Novel polymer-based nanocomposites for application in heavy metal pollution remediation

Emerging Researcher Symposium

Lara Kotzé-Jacobs
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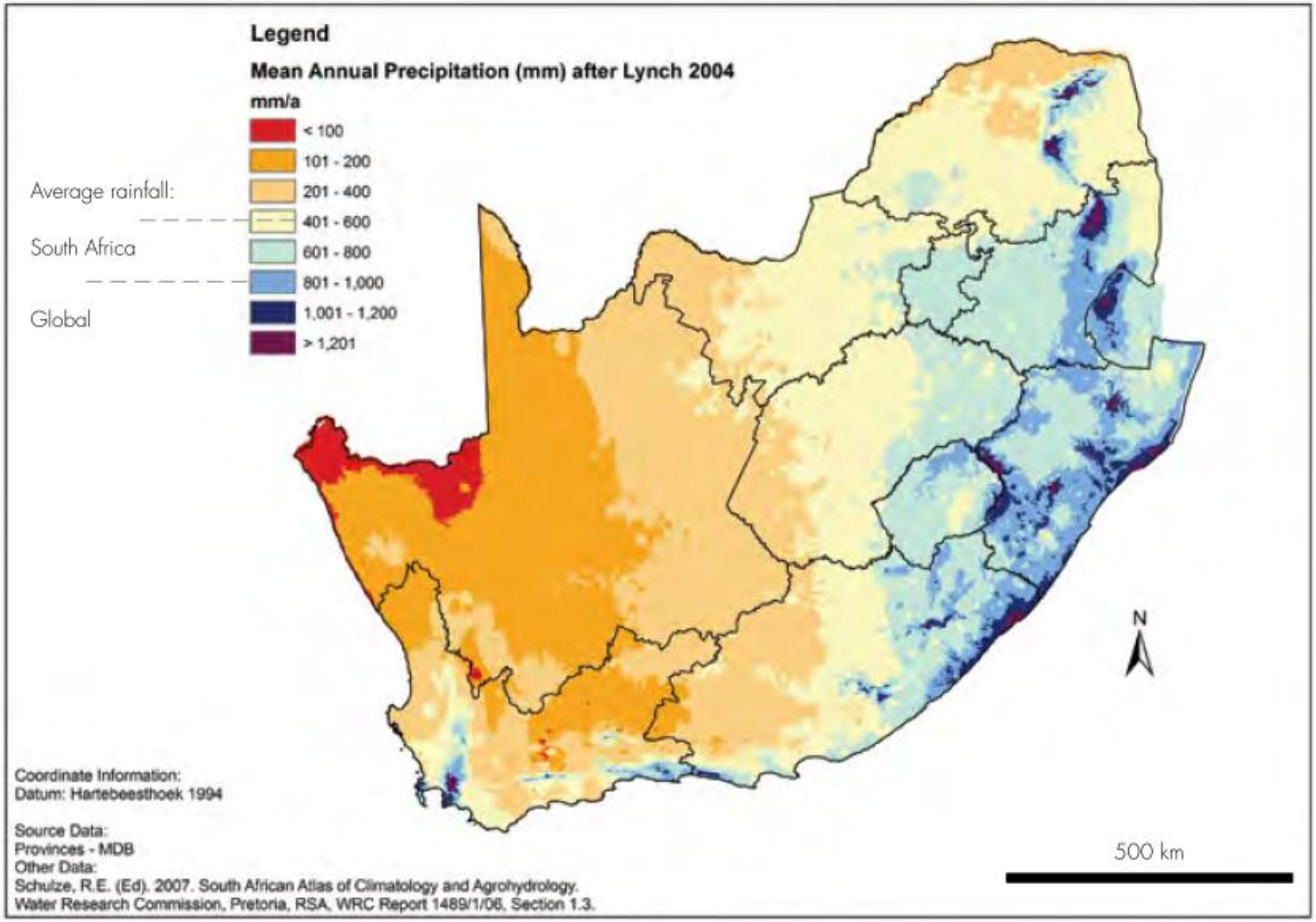
Introduction: SA's water problem

- SA is a water scarce country



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and

Introduction: Heavy metals

- Cr, Ni, Cu, Pb, As etc.
- Exposure can cause liver and kidney damage and also cancer
- Heavy metals can accumulate in food sources through heavy metal contamination of soil and plants

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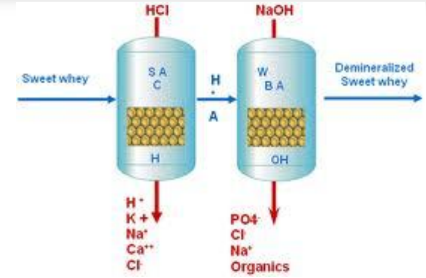
Removal of heavy metals



- Small volume applications: ion exchange
- Larger volumes eg. acid mine drainage: neutralisation and precipitation as well as reverse osmosis (membrane process)

- Ion exchange and reverse osmosis although very efficient is expensive (resins and membranes)

- Neutralisation and precipitation is not 100% effective at removing heavy metals at low concentrations <10ppm

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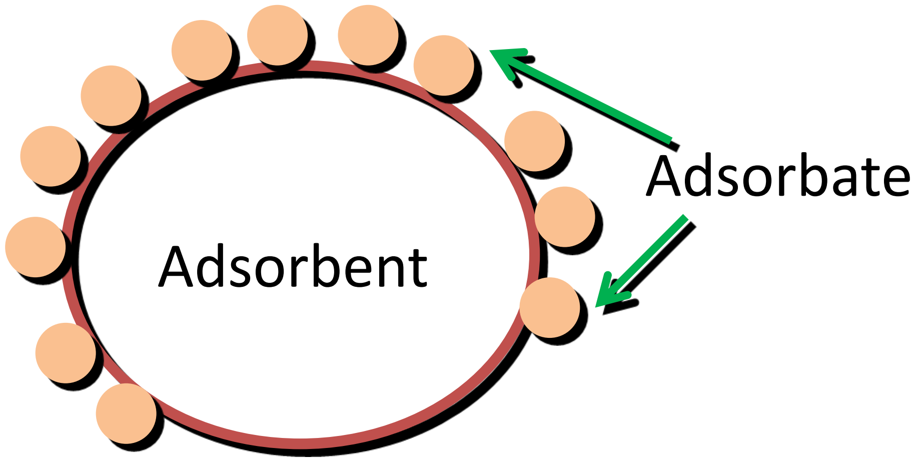
Adsorption for removal of heavy metals

- Most well known – activated charcoal/carbon
- A**d**sorption of atoms, ions or molecules from a gas, liquid, or dissolved solid to a surface – surface phenomenon

