



Synthesis and Characterisation of an Activated Carbon-Ag-SiO₂ Nanocomposite for Removal of Heavy metals and Organic waste from water

James Nyirenda^{1,2}, George Kalaba¹, Onesmus Munyati¹

¹Department of Chemistry, School of Natural Sciences, University of Zambia, Box 32379, Lusaka, Zambia

²Department of Pharmaceutical Sciences, College of Pharmacy, University of Illinois at Chicago, Chicago, Illinois 60612, United States



Introduction/Background

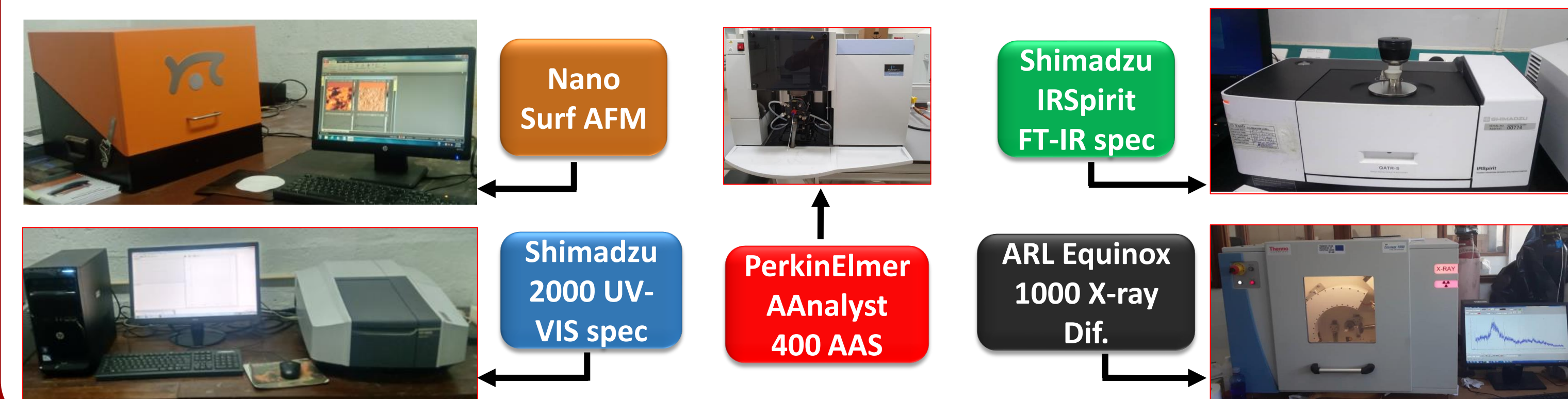
Access to clean and quality water remains a challenge in third world countries. The world's sources of fresh water are being threatened by microbiological, organic and inorganic pollutants such as pathogens [1], dyes [2], persistent organic pollutants (POPs) [3], pharmaceuticals [4] and heavy metals [5]. The release of heavy metals in fresh water sources is of significant concern globally because of their potential adverse effects on both human health and the environment [6]. In Zambia, some residents have been reported to suffer from many health complications due to consumption of water contaminated with heavy metals [7]. We report synthesis and characterization of an activated carbon-supported silver-silica nanocomposite (AC-Ag-SiO₂) for removal of Cu²⁺, Pb²⁺, Cd²⁺ and Zn²⁺ ions from single and multi-metal aqueous solutions.

Material & Methods

Raw carbon bioresource (*Zea mays* waste cobs), Cadmium nitrate tetra-hydrate (Cd(NO₃)₂·4H₂O), Zinc nitrate hexahydrate (Zn(NO₃)₂·6H₂O), Copper sulphate (CuSO₄), lead nitrate (Pb(NO₃)₂), sodium silicate (Na₂SiO₃), ammonium hydroxide (NH₄OH), hydrochloric acid (HCl), sodium hydroxide (NaOH), ethanol (C₂H₅OH), silver nitrate (AgNO₃), native starch, 98% sulphuric acid (H₂SO₄), and distilled water.

Activated carbon was synthesized by thermal treatment. Silver, Silica NPs and ultimately the Activated carbon-Silver-Silica composite were synthesized as shown in the scheme (Figure 1) [8].

Instrumentation



Results

Characterization of the nanoparticles was done UV-Vis spectrophotometry, Fourier Transform Infrared spectrometry, X-ray diffraction and Atomic Force Microscopy.

