2023 ENGINEERING INSTITUTION OF ZAMBIA SYMPOSIUM

Developing of Nanofibers from *Moringa oleifera* Biomass for Lead Ion Removal from Contaminated Water: Investigating Co-existing Ions and Regeneration – A Case Study of Kabwe Town

PRESENTER : Ronald Ngulube

DATE : April 2024

Avani Victoria Falls Resort, Livingstone, Zambia

CONTENTS

BACKGROUND

- Kabwe, was once a major producer of Pb, Zn, Cd and Ag [1]
- However, mine operated without environmental pollution controls [2]
- In June 1994, the mine operations were shut down

***Fig 1**. Mining places in Kabwe town*

BACKGROUND Cont’d

Fig 2. water bodies contamination

- 2007, Kabwe ranked most polluted town in Africa [3]
- Water samples from operating wells showed Pb(II) concentrations of 2 - 5 mg/L against WHO safety limit of 0.15 mg/L
- Pb(II) poisoning can seriously damage the kidney, liver, brain and nervous and system in humans [4]

RESEARCH PROBLEM

Heavy Metal Removal Technologies

Electrochemical

- Electrocoagulation
- Electrodeposition
- Electroflotation

Physiochemical → **Adsorption**

- Precipitation
- Ion exchange

Adsorption

- Activated carbon
- Carbon Nanotubes
- Wood Sawdust

CURRENT METHODS

- Photocatalysis
- Membrane Filtration
- **Nanotechnology (Nanofiber) [5]**

APPLICATTION OF NANOFIBERS

***Fig 3**. Application of nanofibers*

ADSORPTION

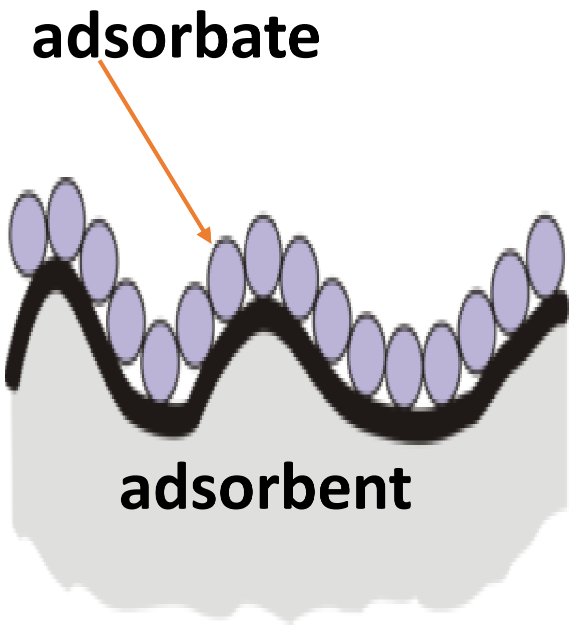

Fig 4. *Relationship between adsorbate and adsorbent*

Adsorption process [5]

Physisorption

- ❑ Weak forces
- ▪ Van de waals forces
- ▪ Polar forces

Chemisorption

- ❑ Strong forces
- ▪ Covalent bond

Fig 5. *Adsorption process*

RESEARCH OBJECTIVE

Aim

- Develop nanofiber adsorbent from *M. oleifera* extract and polyacrylonitrile (PAN) polymer blend as an effiective adsorbent for Pb(II) removal from polluted water.

Objectives

1. Extract polyelectrolyte from *M. oleifera* seeds
2. Synthesise and characterise of *M. oleifera*/PAN nanofiber
3. *To evaluate the effect of interference from competing cations salts (NaCl)*
4. *To investigate the effect of competing ions (binary and multi-ion system)*
5. *To investigate regeneration of the adsorbents*