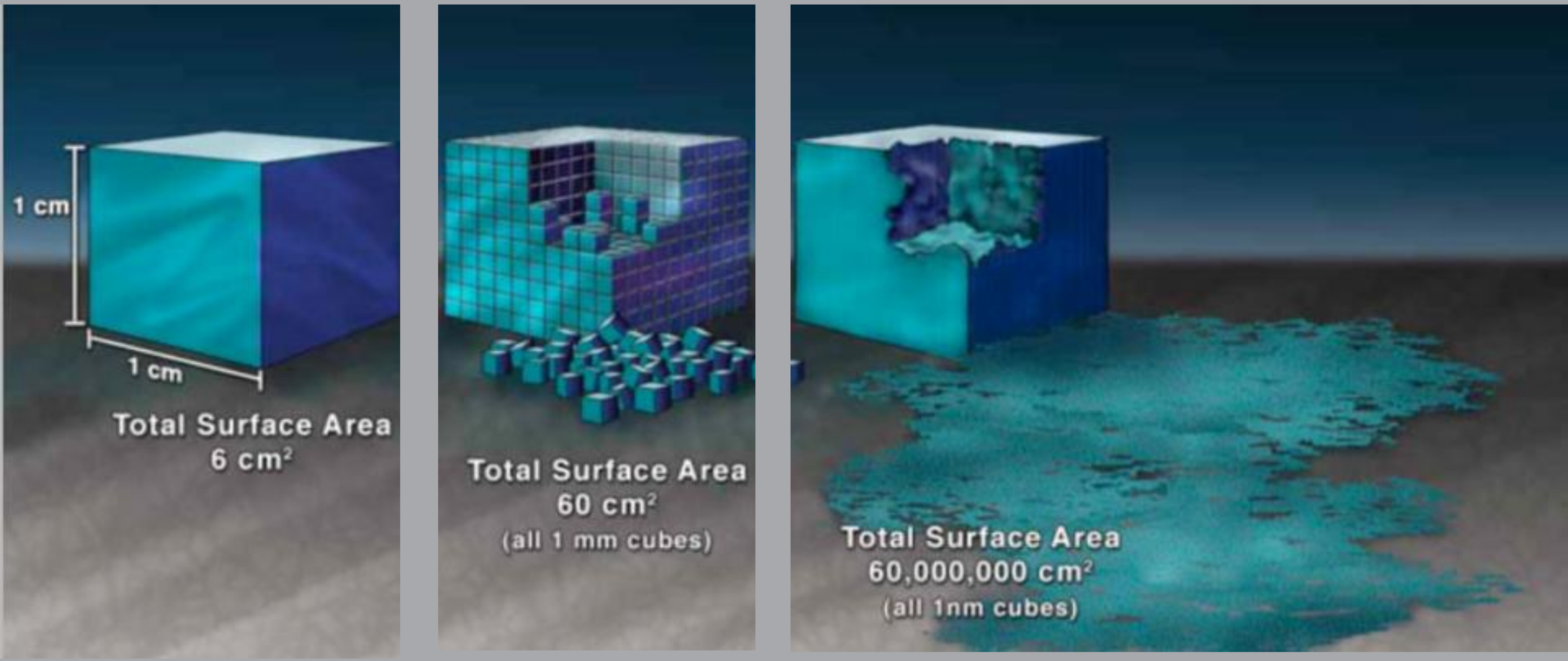


- A**b**sorption is a condition in which something takes in another substance- bulk phenomenon

Why use polymers nanocomposites as adsorbents?

- Nanocomposites are composites of polymers and inorganic/organic material where at least one of the components are smaller than 100nm
- Relative affordability of polymer nanocomposites
- Relative ease of manufacture of polymer nanocomposites

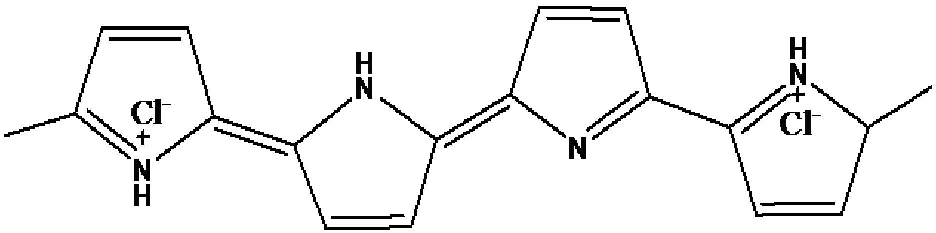
Nanocomposites



Larger surface ~ Increased adsorption

Materials and methods

- Polypyrrole



- Alumina <50nm

- Reagents are combined and polimerized with $FeCl_3$ to form the PPy/Alumina nanocomposite

Analysis of adsorption efficiency

- Adsorption of Cr(VI)

Cr(VI) free water

Magnetic stirrer

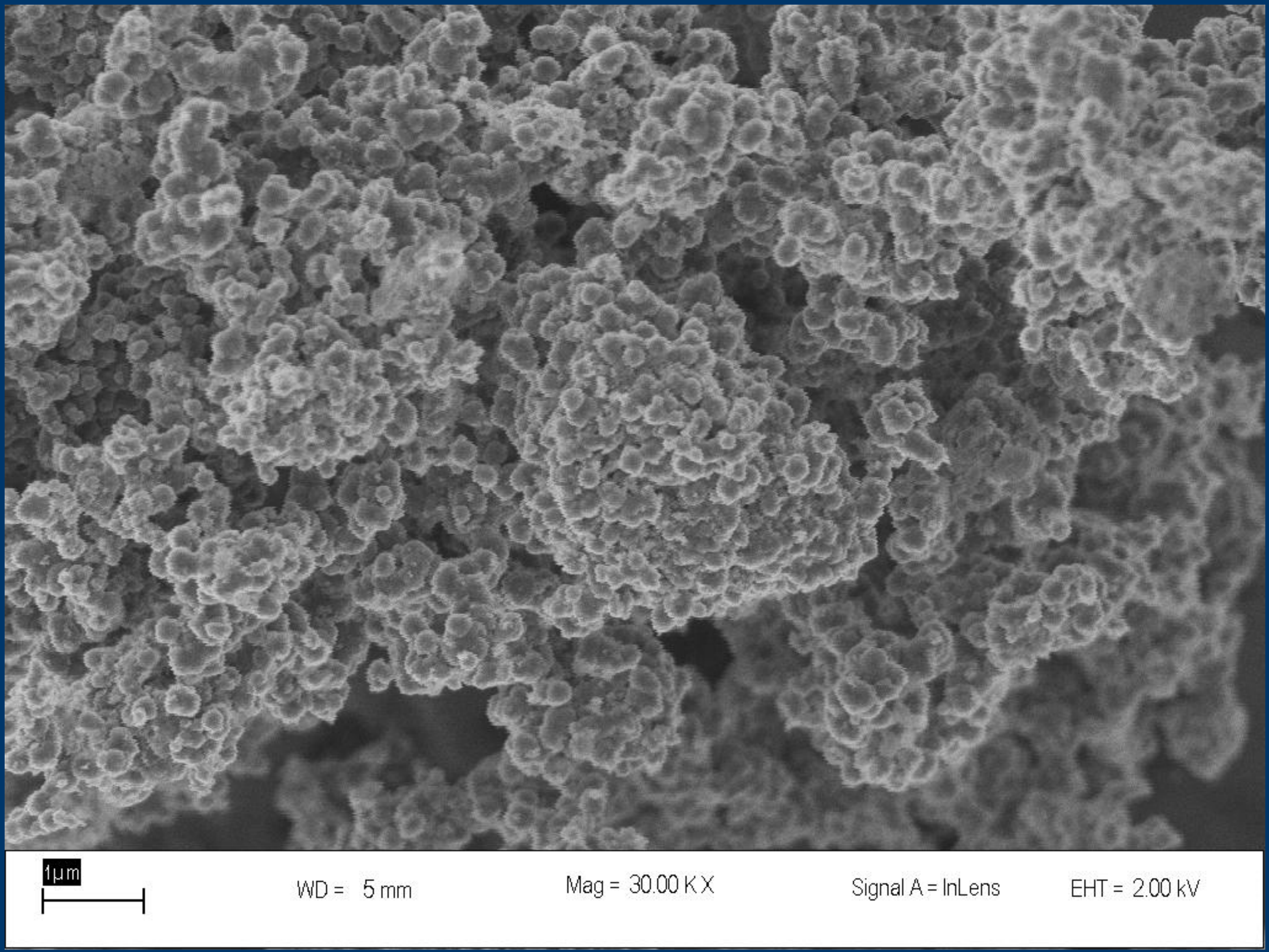
- Adsorption is evaluated at different nanocomposite loadings, different pH's as well as initial heavy metal concentrations

