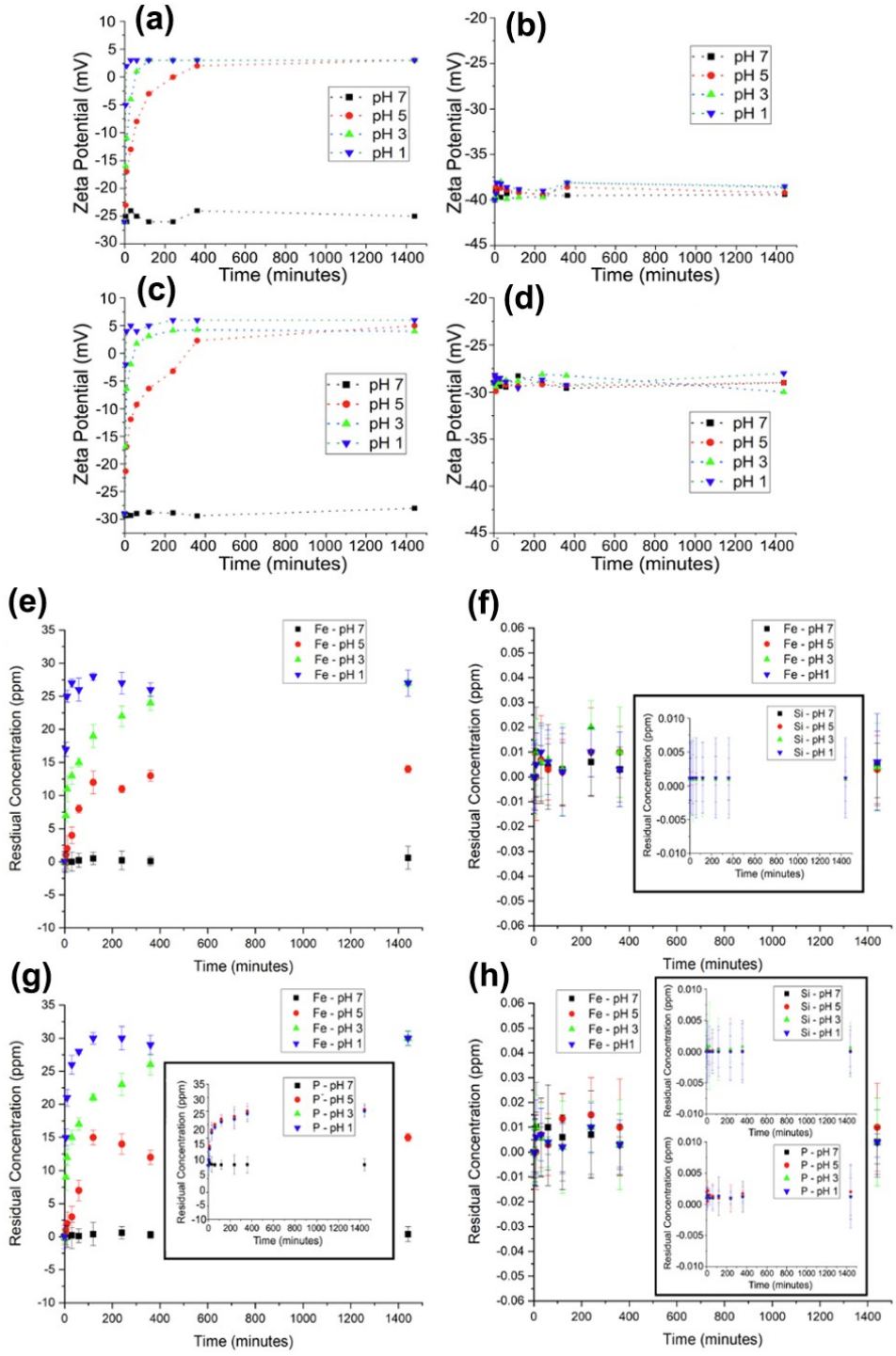


Fig . S1 TEM micrographs of (a) 12 nm Fe_3O_4 NPs; (b) 34 nm SiO_2@Fe_3O_4 (core-shell) NPs; XRD patterns of (c) Fe_3O_4 NPs; (d) SiO_2@Fe_3O_4 NPs (magnetite reference patterns represented by blue line, silica reference pattern represented by the red line); DLS measurement of the hydrodynamic diameter of (e) Fe_3O_4 NPs at pH 7 and; (f) SiO_2@Fe_3O_4 NPs at pH 7.