Characterisation of the silica, silver and AC-Ag-SiO₂ composite materials

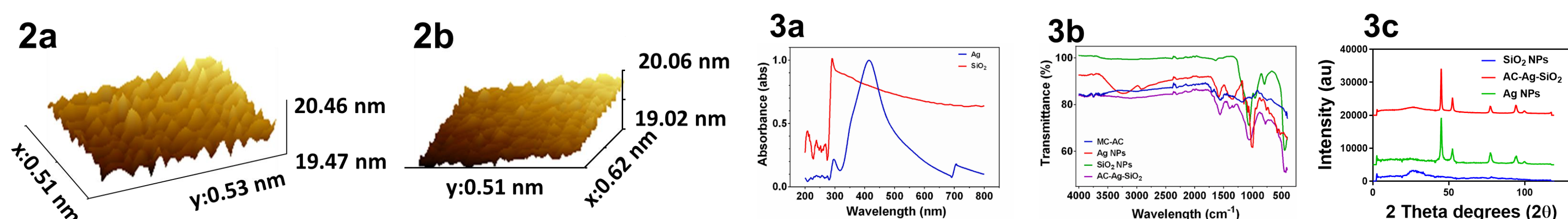


Figure 2

AFM image of the synthesized (2a) silver (Ag NPs), (2b) silica (SiO₂ NPs). Both were spherical in morphology.

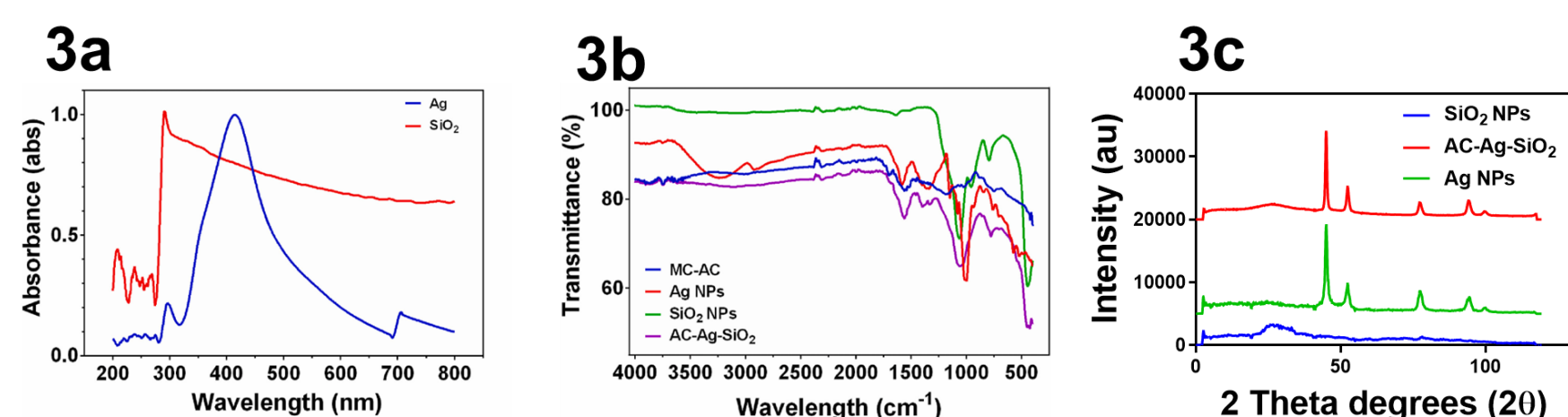


Figure 3

UV-Vis (3a), FT-IR (3b) and X-ray diffraction (3c) spectra of SiO₂ NPs, Ag NPs, MC-AC and AC-Ag-SiO₂ composite.