- Additional studies include studies at 25 , 35 and 45 C to determine thermodynamic parameters of adsorption

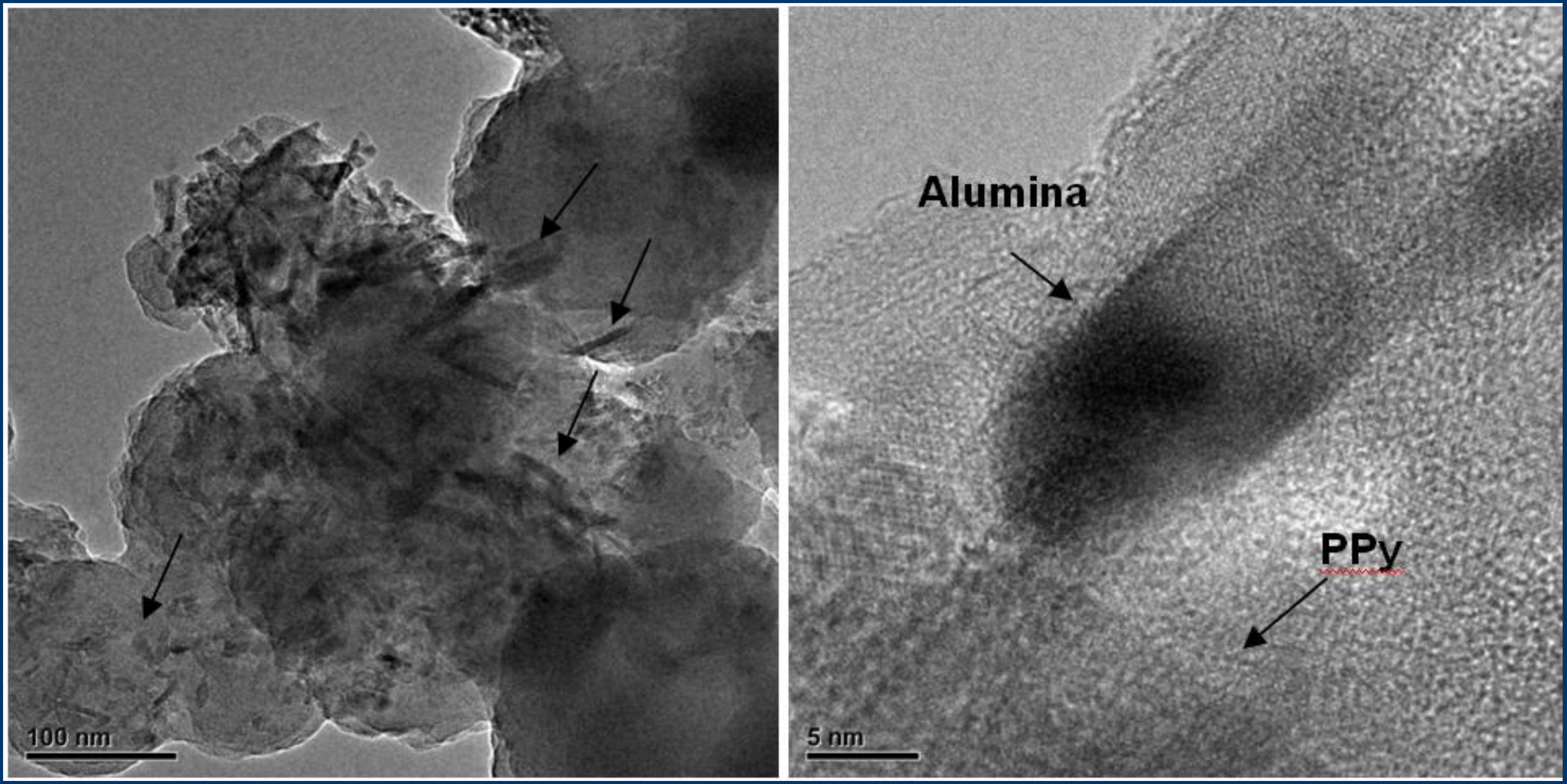
Potable water < 0.05 ppm Cr(VI)
Surface discharge < 0.1ppm Cr(VI)

US EPA

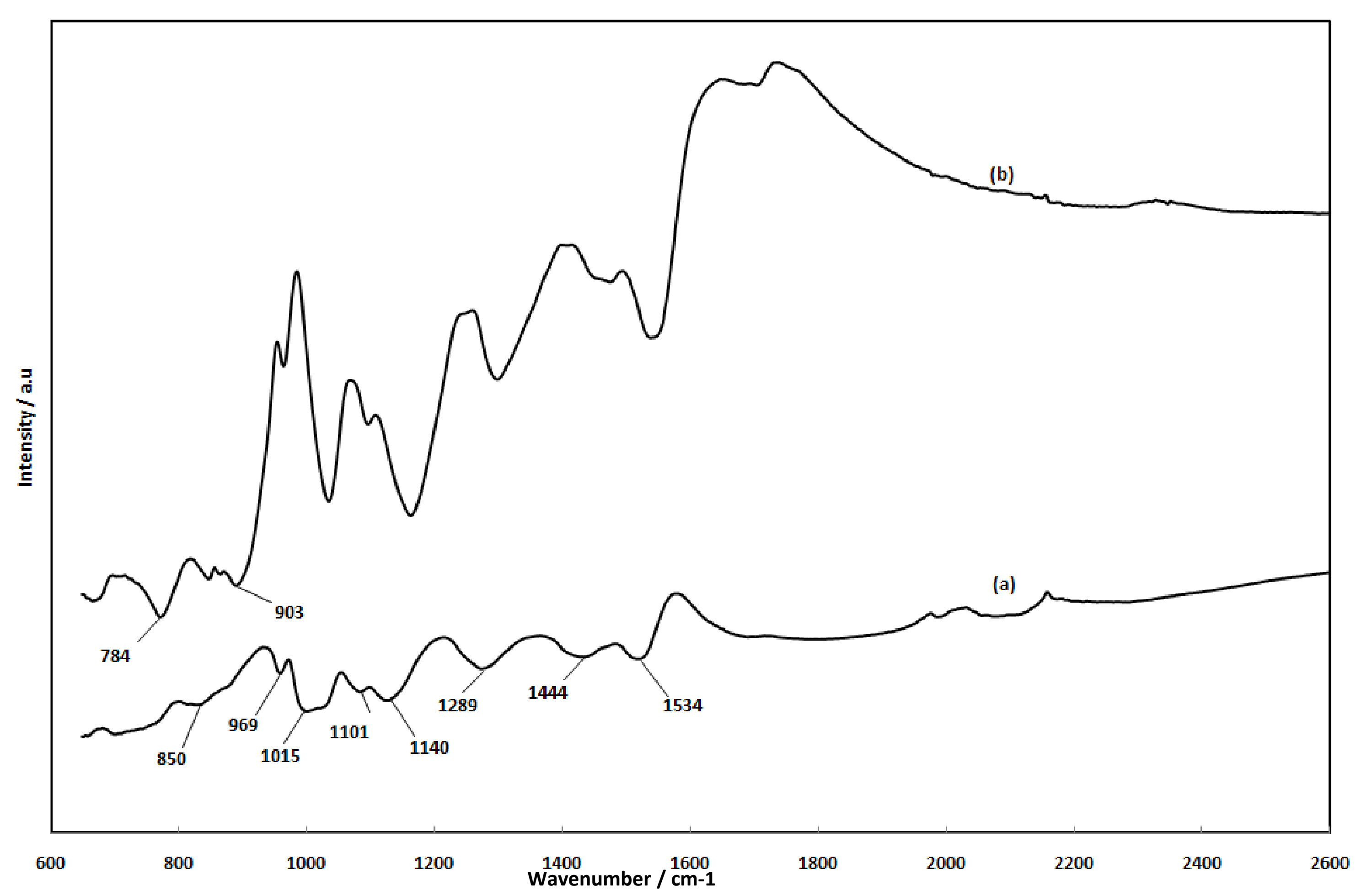
Characterisation: Scanning Electron Microscopy