Fig. S2



Dissolution AND NP leaching data (a) Zeta potential measurements of Fe_3O_4 NPs (pH 7, pH 5, pH 3 and pH 1; (b) zeta potential measurements of SiO_2@Fe_3O_4 NPs; (c) zeta potential measurements of $(PO)_x$-Fe_3O_4; (d) zeta potential measurements of $(PO)_x$-SiO_2@Fe_3O_4 NPs from pH 7, pH 5, pH 3 and pH 1. ICP-OES data for NP dissolution and leaching (e) Fe_3O_4 NPs; (f) SiO_2@Fe_3O_4 NPs (Si concentration insert); (g) $(PO)_x$-Fe_3O_4 NPs (P concentration insert); (g) $(PO)_x$-SiO_2@Fe_3O_4 NPs (Si and P concentration insert). ICP-OES measurements were taken at 5, 10, 30, 60, 120, 240, 360 and 1440 minutes.[18]

Fig. S3

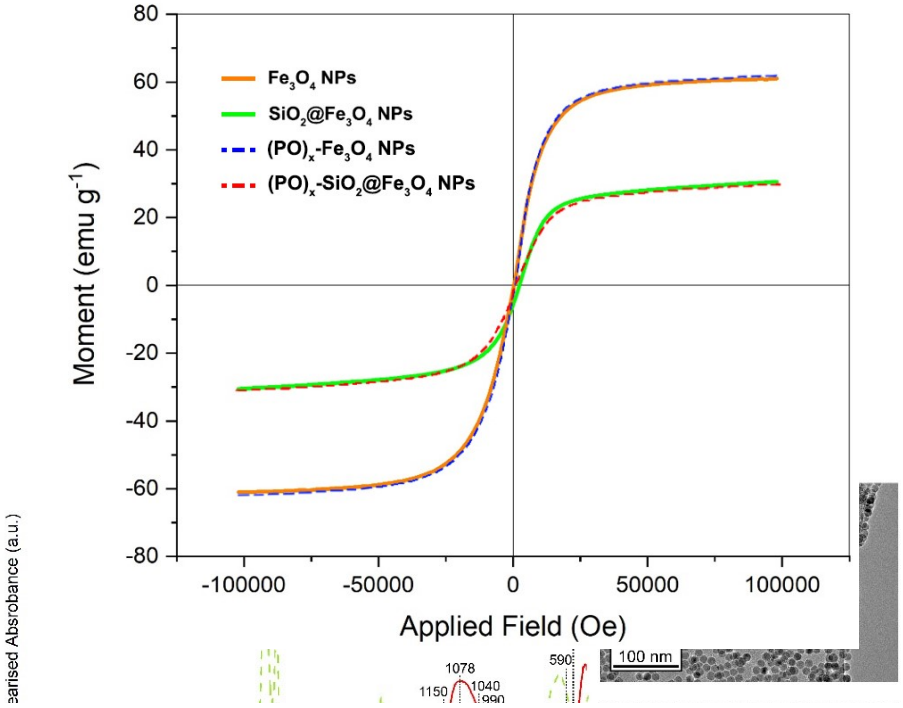


Fig. S4

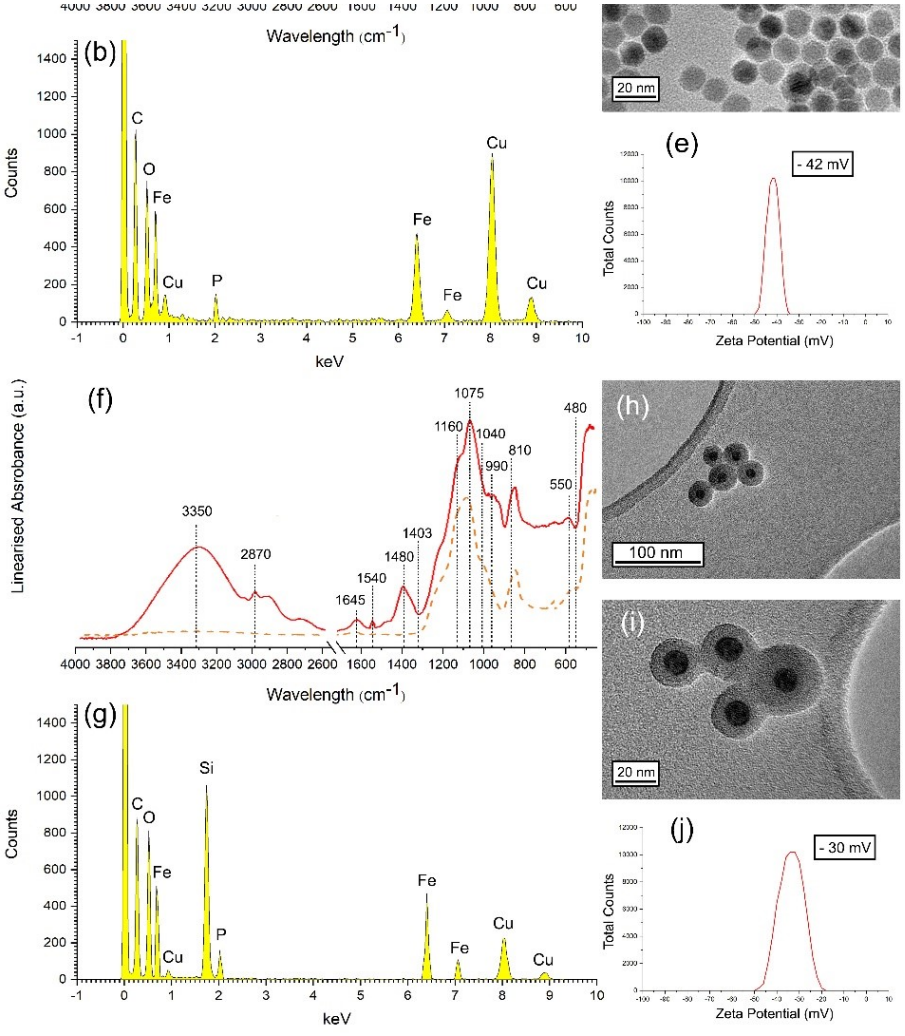


Fig. S3 Vibrating Sample Magnetometry (VSM) at 300 K of both Fe_3O_4 and SiO_2@Fe_3O_4 NPs and functionalised $(PO)_x$-Fe_3O_4 and $(PO)_x$-SiO_2@Fe_3O_4 NPs. With the absence of hysteresis, NP complexes showing superparamagnetism.