Effect of pH, contact time, temperature and dosage

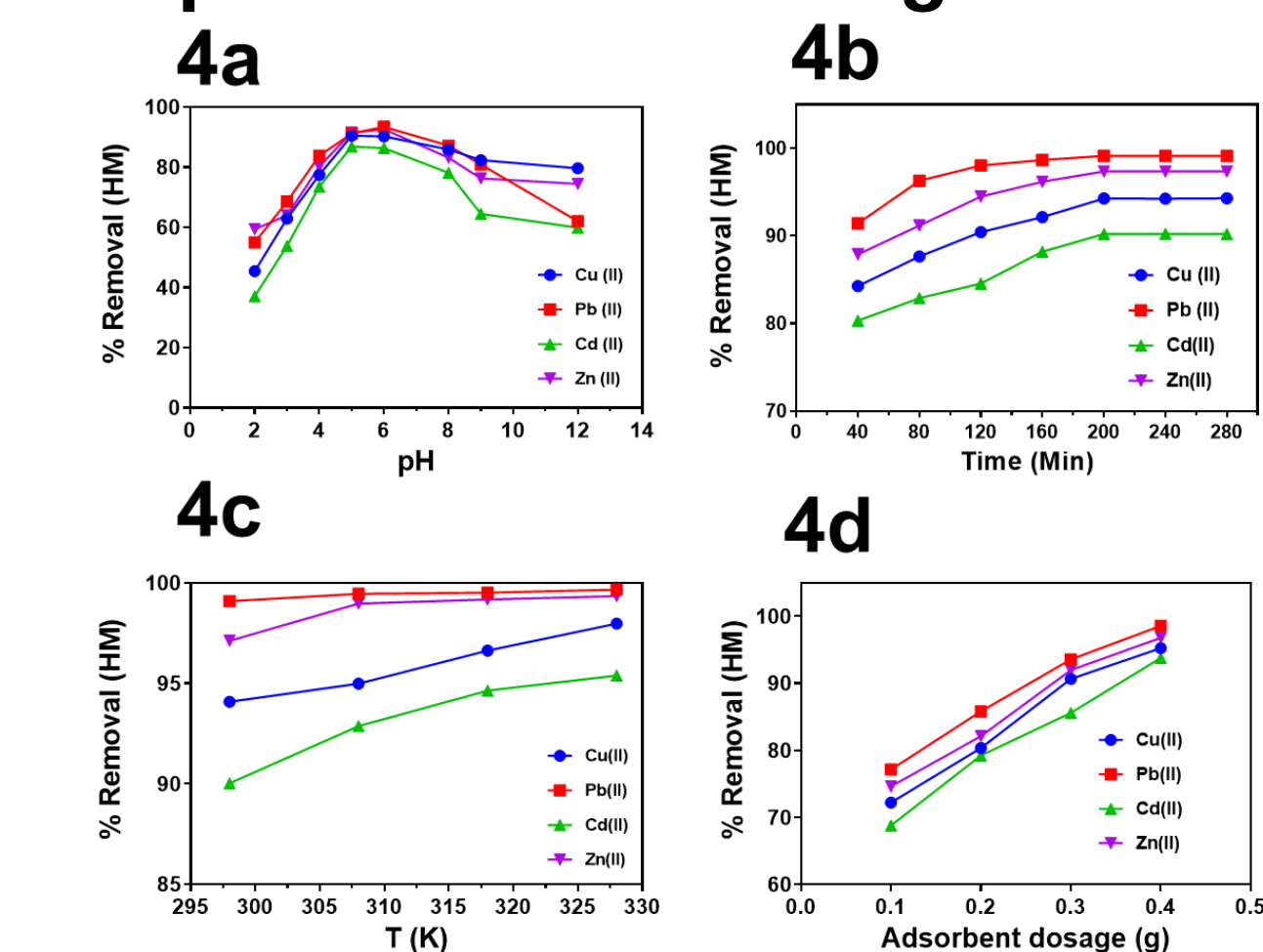


Figure 4

(4a) pH (5.5), (4b) contact time, (4c) temperature (298-328 K), (4d) adsorbent dosage (0.1-0.4 g) on percent removal of Cu²⁺, Pb²⁺, Cd²⁺ and Zn²⁺ ions by the AC-Ag-SiO₂ composite (dosage = 0.1 g, T = 298 K, V_{solution} = 0.1 L, t = 200 min and initial metal conc. = 10 mg/L)