Characterisation: Transmission Electron Microscopy

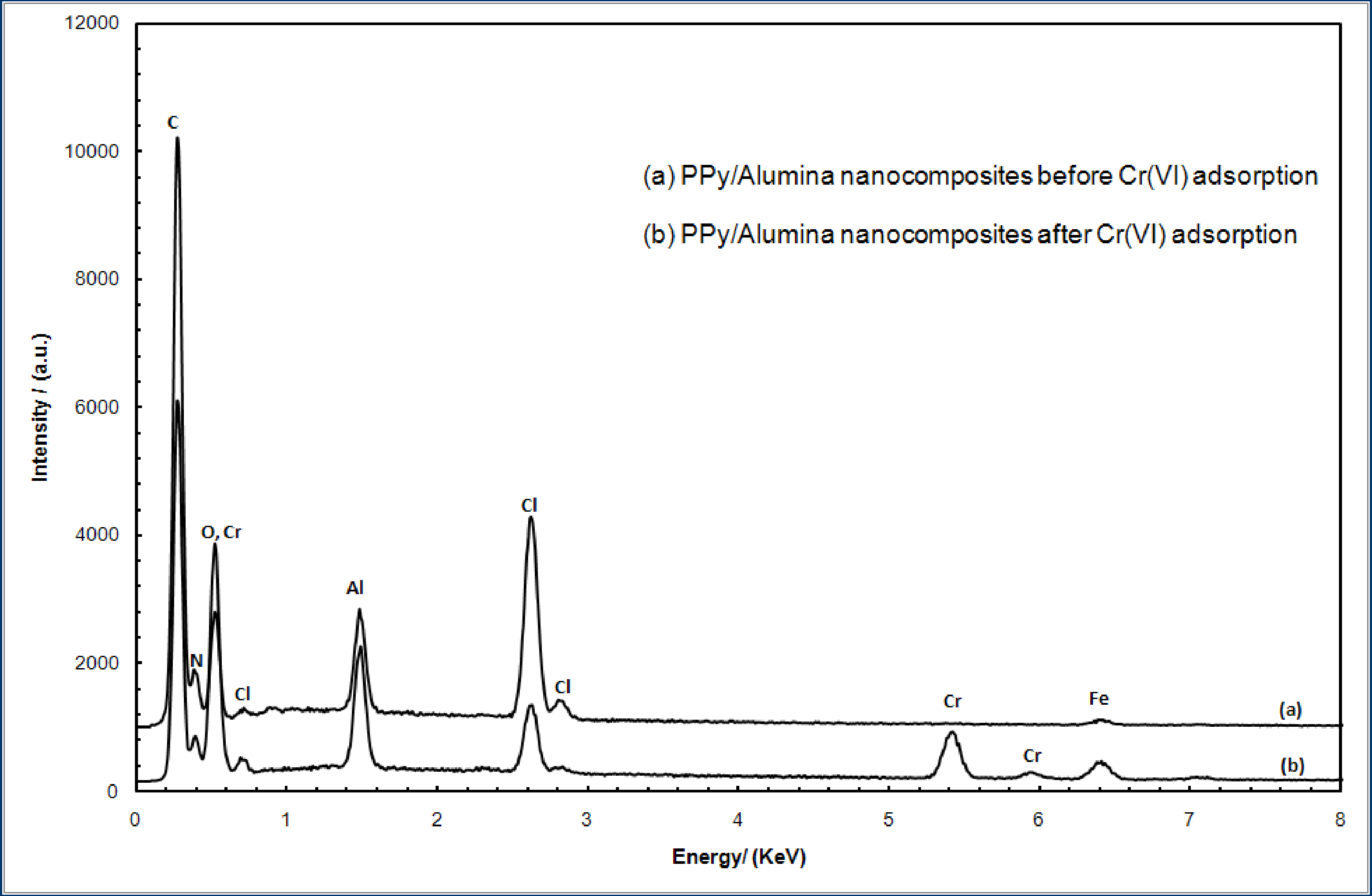


Characterisation: ATR-FTIR



ATR-FTIR spectra of a) PPy/Alumina nanocomposite with b) Cr(VI) adsorbed

Characterisation: X-Ray Photoelectron Spectroscopy



