Polymer based nanocomposites for the removal of Cr(VI) from water

Emerging Researcher Symposium

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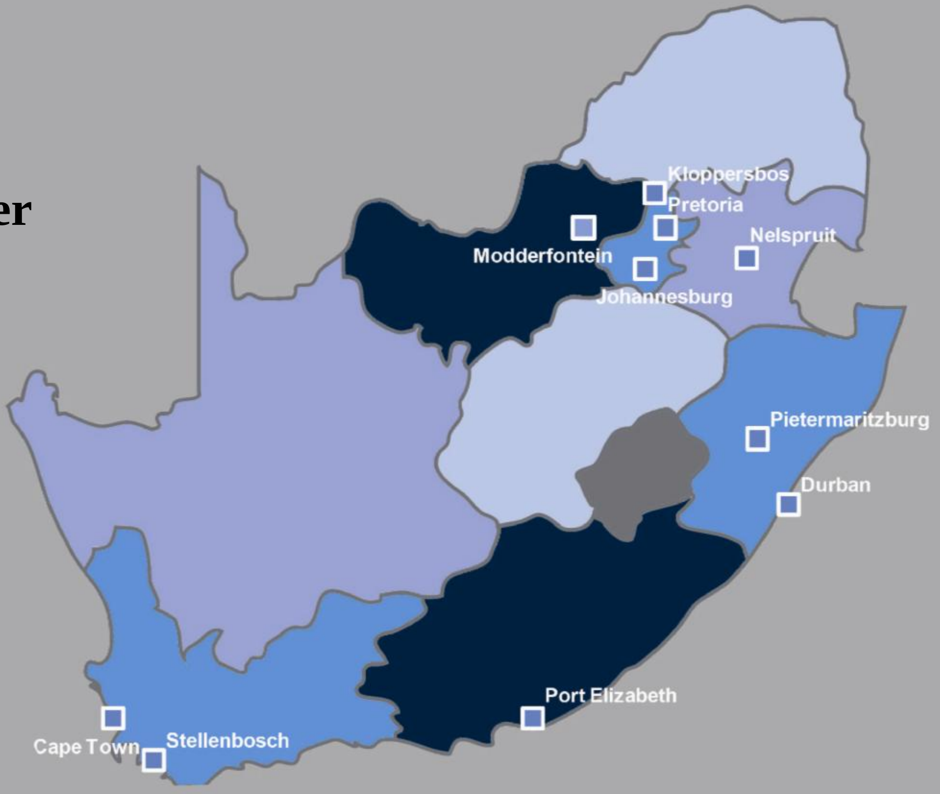
Outline

- Background
    - Problem statement
    - Health impacts
- Remedies
- Objectives
- Experimental procedure
- Results
    - Characterization
    - Batch sorption
    - Continuous sorption
- Conclusions

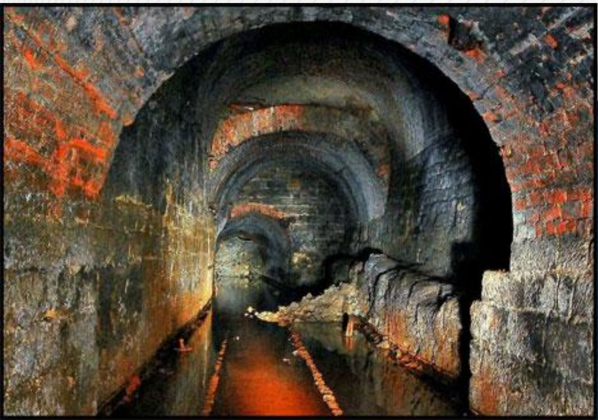
Background

The water industry faces problems on national and global level that needs to be addressed:

- **Fresh water reduces due to droughts**
- **Chemical (metals, fluoride, nitrate and other chemicals) and biological contamination**
- **Acid mine drainage**
- **Little/disregard for the environmental consequences of INDUSTRIAL activity**



Industrialization & Heavy-metals – The problem



Abandoned mines

Electroplating

Alloy manufacturing

Acid mine drainage

Effluent
Cr, Ni, Cu, Pb, Hg, Cd, As, Fe…

Wastewater discharge to surface water

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Health effects

Drinking water containing Heavy metals (even at low concentrations) can cause:

- Skin cancer
- Liver damage
- Mental retardation
- Carcinogenic
- Kidney damage

Environ Health Perspect. 1983 February; 48: 113–127.

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Research Article

Public health consequences of heavy metals in dump sites.

T W Clarkson, B Weiss, and C Cox

Special Theme – Environment and Health

Theme Papers

Environmental lead exposure: a public health problem of global dimensions

Shilu Tong,[1] Yasmin E. von Schirnding,[2] & Tippawan Prapamontol[3]

Hazards of heavy metal contamination

Lars Järup

Department of Epidemiology and Public Health, Imperial College, London, UK

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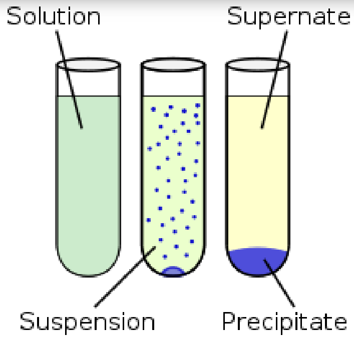
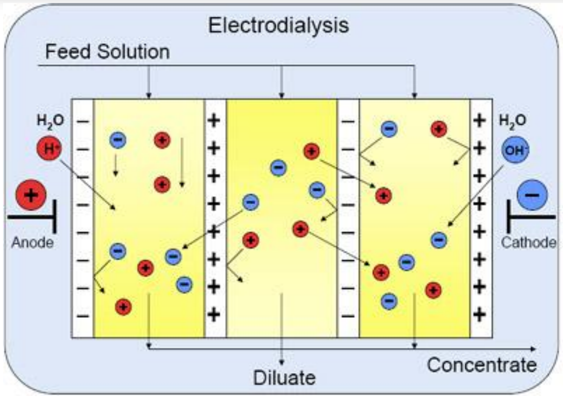
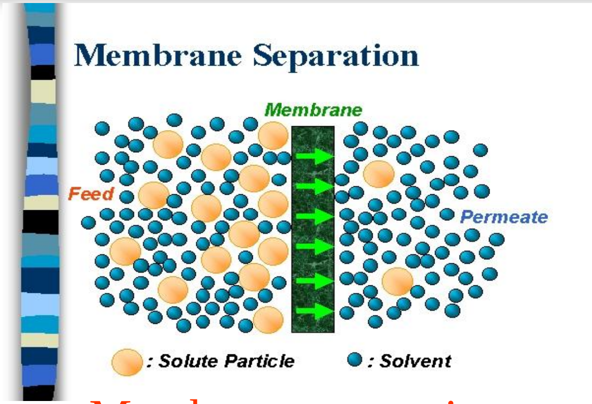
Conventional technologies Vs our approach