Thermodynamic and kinetic characteristics of the composite

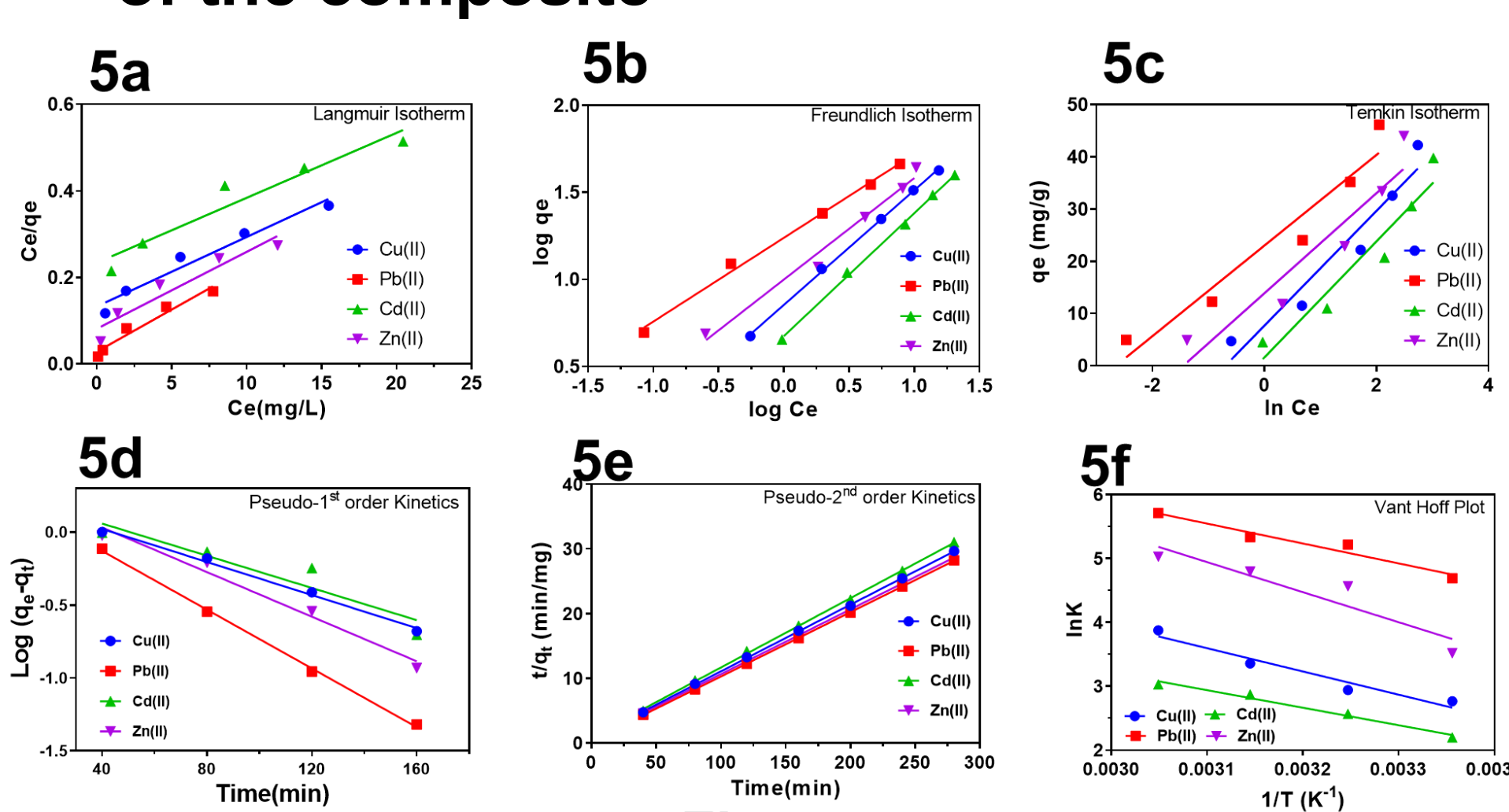


Figure 5

(5a) Langmuir, (5b) Freundlich and (5c) Temkin adsorption isotherms, (5d) Pseudo-1st order kinetics, (5e) Pseudo-2nd order kinetics, (5f) Van't Hoff plot for Cu²⁺, Pb²⁺, Cd²⁺ and Zn²⁺ ions adsorption onto AC-Ag-SiO₂ composite. The **Freundlich isotherm model (R² > 0.99)** and **pseudo-second-order kinetic mode (R² > 0.999)** providing a better fit to the experimental data.

Results, continued

Methylene Blue binding

Methylene blue adsorption was carried out using 1g of activated carbon and 30 mL of MB and agitated at 250 rpm at 25 °C and 1 atmosphere.

Removal of MB (6) at equilibrium was 99.69 ± 0.3 % at 50 mg/L and the lowest was 96.47 ± 0.1% at 350 mg/L.