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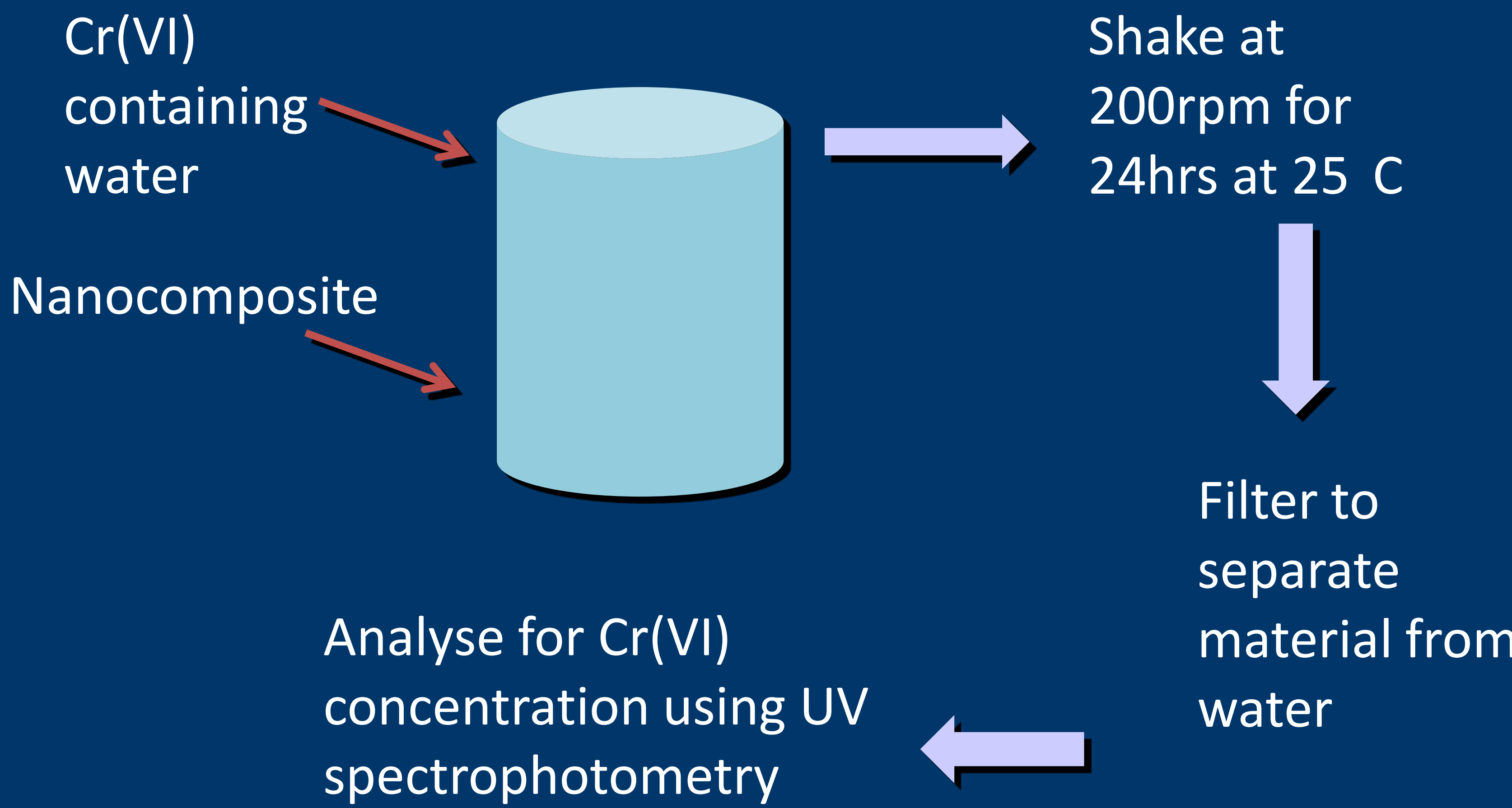
Process of Cr(VI) adsorption



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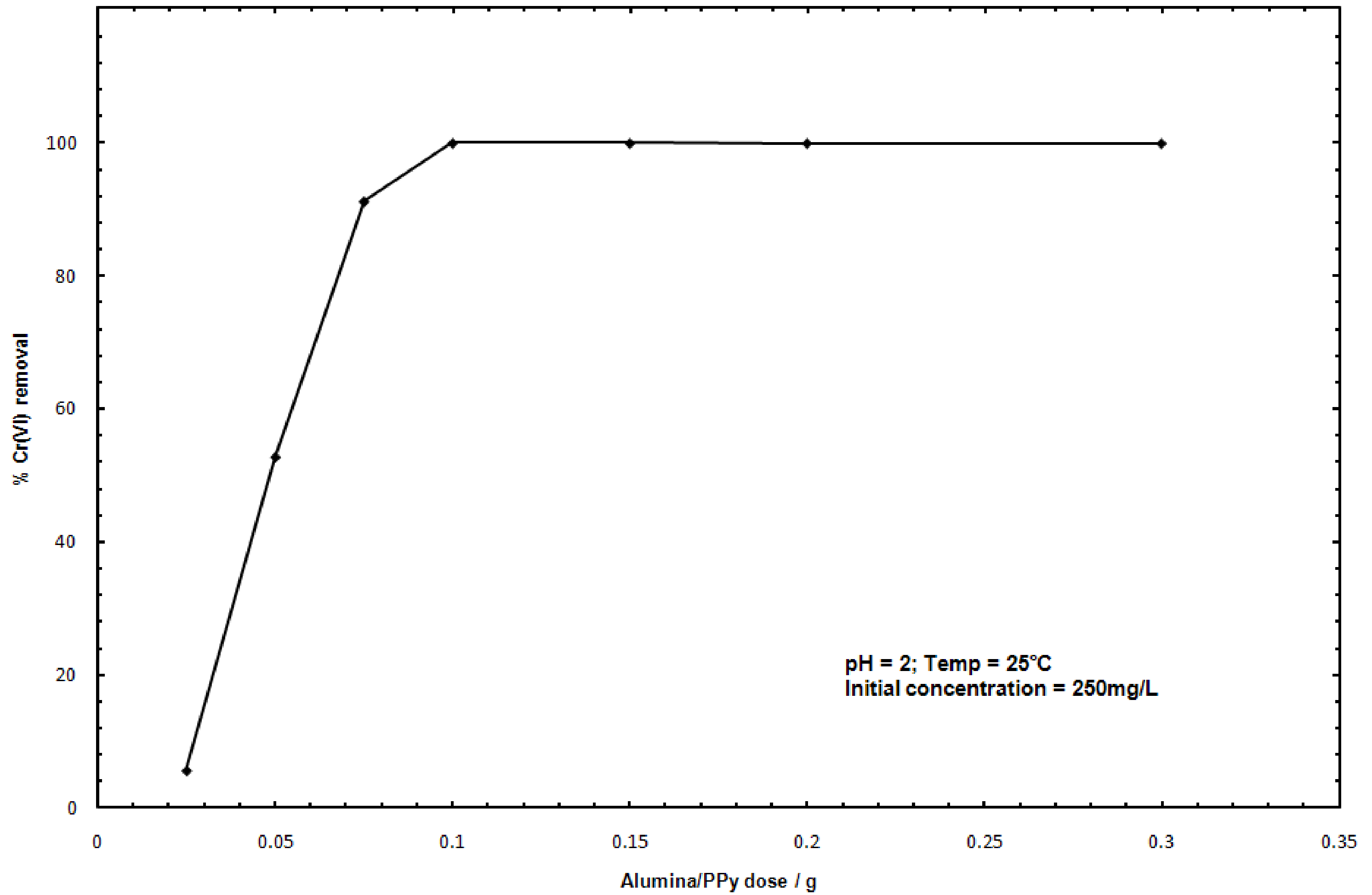
Results – Nanocomposite loading study