Fig. S4 (a) ATR-FTIR spectra obtained for OA-Fe_3O_4 NPs (green dashed line) and $(PO)_x$-Fe_3O_4 NPs (red line). Normalised with respect to the Fe–O stretching peaks; (b) EDX spectrum acquired in TEM mode for a $(PO)_x$-Fe_3O_4 NP sample; (c)-(d) TEM images depicting the 12 nm $(PO)_x$-Fe_3O_4 NPs; (e) z-potential negative value obtained for the $(PO)_x$-Fe_3O_4 NPs at pH 7; (f) ATR-FTIR spectra obtained for SiO_2@Fe_3O_4 NPs (orange dashed line) and $(PO)_x$-SiO_2@Fe_3O_4 NPs (red line). Normalised with respect to the O-H stretching peaks; (g) EDX spectrum acquired in TEM mode for a $(PO)_x$-Fe_3O_4 NP sample; (h)-(i) TEM images depicting the 30 nm $(PO)_x$-SiO_2@Fe_3O_4 NPs; (j) z-potential negative value obtained for the $(PO)_x$-SiO_2@Fe_3O_4 NPs at pH 7.

Table. S1

Table. S1 $(PO)_x$-Fe_3O_4 and $(PO)_x$-SiO_2@Fe_3O_4 maximum loading capacities at pH 7.