EXPERIMENTAL SET-UP

M. oleifera seed extract by saline method

De-fatting of *M. oleifera* seed powder

MO seed powder → Mixing
95% ethanol → Mixing

Mixing
30 min
↓
Filtration
↓
Drying
24 hrs at r.t
↓
de-fatted seeds

M. oleifera extract

de-fatted seeds → Mixing
NaCl → Mixing

Mixing
60 min
↓
Filtration
↓
Freeze Drying
↓
***M. oleifera* seed extract**

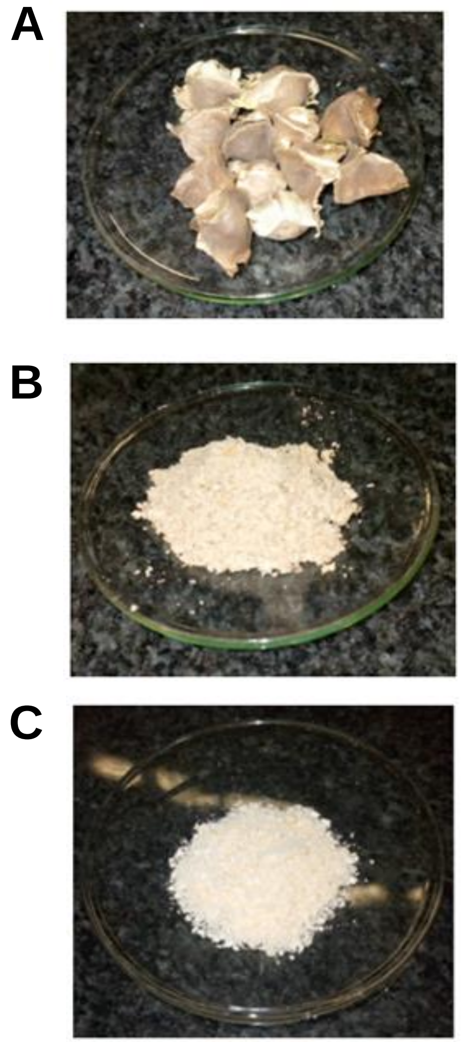

Fig 6. *Diagram of M. oleifera (a) seed (b) powder and (c.) powder extract*

EXPERIMENTAL SET-UP Cont'd

Electrospinning Technique

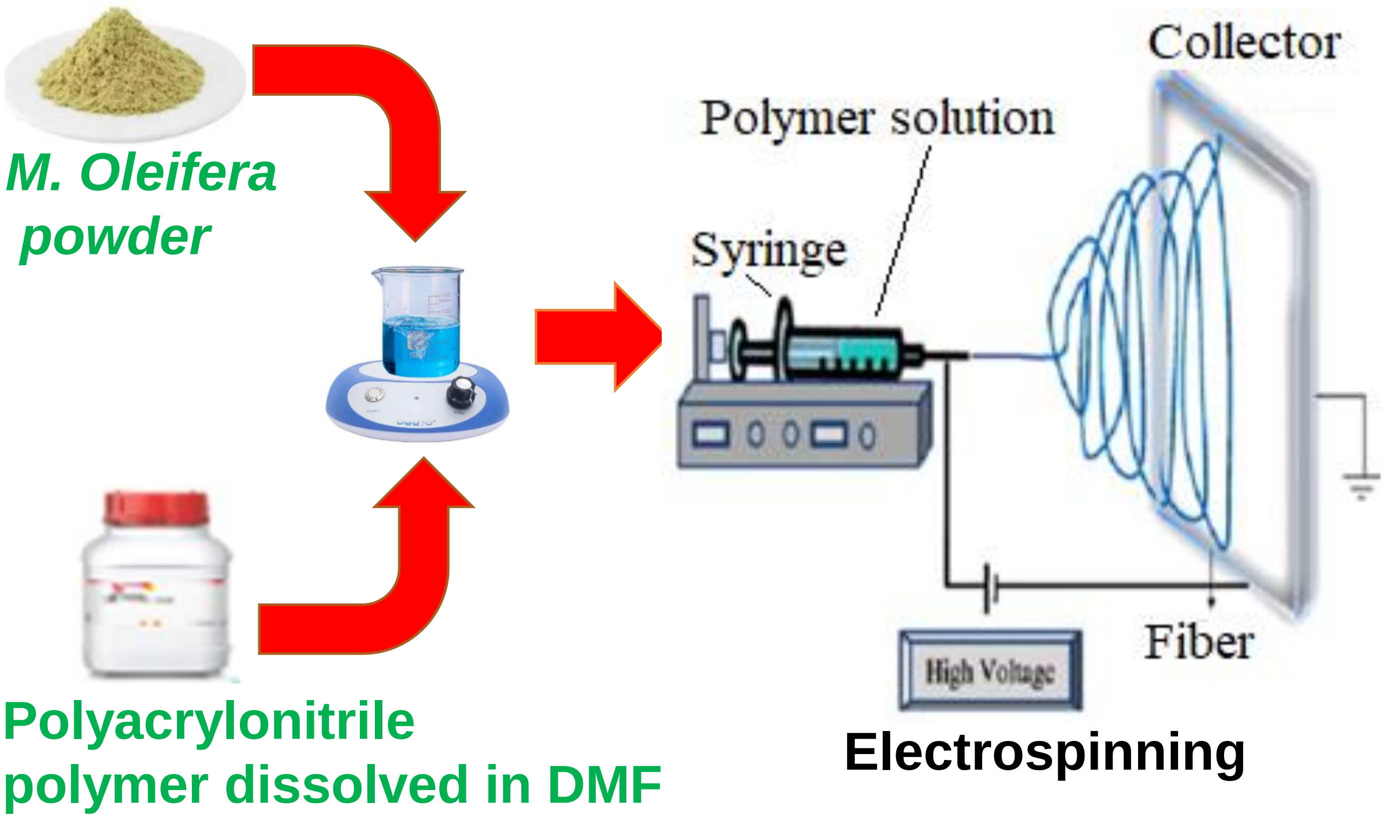

Fig 6. *Schematic diagram of electrospinning*

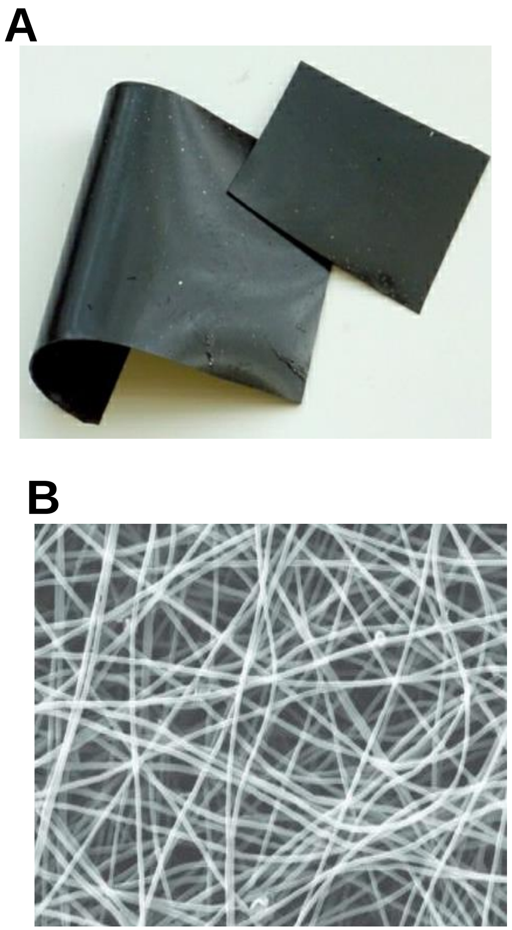

Fig 7. *nanofiber (a) mats and (b) structure*

- **Electrospinning parameters**
  - Concentration: PAN/*M. oleifera* (0.8 g PAN and 3 g *M. oleifera* in 10 mL DMF)
  - Voltage (10 KV), - Distance (15 cm), - Flow rate (0.8 ml/hr)

ADSORPTION EXPERIMENT

$$RE = \frac{(C_i - C_t)}{C_i} x\,100 \quad (1)$$

where RE is the removal (mg/L). efficiency (%), C_i and C_t are the initial and concentration at time t respectively

$$K_d = \frac{q_e}{C_e} \qquad (2)$$

$$K = \frac{K_{d\,(Pb(II)ions}}{K_{d\,(co-existing\ ions)}} \qquad (3)$$

where K_d is the distribution coefficient, *K* is the selectivity, Ce is the equilibrium concentration, respectively (mg/L) and qe is the equilibrium adsorption capacity (mg/g)

CHARACTERISATION

- Scanning electron microscopy **(SEM)**
- Fourier transform infrared **(FTIR)**
- ImageJ software
- Inductively coupled plasma mass spectrometry **(ICP-MS)**