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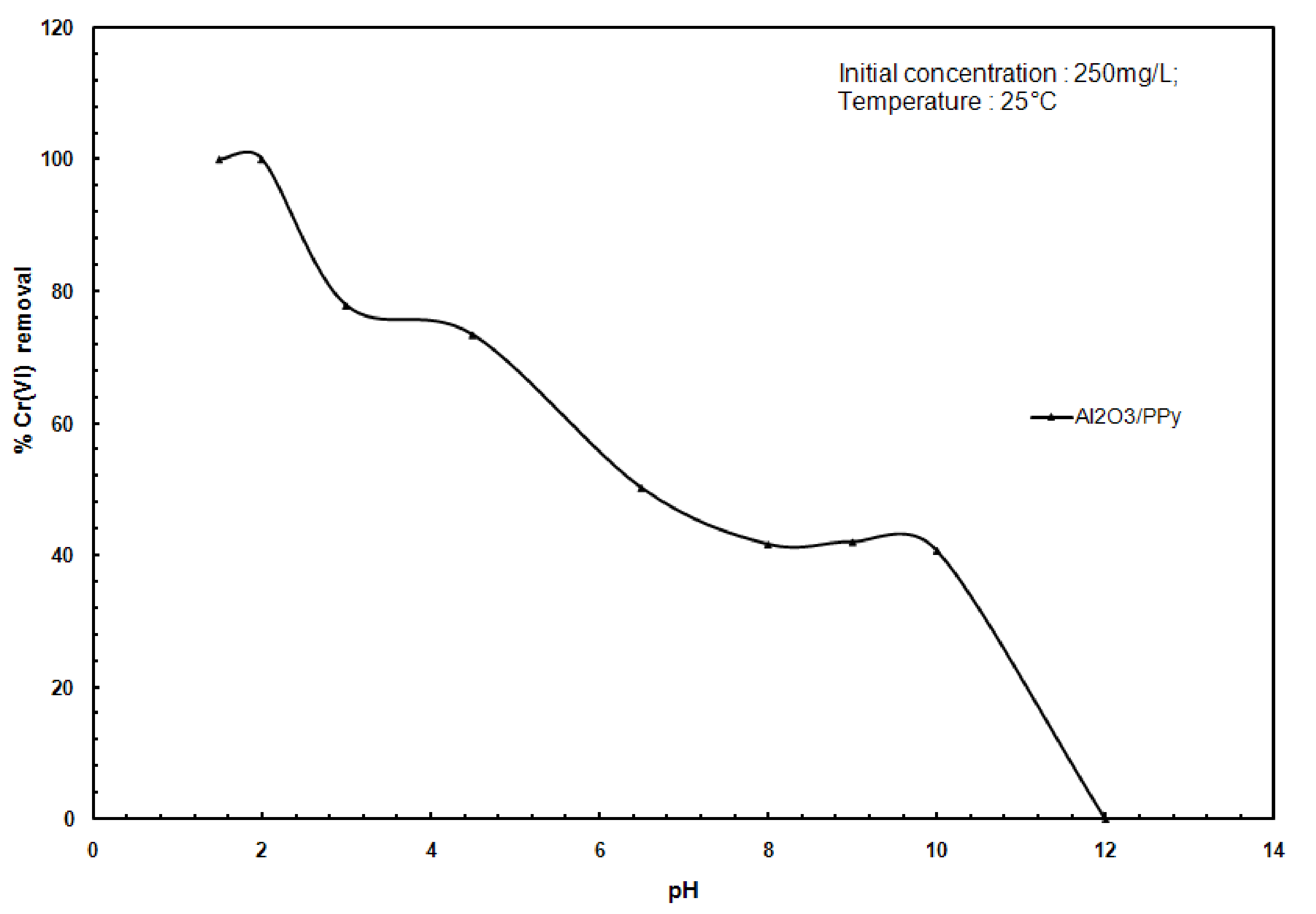
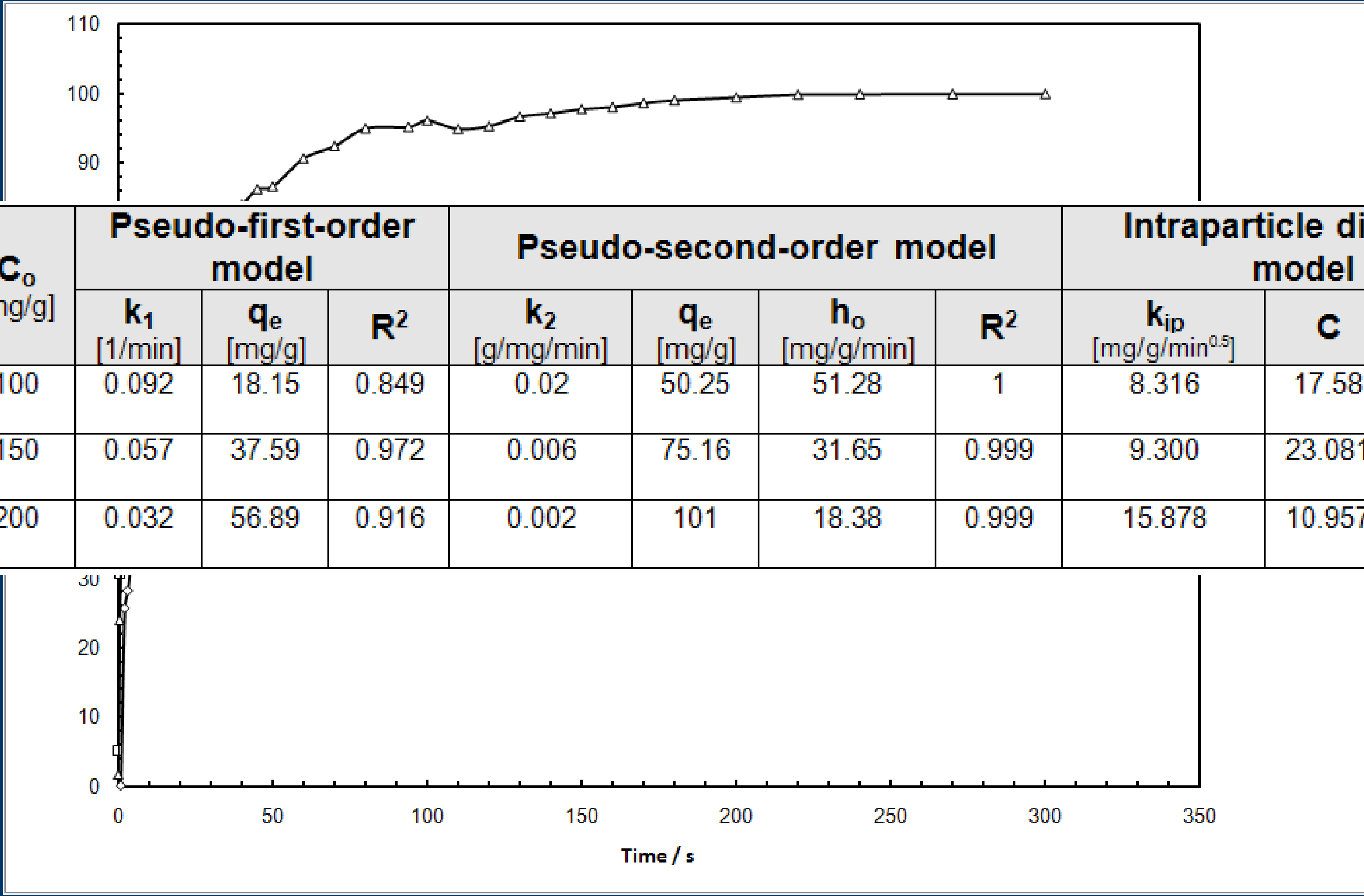
Results – pH studies