Precipitation
Sludge disposal problem
Ineffective @ low conc.

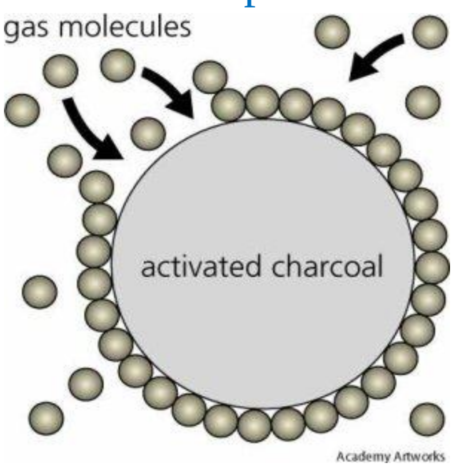


Electrodialysis
High Cost



Membrane separation
High Cost
Fouling

Adsorption



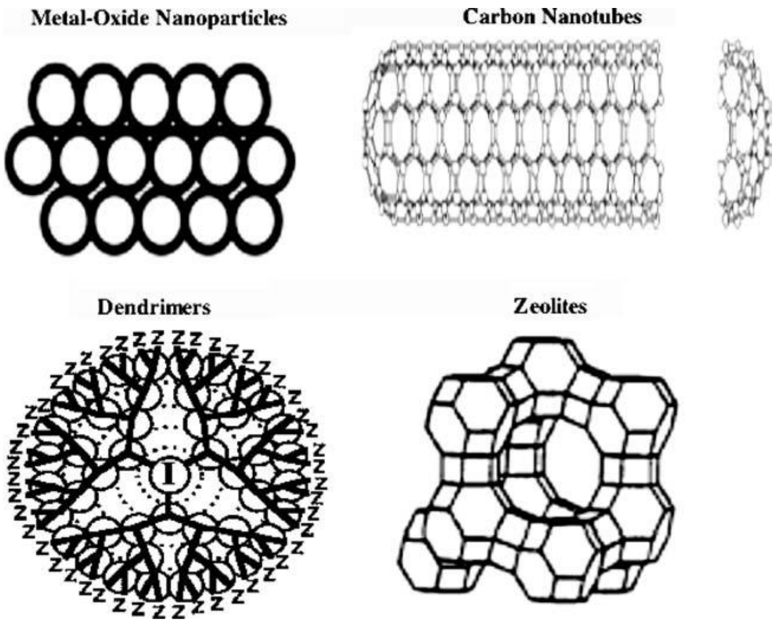
Robust in nature
Mass transfer resistance

Our approach

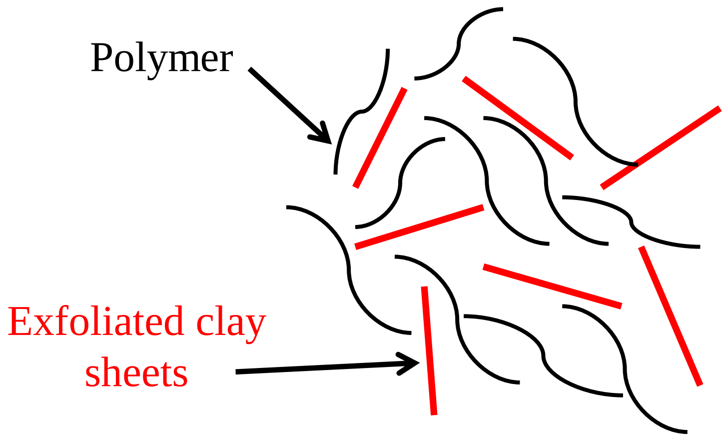
Nanotechnology (Nanosorbents)

Characteristics:
- large surface area
- potential for self assembly
- high specificity
- high reactivity
- catalytic potential

Adsorbents

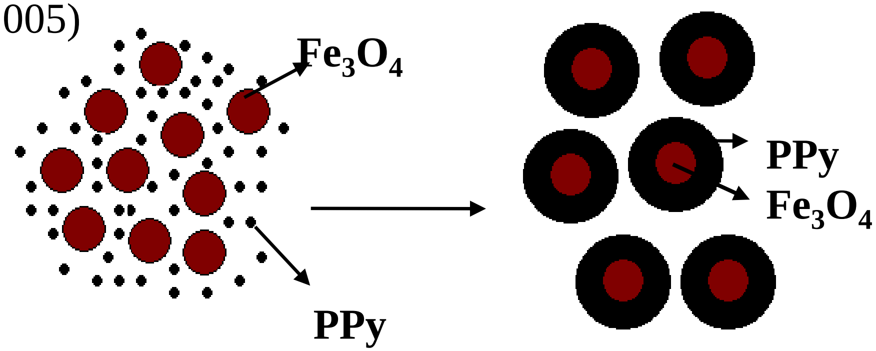


(Savage and Diallo, 2005)



Polymer/Clay nanocomposites

(Present study)



PPy/Fe_3O_4 Nanocomposites

(Bhaumik et al., 2011)