RESULTS AND DISCUSSION

SEM Analysis

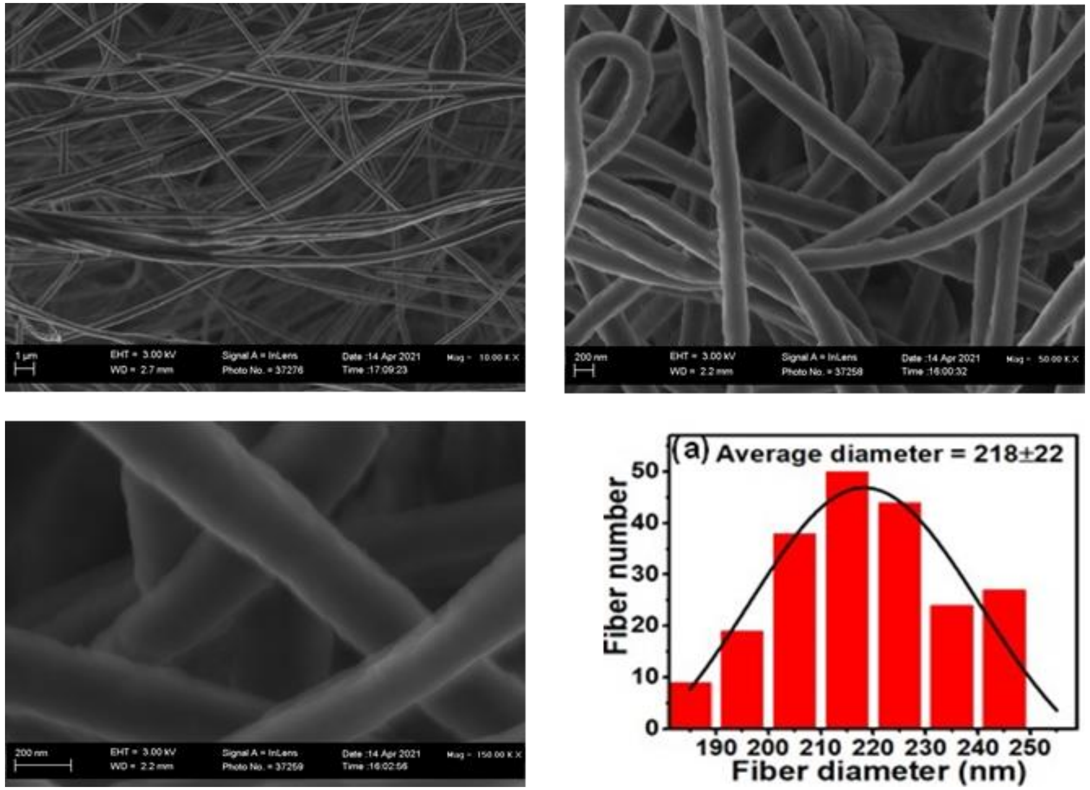

Fig 8. SEM Images and) diameter distribution of nanofiber

FTIR analysis

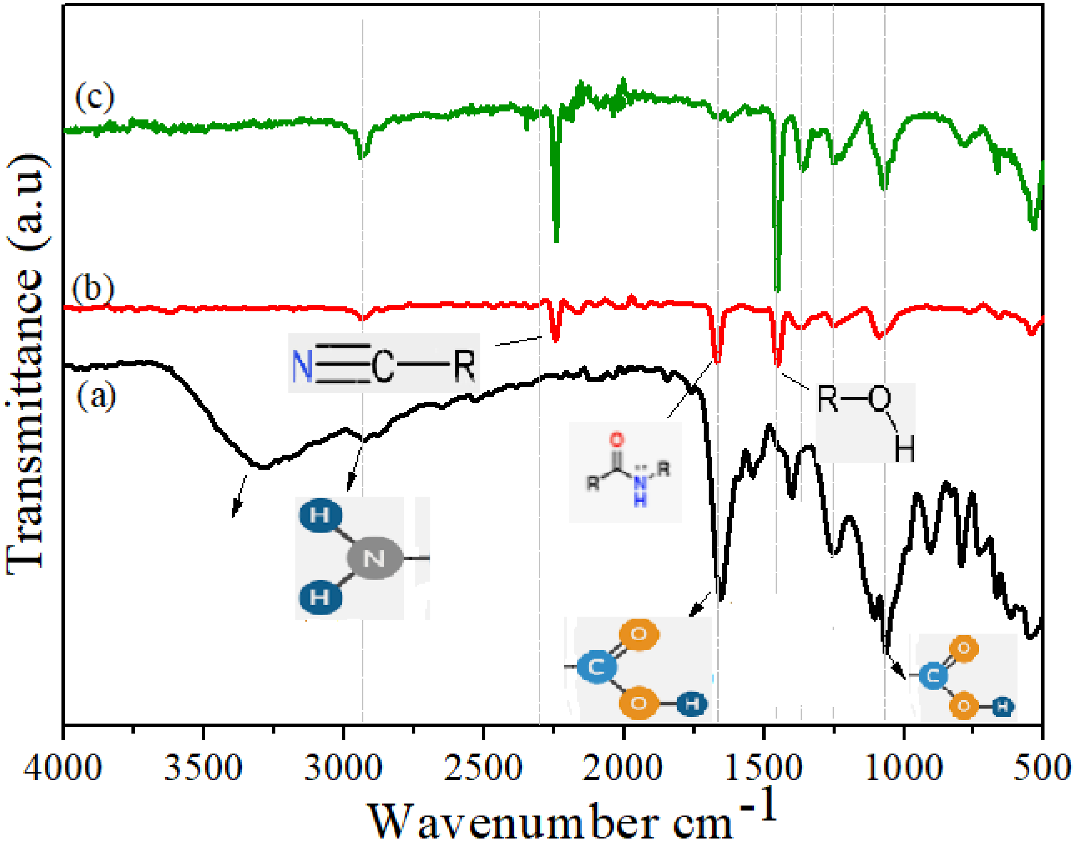

Fig 9. *FTIR spectra of (a) M. oleifera powder, (b) PAN powder and (c) PAN/M. oleifera nanofibers.*