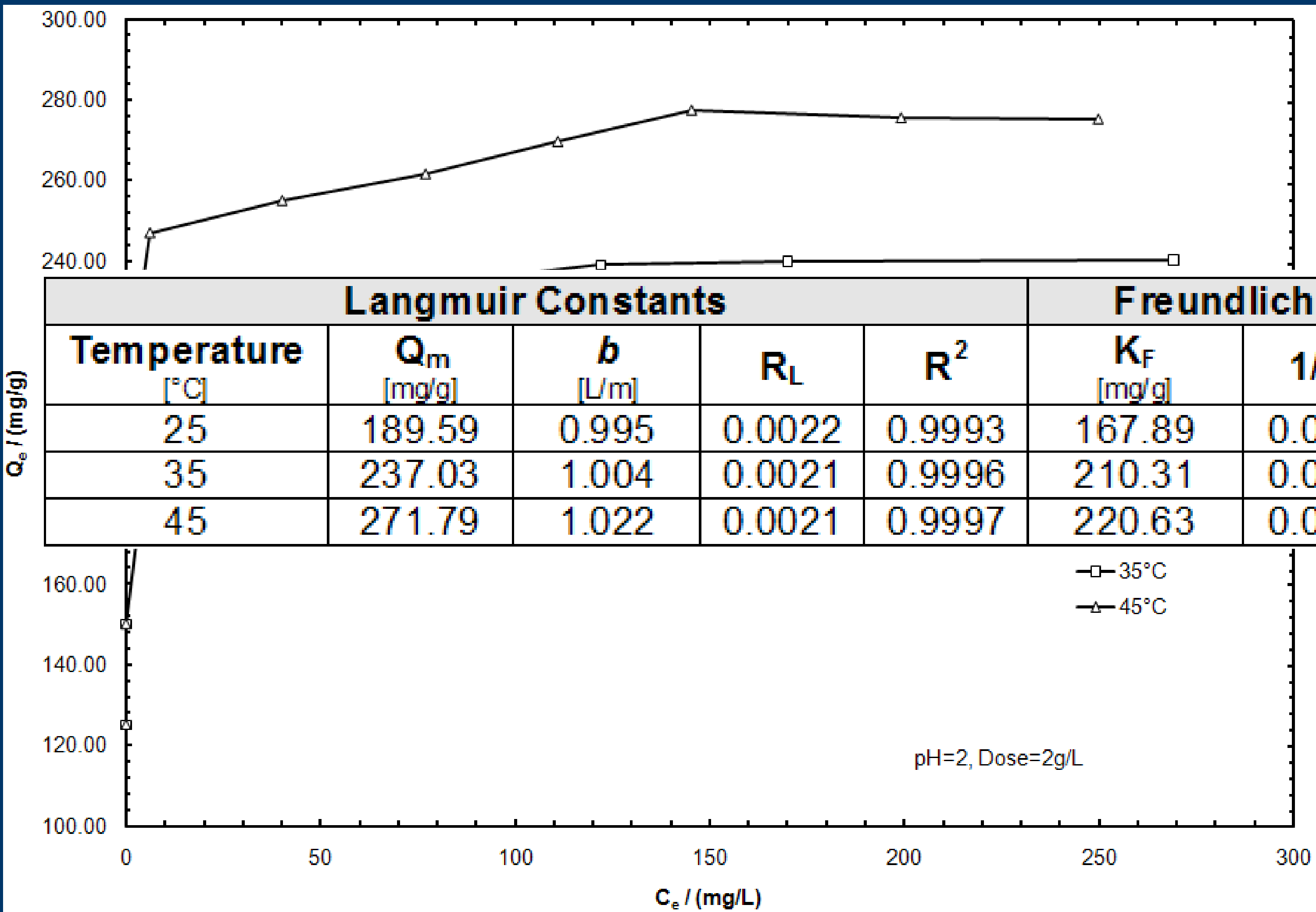


Results – Kinetics studies



C_o [mg/g]	Pseudo-first-order model			Pseudo-second-order model				Intraparticle diffusion model		
	k_1 [1/min]	q_e [mg/g]	R^2	k_2 [g/mg/min]	q_e [mg/g]	h_o [mg/g/min]	R^2	k_{ip} [mg/g/min$^{0.5}$]	C	R^2
100	0.092	18.15	0.849	0.02	50.25	51.28	1	8.316	17.58	0.967
150	0.057	37.59	0.972	0.006	75.16	31.65	0.999	9.300	23.081	0.908
200	0.032	56.89	0.916	0.002	101	18.38	0.999	15.878	10.957	0.934

Results – Adsorption isotherms



Langmuir Constants					Freundlich Constants		
Temperature [°C]	Q_m [mg/g]	*b* [L/m]	R_L	R^2	K_F [mg/g]	1/*n*	R^2
25	189.59	0.995	0.0022	0.9993	167.89	0.019	0.6863
35	237.03	1.004	0.0021	0.9996	210.31	0.022	0.6591
45	271.79	1.022	0.0021	0.9997	220.63	0.042	0.9285