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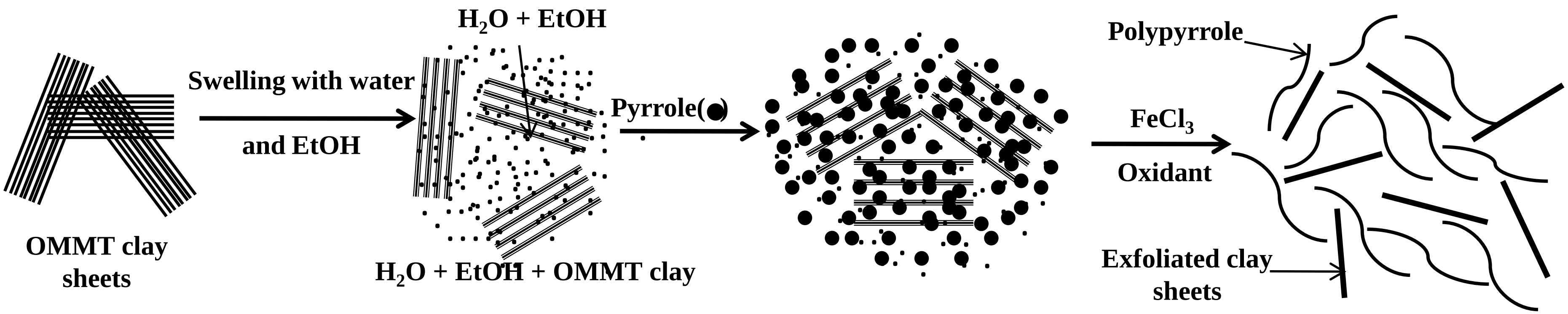
Objectives

- To synthesize and characterize polymer based nanocomposites for Cr(VI) removal from wastewater
- To perform batch adsorption equillibria and kinetics under controlled conditions
- To relate sorbent performance with sorbent properties and water quality
- To apply existing mathematical models to describe isotherms and kinetic data for design parameters
- To test the applicability of the material with real groundwater containing Cr(VI)
- To test the regenerability of the sorbent
- Evaluate sorption performance in a continuous system

Adsorbent preparation



Preparation of the exfoliated polypyrrole/OMMT nanocomposites

Novel magnetic polymer based nanocomposite

•Highly dispersible

•Easy separation

•Use of high gradient magnetic separator

Batch equilibrium and kinetics

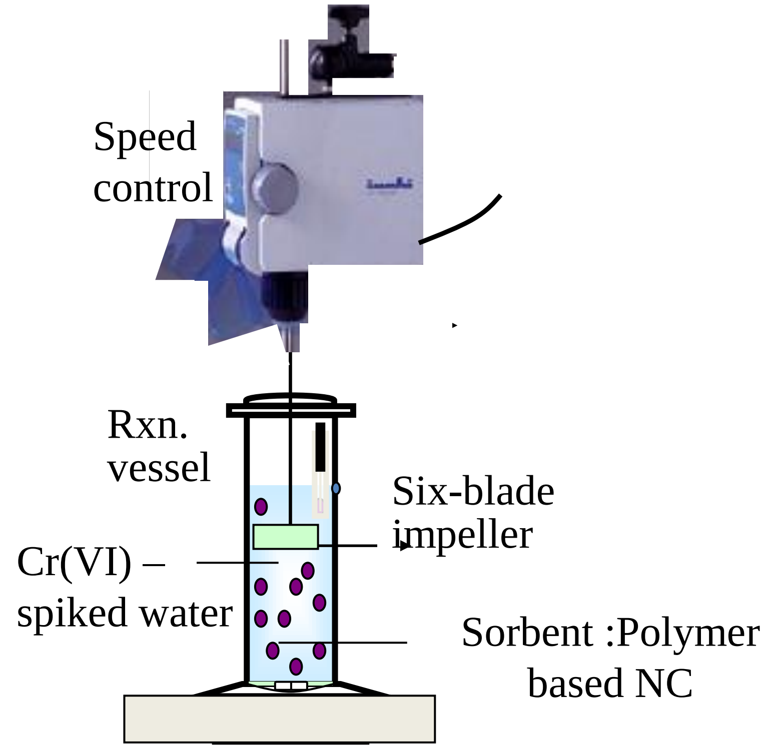
Sorption isotherms

Water bath shaker

Variables

- **Temperature**
- **Initial concentration**
- **pH**
- **Sorbent dose**

Sorption kinetics

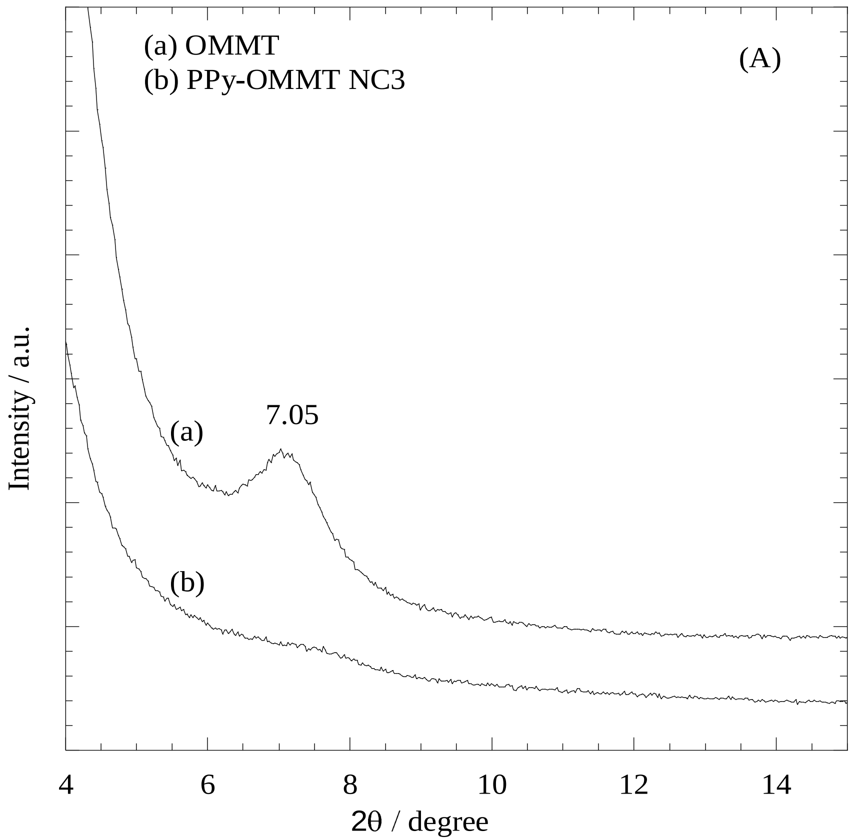


Sorption kinetics study:

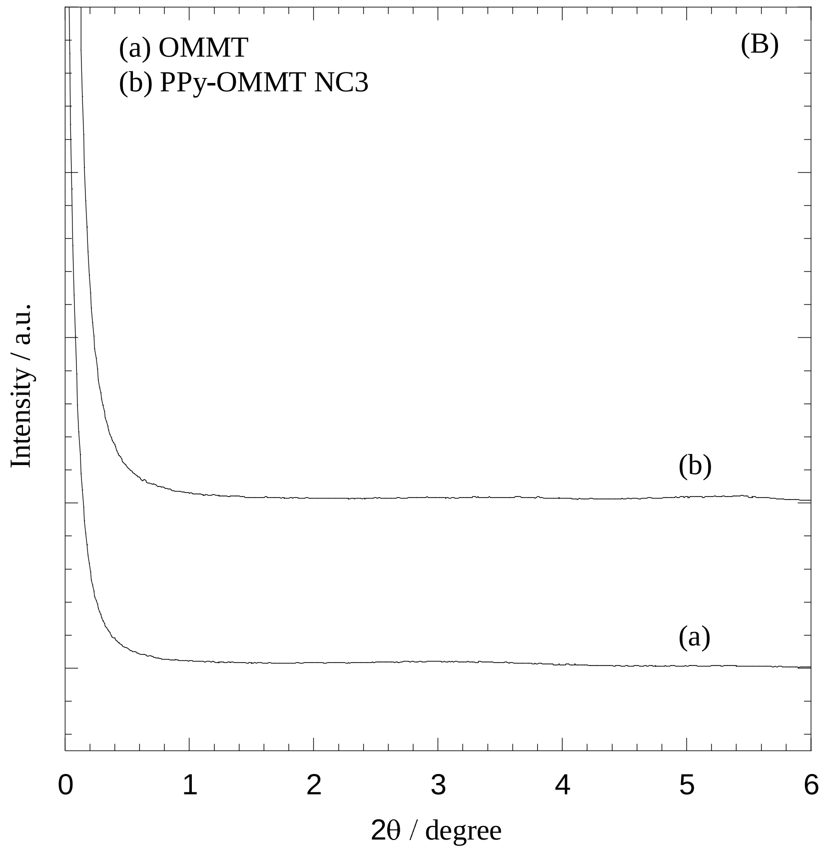
-Determination of reaction kinetic parameters

Results

Characterization
XRD



Wide angle X-ray diffraction patterns of (a) OMMT and (b) PPy-OMMT NC



Small angle X-ray diffraction patterns of (a) OMMT an (b) PPy-OMMT NC

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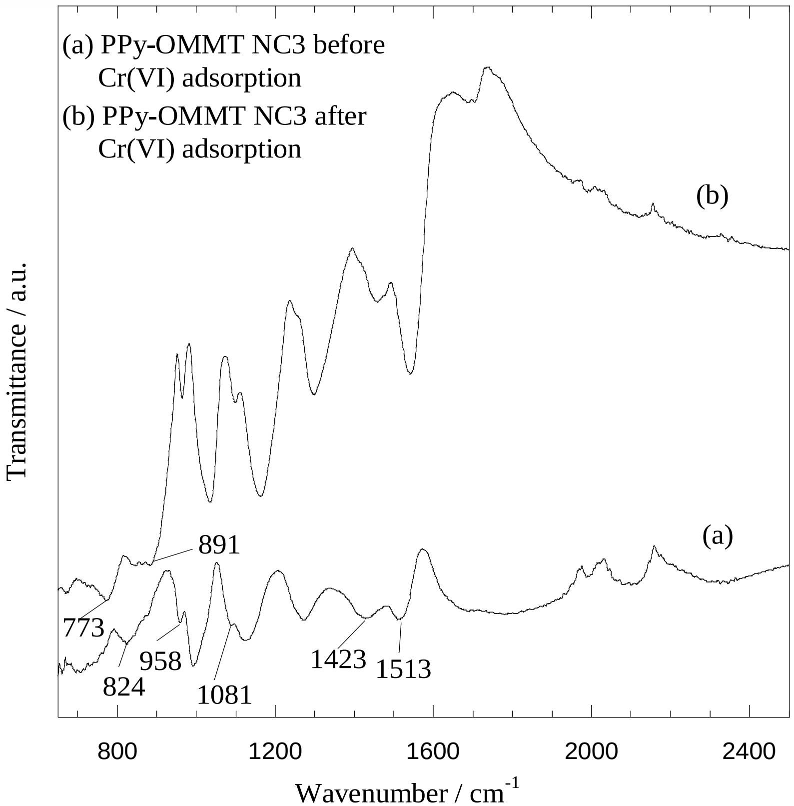
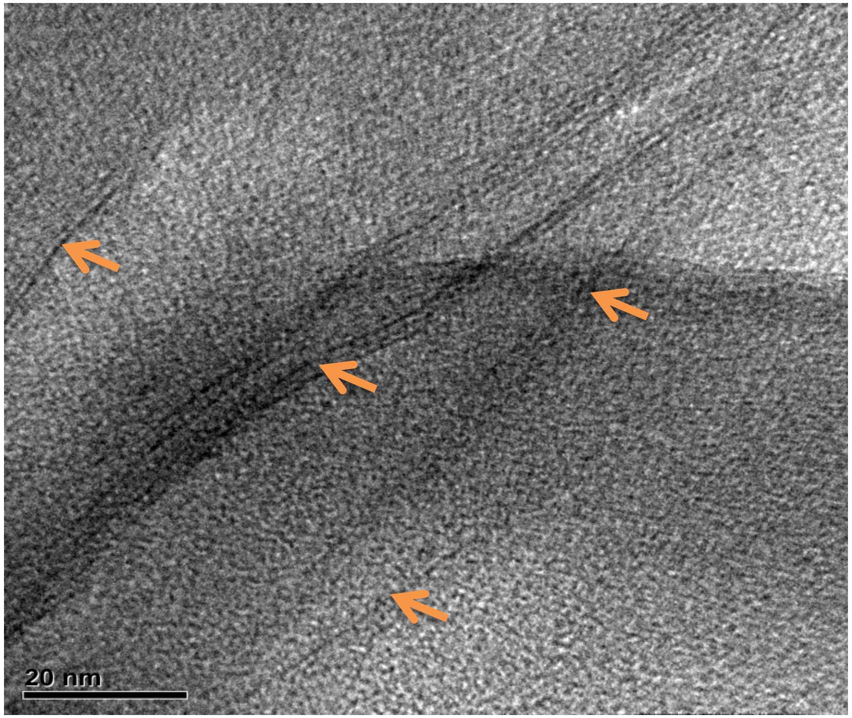
ATR-FTIR and TEM analysis