	PO_x-Fe_3O_4	**PO_x-SiO_2@Fe_3O_4**
Metal Ion	**Maximum loading capacity (mg Metal Ion per g MNP)**	
Cs(I)	464.00	432.80
K(I)	515.84	447.60
Na(I)	451.40	425.28
Ca(II)	420.00	366.00
Cd(II)	427.24	376.80
Co(II)	537.44	539.88
Cu(II)	536.64	530.80
Mg(II)	540.60	546.36
Mn(II)	533.48	521.60
Mo(II)	386.00	588.40
Ni(II)	540.04	542.56
Pb(II)	302.00	275.60
Sr(II)	532.68	486.80
Al(III)	544.80	560.80
Ce(III)	592.40	551.80
Cr(III)	590.40	560.40
Eu(III)	798.18	734.40
Fe(III)	798.27	798.22
La(III)	703.80	644.56

Table. S2 Extraction percentage of selected contaminant species with $(PO)_x$-Fe_3O_4 and $(PO)_x$-SiO_2@Fe_3O_4 at pH 7.

Table. S2

	PO_x-Fe_3O_4	**PO_x-SiO_2@Fe_3O_4**
Metal Ion	Extraction % (RSD %)	
Cs(I)	58.00 (2.40)	55.95 (3,84)
K(I)	64.48 (3.12)	66.35 (3.97)
Na(I)	56.43 (2.97)	54.10 (4.00)
Ca(II)	52.50 (4.00)	45.75 (3.16)
Cd(II)	53.41 (3.16)	47.10 (2.63)
Co(II)	67.18 (2.63)	70.10 (2.06)
Cu(II)	67.08 (2.06)	68.30 (3.55)
Mg(II)	67.56 (3.55)	53.16 (1.46)
Mn(II)	66.69 (1.64)	60.85 (3.14)
Mo(II)	48.25 (3.17)	73.55 (1.00)
Ni(II)	67.51 (1.24)	67.49 (2.29)
Pb(II)	37.75 (2.29)	34.45 (3.66)
Sr(II)	66.59 (2.20)	67.82 (3.35)
Al(III)	68.10 (3.07)	65.20 (1.96)
Ce(III)	74.01 (1.11)	68.98 (1.86)

Cr(III)	73.80 (1.86)	70.05 (2.13)
Eu(III)	99.77 (1.34)	91.80 (3.34)
Fe(III)	99.78 (2.34)	98.28 (2.19
La(III)	87.98 (2.09)	74.07 (2.41)

Table. S3 Total removed of metals ions from solution with $(PO)_x$-Fe_3O_4 NPs and Extraction percentage of selected contaminant species with $(PO)_x$-SiO_2@Fe_3O_4 NPs with varying pH (pH 3 – pH 11 respectively)

Table. S3

		PO_x-Fe_3O_4		PO_x-SiO_2@Fe_3O_4
Metal Ion	pH	Total Removed from Solution % (RSD %)	pH	Extraction % (RSD %)
Cs(I)	11	100.00 (4.12)	3	46.75 (1.06)
K(I)	11	99.75 (2.15)	3	65.85 (1.41)
Na(I)	11	69.55 (4.10)	3	51.10 (3.17)
Ca(II)	11	70.53 (2.33)	3	45.35 (3.68)
Cd(II)	11	100.00 (4.40)	3	46.80 (1.29)
Co(II)	11	100.00 (2.08)	3	46.75 (1.09)
Cu(II)	11	99.88 (4.21)	3	65.10 (3.04)
Mg(II)	11	98.07 (2.15)	3	49.11 (3.92)
Mn(II)	11	95.75 4.57)	3	55.85 (3.74)
Mo(II)	11	98.35 (3.78)	3	69.90 (2.87)
Ni(II)	11	99.87 (2.04)	3	62.75 (2.54)
Pb(II)	11	99.88 (4.18)	3	28.10 (3.77)

Sr(II)	11	70.53 (2.45)	3	48.85 (1.66)
Al(III)	11	93.05 (4.17)	3	64.25 (3.04)
Ce(III)	11	99.87 (3.43)	3	67.75 (3.67)
Cr(III)	11	86.65 (4.83)	3	67.25 (1.55)
Eu(III)	11	99.05 (4.64)	3	86.80 (2.14)
Fe(III)	11	100.00 (2.18)	3	96.41 (1.91)
La(III)	11	100.00 (2.94)	3	68.22 (1.45)