RESULTS AND DISCUSSION Cont'd

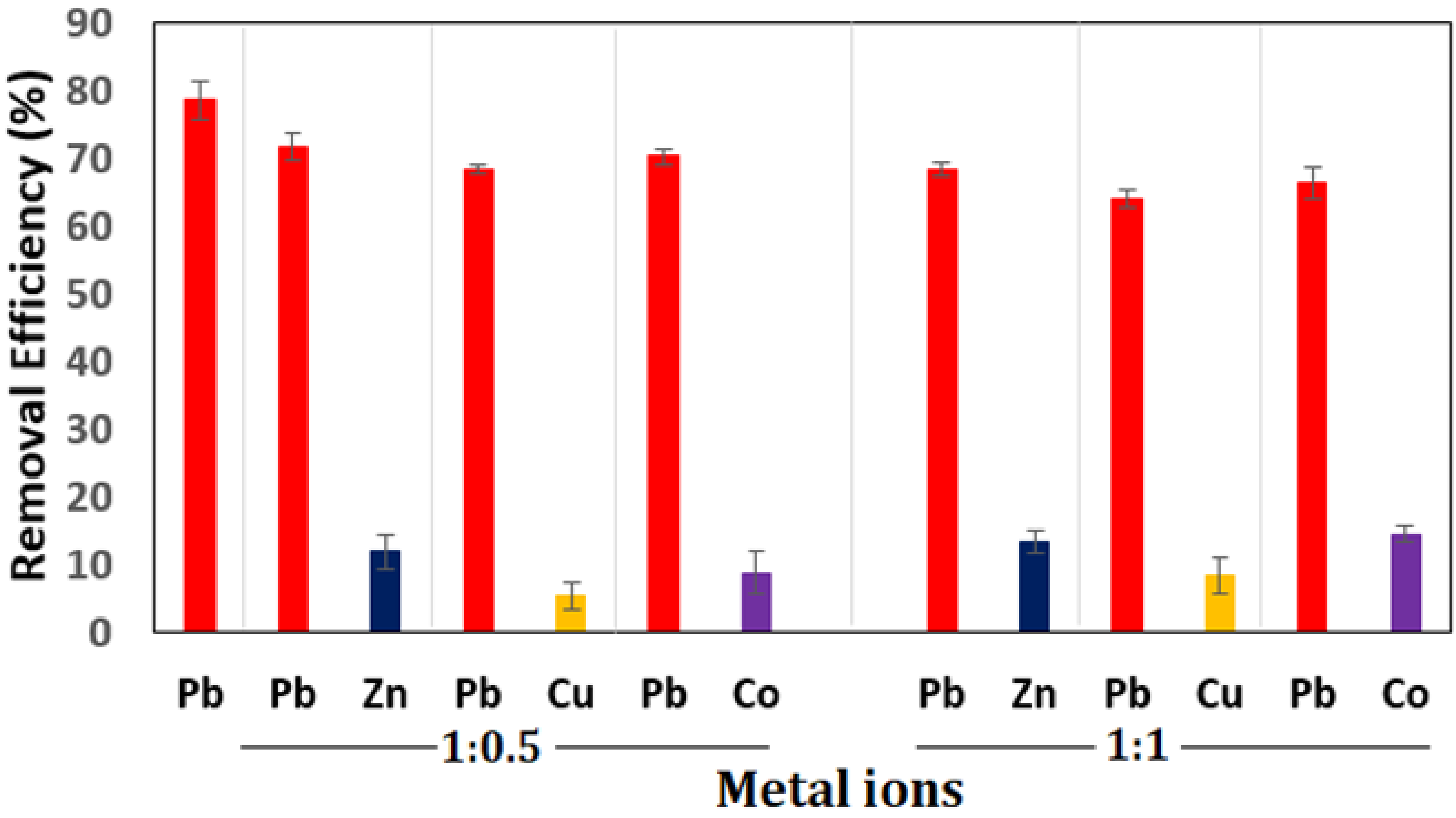

Fig 10: *Effect of the coexisting ions onto PAN/M. oleifera*

RESULTS AND DISCUSSION Cont'd

Table 1: *The water samples sources and their contaminant levels*

Water Sample Sources	Metal ion concentration (mg/L) Pb(II)	Zn(II)	Cu(II)	Co(II)
Shallow wells from Kabwe Mine Township	4.30	2.29	0.92	1.35
Effluent from Kabwe Mine	12.05	10.46	3.90	8.28