FTIR spectra of the PPy-OMMT NC (a) before and (b) after adsorption with Cr(VI)



Transmission electron microscopic image of the PPy-OMMT NC

OMMT clay – $9.79 m^2/g$
PPy-OMMT NC – $16.076 m^2/g$

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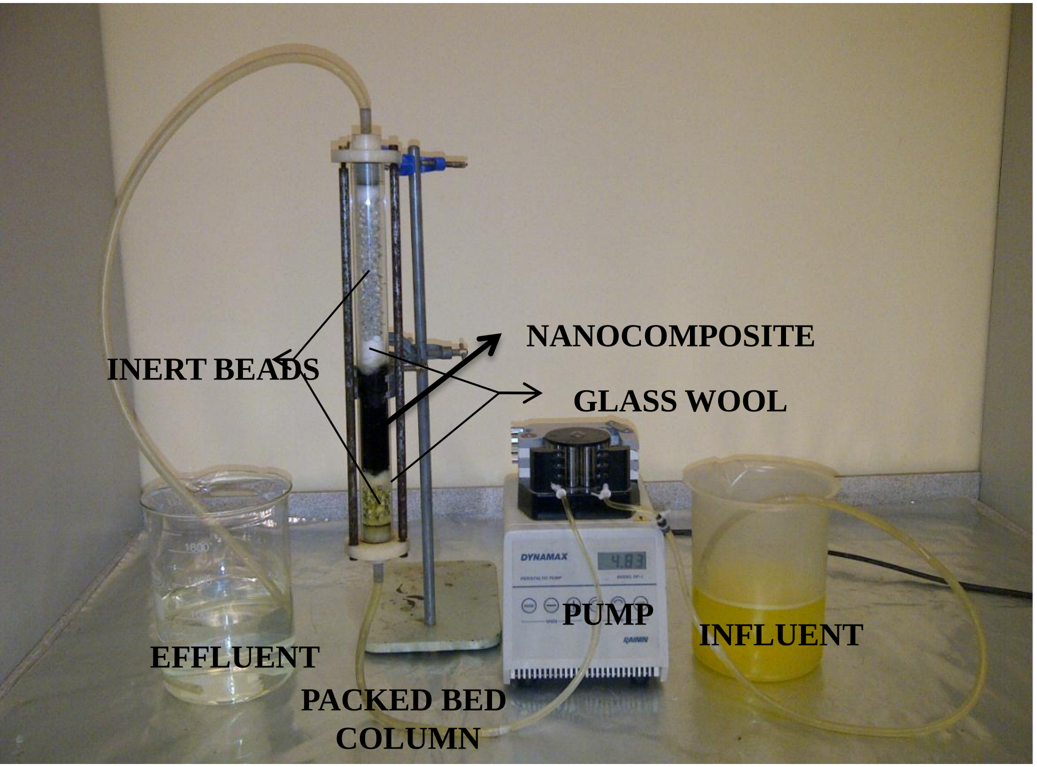
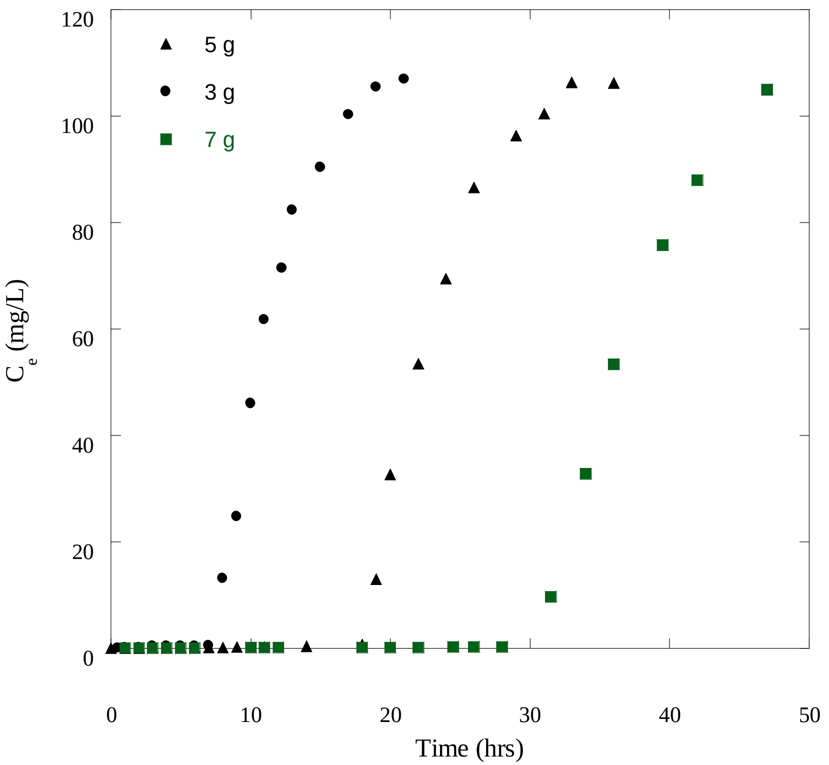
Column – dynamic study