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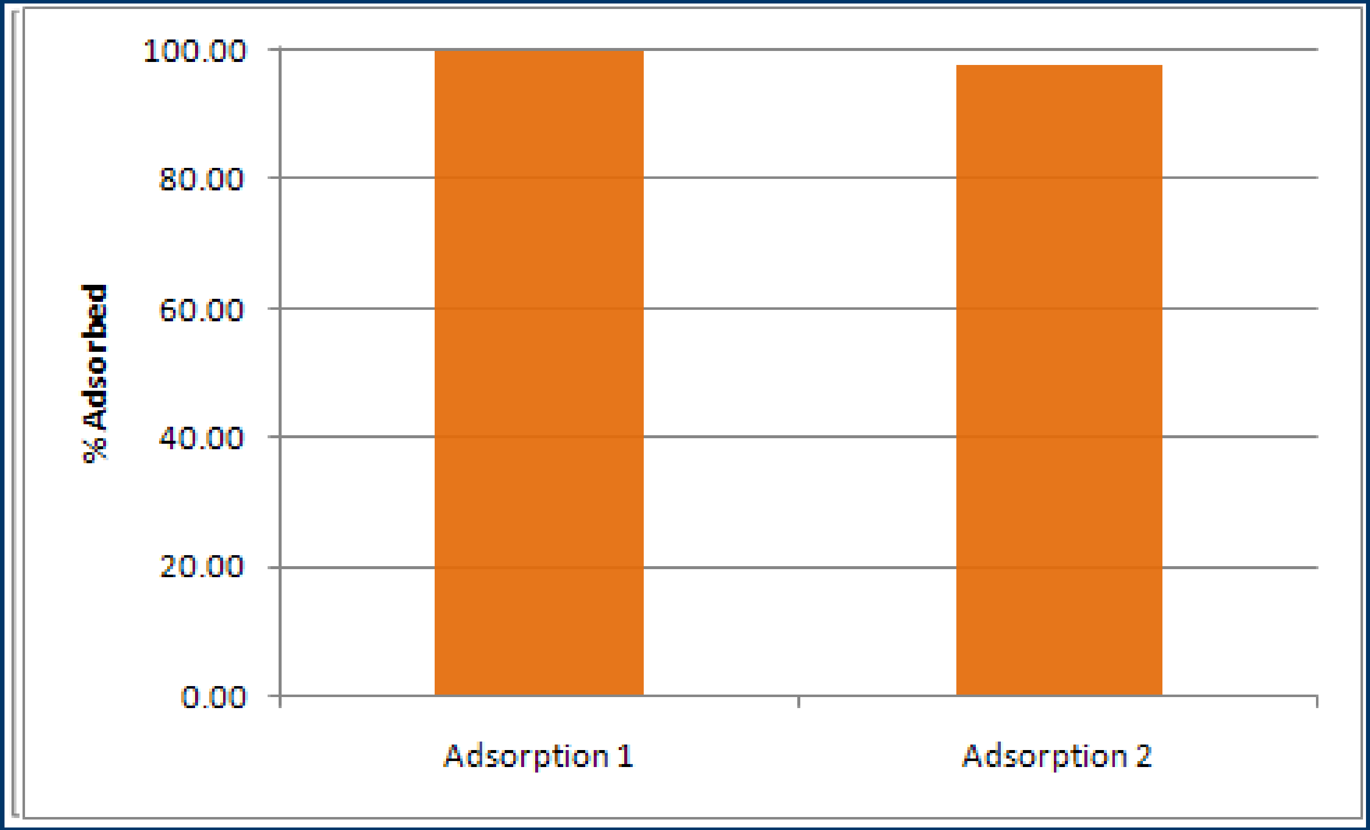
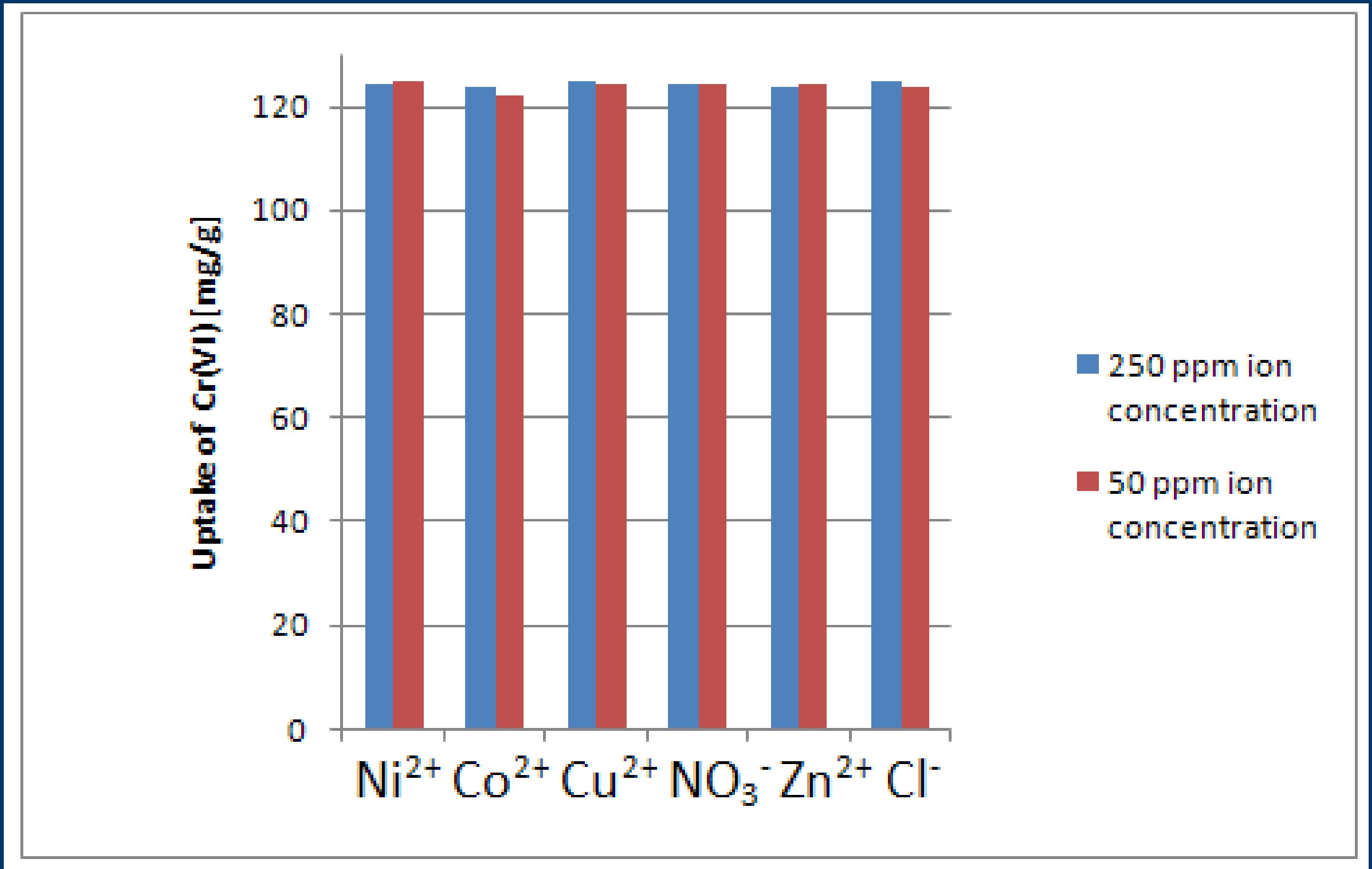
Results – Regeneration experiments

At higher Cr(VI) concentrations
At lower Cr(VI) concentrations

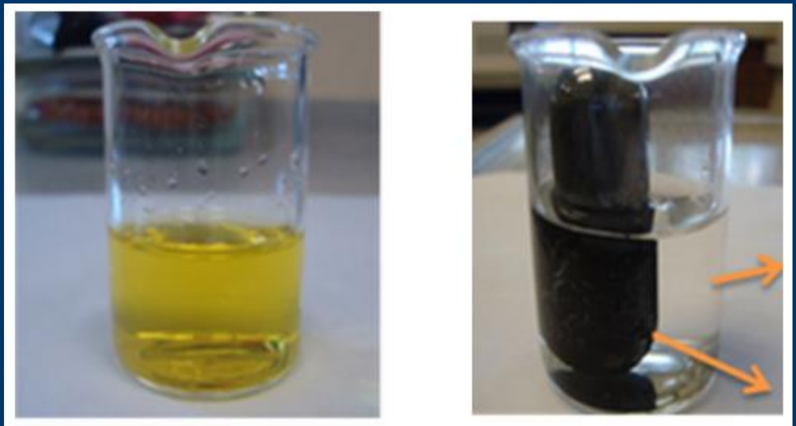


Results – Co-existing ions



Summary

Material Characteristic	PPy/Alumina	PPy/Magnetite
Max adsorption capacity (25°C)	~190mg Cr(VI)/g material	~169 Cr(VI)/g material
Time for 100% removal (100ppm, 150ppm, 200ppm)	20min, 80min, 100min	20min, 110min, 150min
Kinetic model	Pseudo-second order	Pseudo-second order
Isotherm model	Langmuir	Langmuir



M. Bhaumik et al. / Journal of Hazardous Materials 190 (2011) 381–390

Cr(VI) free water

Magnetic stirrer

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Conclusions

- Developed a PPy/Alumina nanocomposite
- Improved adsorption capacity for Cr(VI) when compared to Fe_3O_4 nanocomposite and other low cost materials
- Regeneration up to 3 cycles was possible at low Cr(VI) concentrations
- Co-existing ion studies showed material specificity for Cr(VI)

Acknowledgements

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Thank you

Questions?