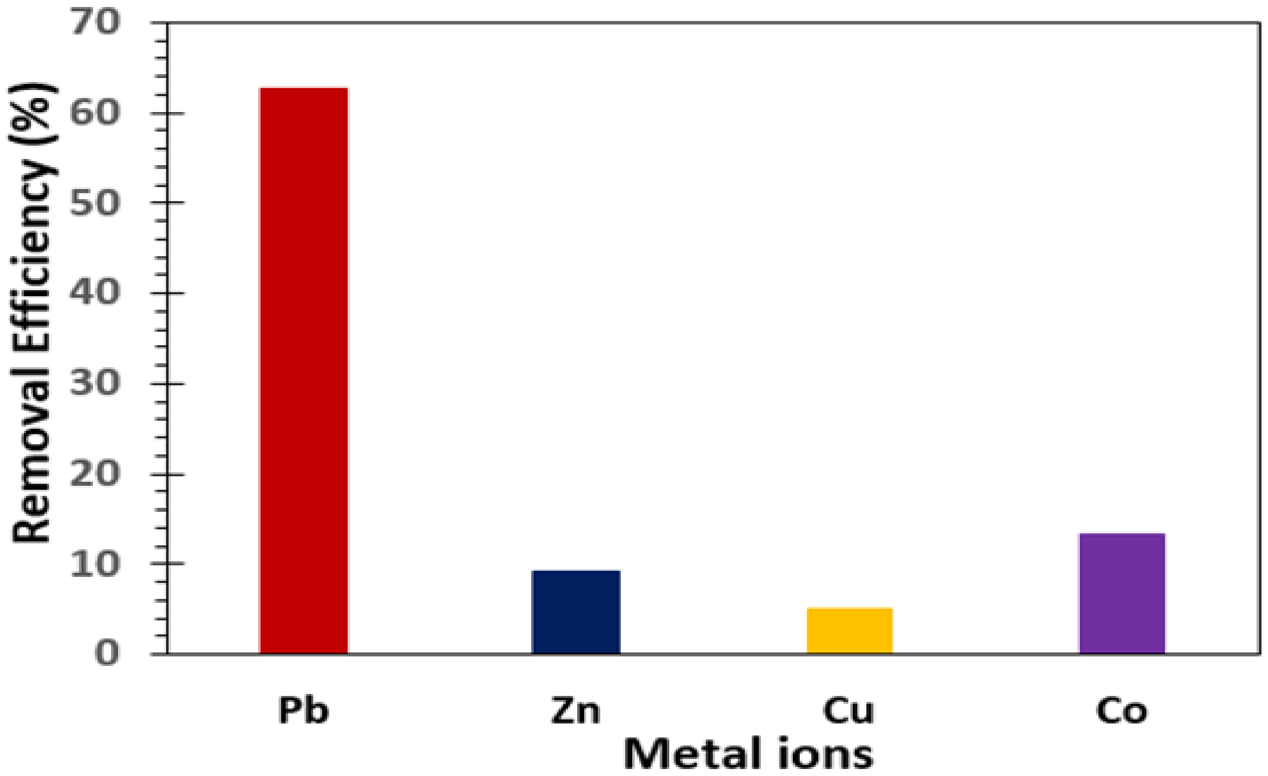

Fig 11: *Effect of the coexisting ions on the adsorption of Pb(II)*

RESULTS AND DISCUSSION Cont'd

Table 2: *The values of K_d and K of coexisting ions*

Adsorbent	K_d (L/g)	K
PAN/*M. oleifera*	23.6	-
	1.3	17.5
	1.6	15.0
	1.4	10.3

RESULTS AND DISCUSSION Cont'd

Regeneration studies

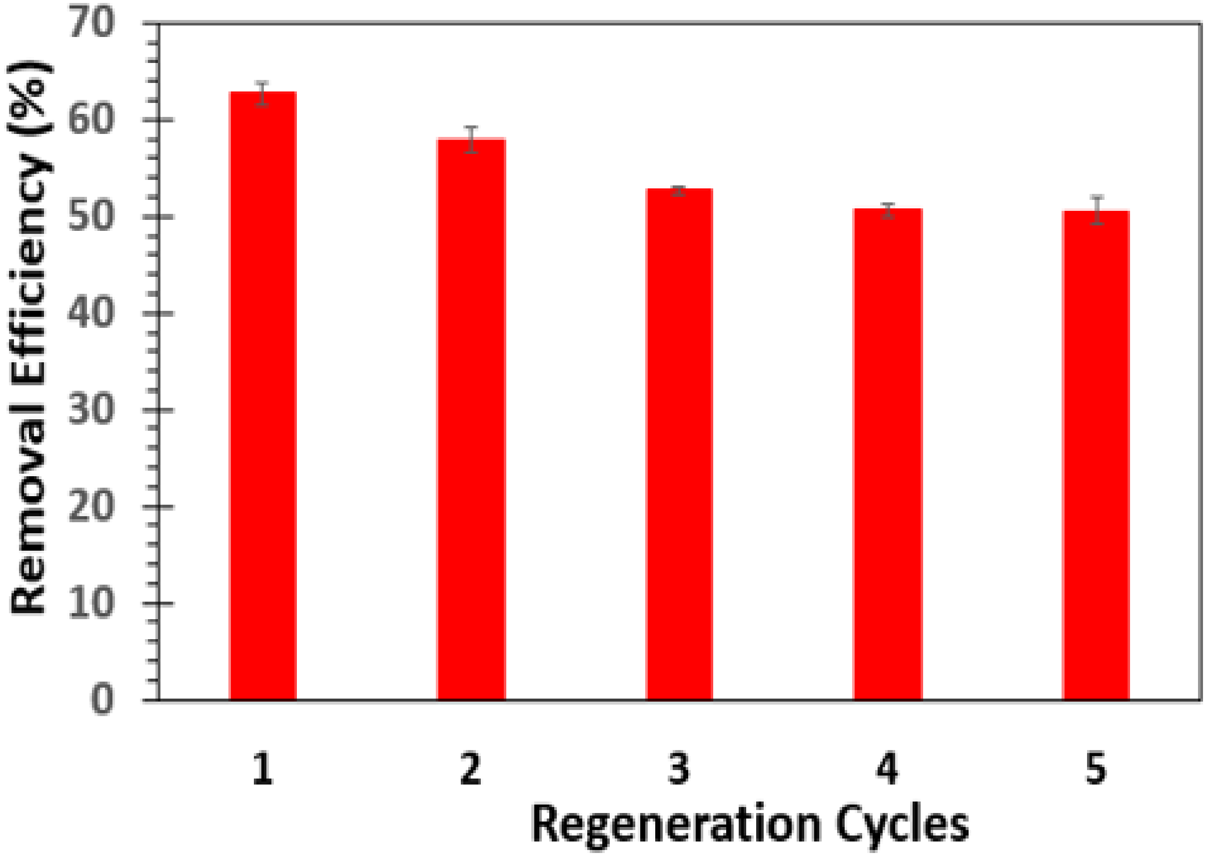

Fig 12. *Adsorption capacity during five adsorption-desorption cycles*

SEM Images

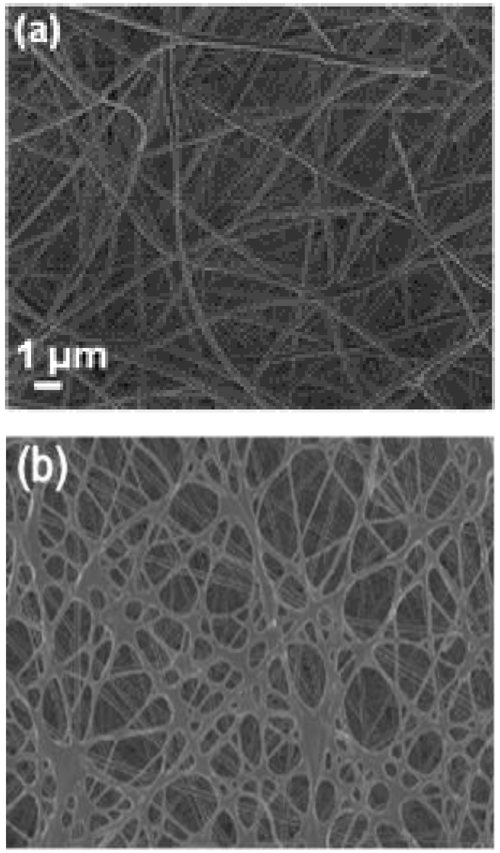

Fig 13. *Morphology of fiber (a) before and (b) after five cycles of adsorption-desorption*

CONCLUSION

Successful fabrication of composite nanofiber adsorbent with desirable characteristics for Pb(II) removal from aqueous water.

Demonstrate that the electrospun composite nanofibers could be used as an effective adsorbent for Pb(II) ions from contaminated waters in Kabwe town of Zambia

FUTURE PERSPECTIVE

The batch adsorption systems come with limitations in replicating real-world applications.