Continuous column adsorption small scale system



Breakthrough curves of Cr(VI) sorption by PPy-OMMT NC

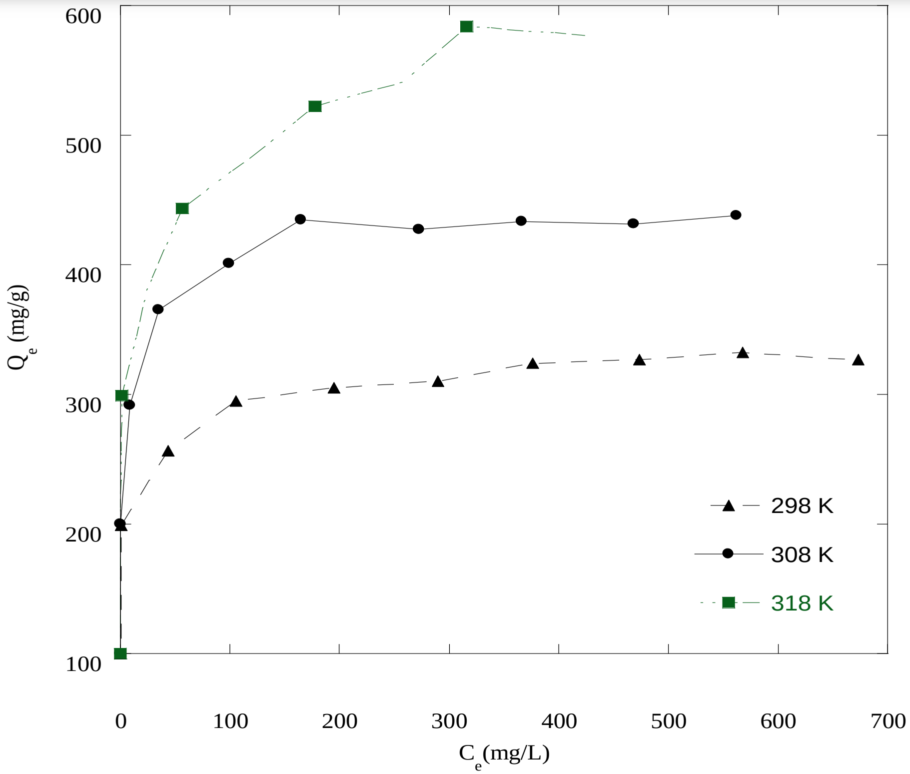
pH 2

C_o = 100 mg/L, 298 K, 3 ml/min

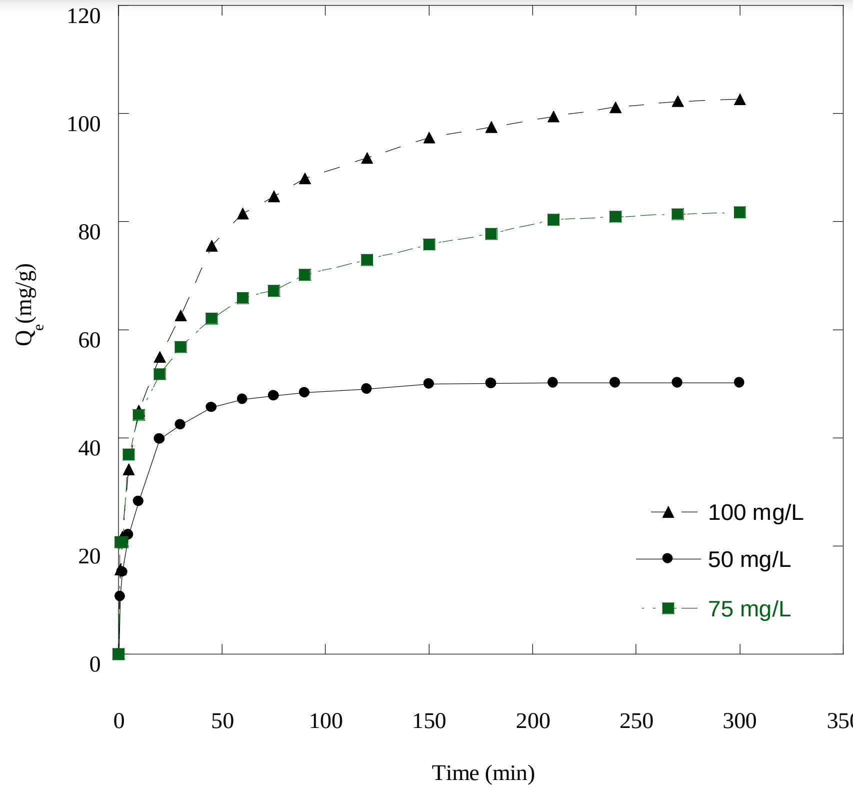
30 cm column

2 cm diameter

Magnetic polymer based nanocomposites



Adsorption kinetics of Cr(VI) onto polymer based magnetic nanocomposite



Adsorption isotherms of Cr(VI) onto polymer based magnetic nanocomposite

$$\frac{C_e}{Q_e} = \frac{1}{q_o b} + \frac{C_e}{q_o}$$

Langmuir isotherm

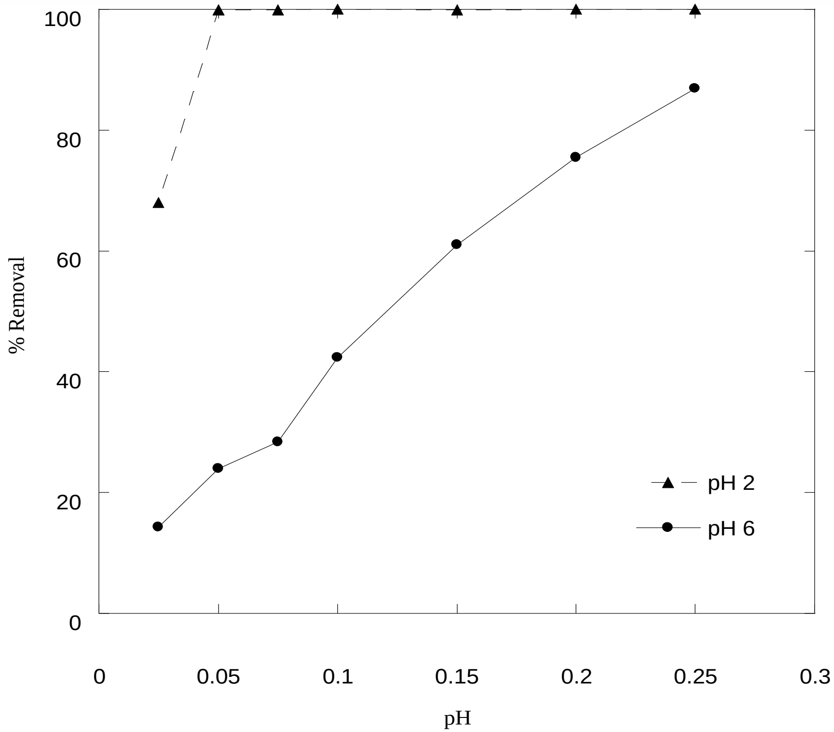
Maximum sorption capacity = 335-580 mg/g

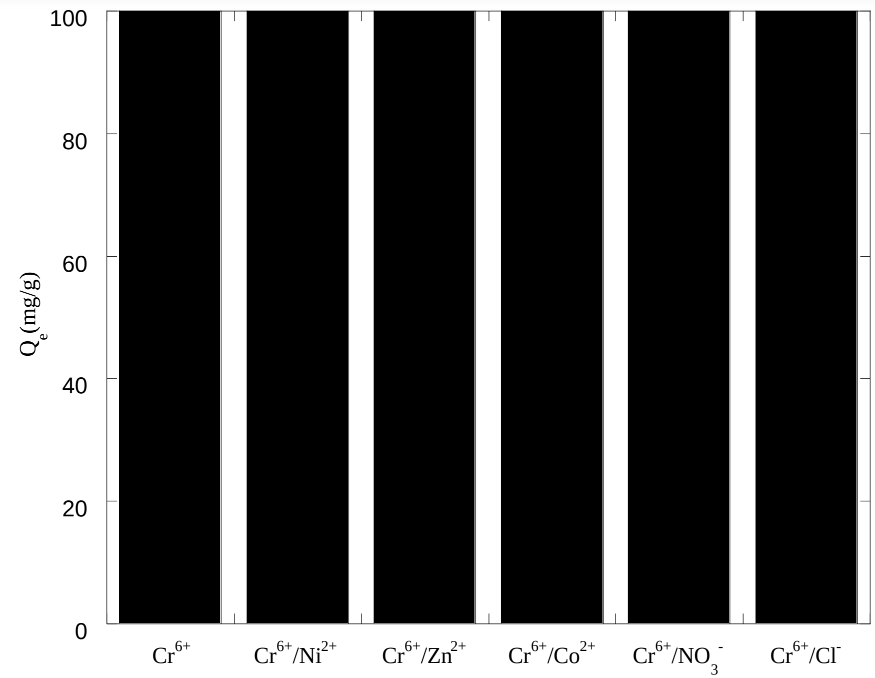
$$\frac{t}{q_t} = \frac{1}{k q_e^2} + \frac{t}{q_e}$$

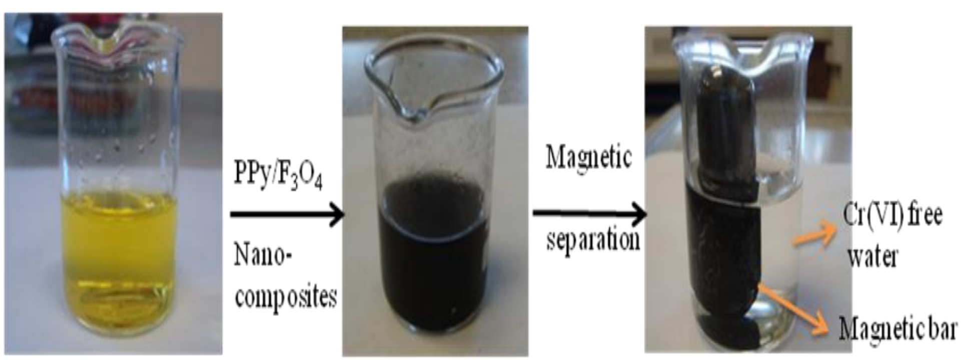
Pseudo second order kinetic model

Chemisorption

Feasibility test for Cr(VI) contaminated ground water and the effect of competing ions