Therefore, it is advisable to explore alternative approaches, such as continuous flow in column systems.

ACKNOWLEDGEMENT

- University of Pretoria
- DAAD Scholarship (Government of Germany)
- Copperbelt University

REFERENCES

1. Environmental Council of Zambia (2008). Zambia Environmental Outlook Report 3. Lusaka: ECZ Publications.

2. Government of the Republic of Zambia (GRZ) (1983). Zambia Secondary School Atlas. London: George Philip and son limited

3. Blacksmith Institute., World Most Polluted Places. New York (2007). www.blacksmithinstitute.org

4. Chang J Wang J Qu J Li Y V Ma L Wang L Wang X and Pan K (2016) "Preparation of α-Fe_2O_3/polyacrylonitrile nanofiber mat as an effective lead adsorbent." *Environmental Science: Nano.* Vol. (3), pp. 894-901.

5. Ge X Ma Y Song X Wang G Zhang H Zhang Y and Zhao H (2017) "β-FeOOH nanorods/carbon foam-based hierarchically porous monolith for highly effective arsenic removal." *ACS Applied Materials & Interfaces.* Vol. (9), pp. 13480-13490.

6. Lakhdhar I Belosinschi D Mangin P and Chabot B (2016) "Development of a bio-based sorbent media for the removal of nickel ions from aqueous solutions." *Journal of environmental chemical engineering.* Vol. (4), pp. 3159-3169.

7. Chang J Wang J Qu J Li Y V Ma L Wang L Wang X and Pan K (2016) "Preparation of α-Fe_2O_3/polyacrylonitrile nanofiber mat as an effective lead adsorbent." *Environmental Science: Nano.* Vol. (3), pp. 894-901.

8. Kebede T G Dube S and Nindi M M (2018) "Fabrication and characterization of electrospun nanofibers from Moringa stenopetala seed protein." *Materials Research Express.* Vol. (5), pp. 125015.

9. Kyzas G Z Kostoglou M and Lazaridis N K (2009) "Copper and chromium (VI) removal by chitosan derivatives—Equilibrium and kinetic studies." *Chemical Engineering Journal.* Vol. (152), pp. 440-448.

10. Sahoo S K and Hota G (2019) "Amine-functionalized GO decorated with ZnO-$ZnFe_2O_4$ nanomaterials for remediation of Cr (VI) from water." *ACS Applied Nano Materials.* Vol. (2), pp. 983-996.

The End

THANK YOU FOR YOUR ATTENTION.