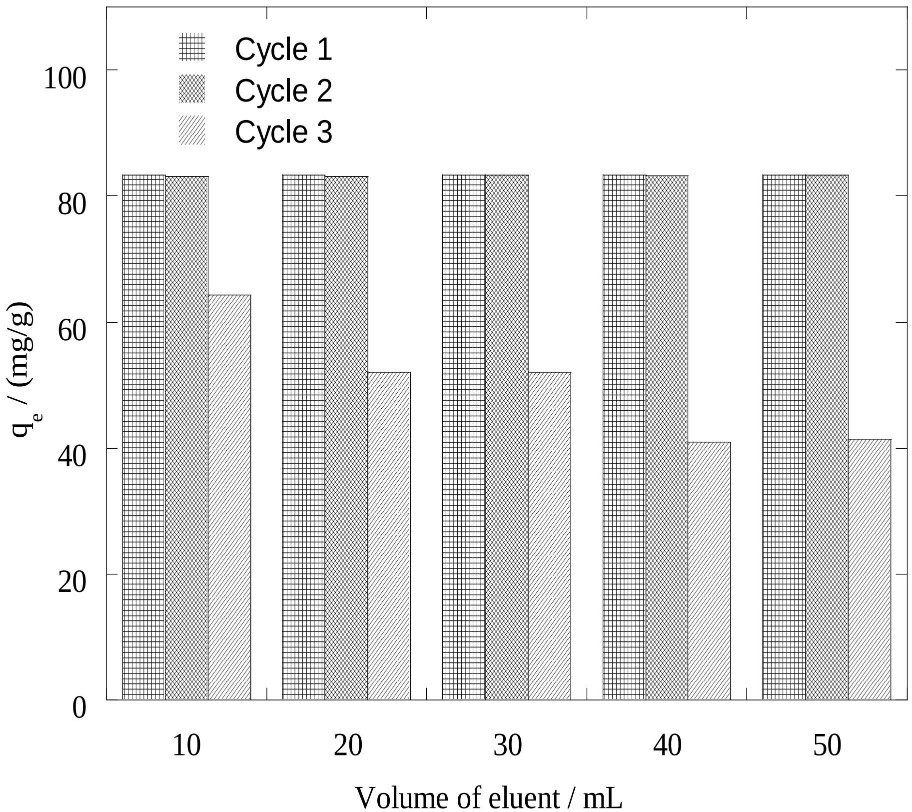




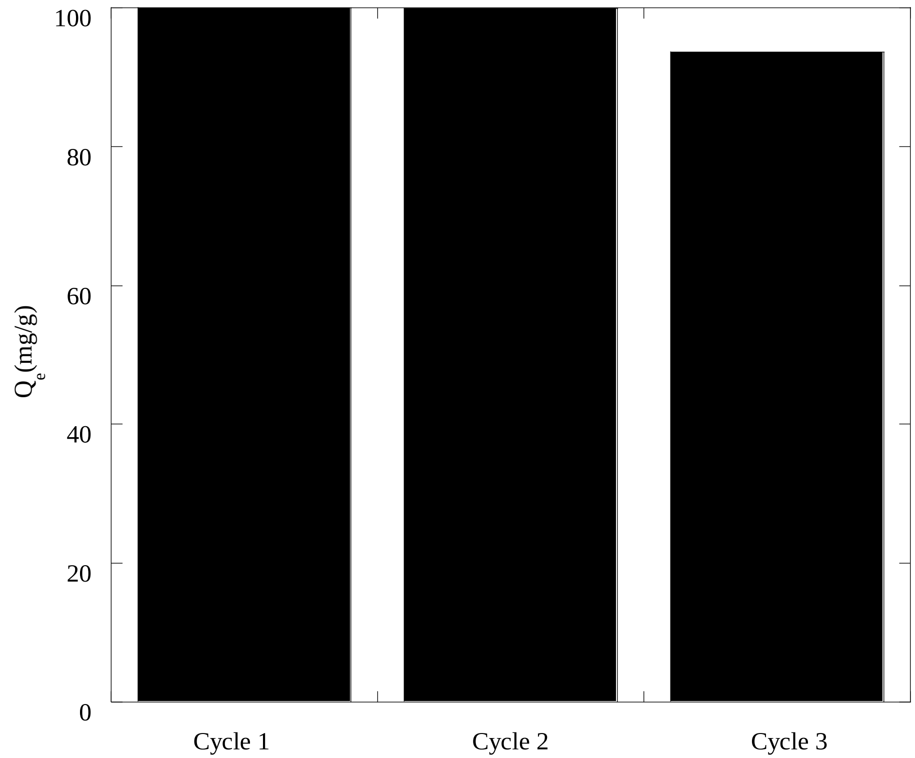


100 ppm Cr(VI) sol. | Nanocomposite + Cr(VI) sol | 0 ppm Cr(VI) sol.

Regeneration studies



Adsorption-desorption cycles for PPy-OMMT NC



Adsorption-desorption cycles for polymer based magnetic nanocomposite

Conclusions

The removal of Cr (VI) ions as a model heavy metals from aqueous solution was carried out in a batch and continuous adsorption mode using polymer based NCs

- PPy-OMMT and the polymer based magnetic NCs was synthesized and characterized for Cr (VI) removal from aqueous solution
- PPy-OMMT NC was exfoliated and exhibited effectiveness in the removal of Cr (VI) ions from aqueous solutions
- Uptake increases with an decrease in pH and an increase in temperature with both nanocomposites
- Fast removal kinetics– due to low mass transfer resistance for both nanocomposites
- Isotherms were best described by the Langmuir isotherm for both nanocomposites
- Kinetics were best described by the Pseudo second order kinetic model for both nanocomposites
- Continuous sorption data reveals an effective Cr(VI) sorption with an increase in sorbent dosage

Output

1. Chromium(VI) Removal from Water Using Fixed Bed Column of Polypyrrole/Fe_3O_4 Nanocomposite, Madhumita Bhaumik, **Katlego Zebedius Setshedi**, Arjun Maity, Maurice S. Onyango, ***Separation and Purification Technology***, Under Review, (2012) I.P- 2.92

2. Exfoliated polypyrrole-organically modified montmorillonite clay nanocomposite as a potential adsorbent for Cr(VI) removal, **Katlego Zebedius Setshedi**, Madhumita Bhaumik, Segametsi Songwane, Maurice S. Onyango, Arjun Maity, ***Water Research***,Under review, (2012) I.P – 4.8

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Thank you

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