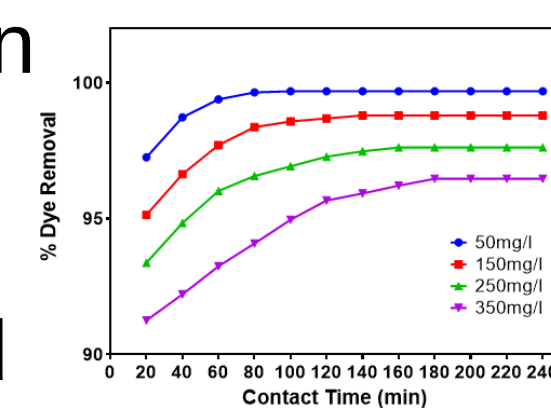


Figure 6

Regeneration of the AC-Ag-SiO₂ composite

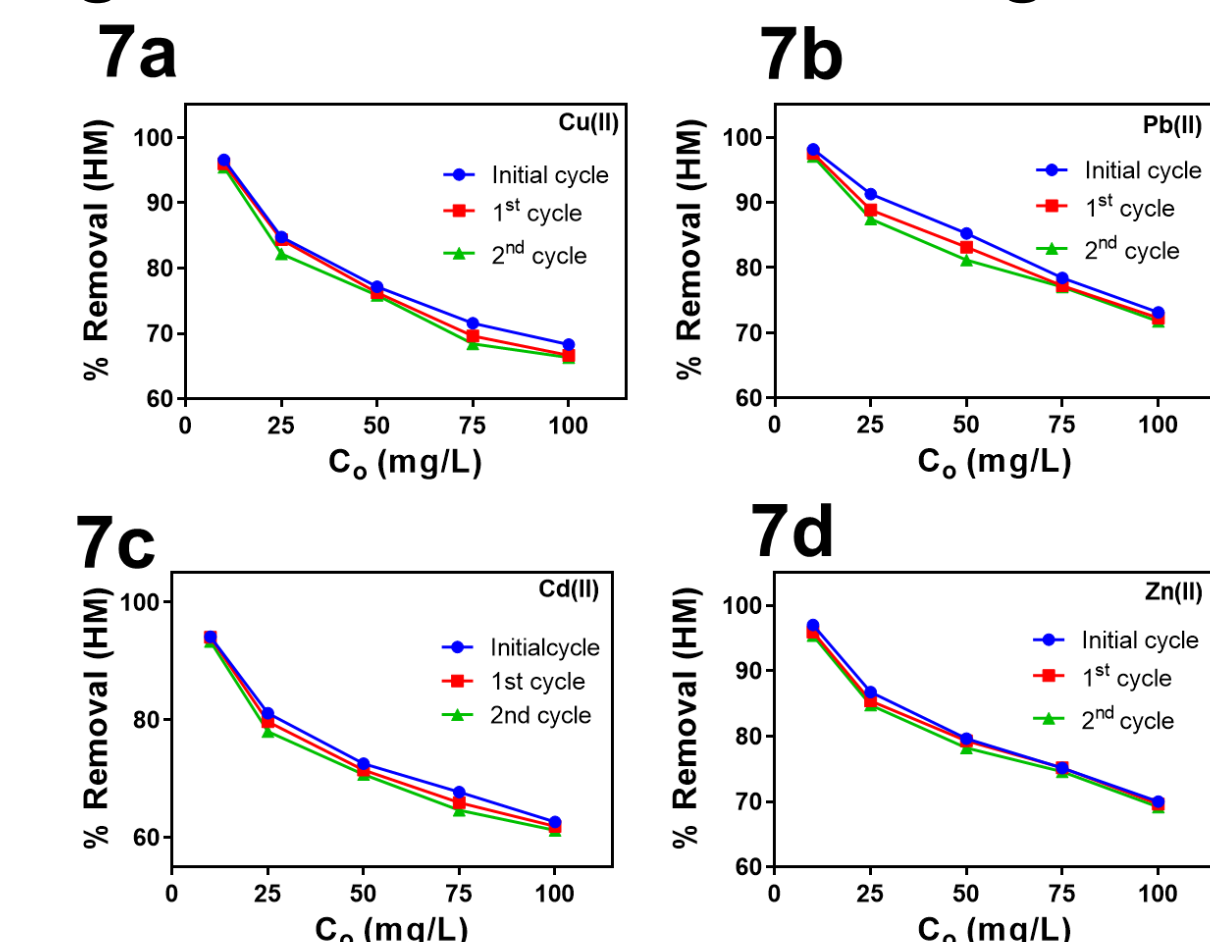


Figure 7

Data shows the initial, first and second cycle percentage removal of (7a) Cu²⁺, (7b) Pb²⁺, (7c) Cd²⁺ and (7d) Zn²⁺ by regenerated AC-Ag-SiO₂ composite.

Conclusions

Regeneration studies on the composite were done to assess reusability. The filter was able to function effectively. The maximum adsorption capacity was found to be 84.75 ± 0.24, 81.30 ± 0.2, 87.72 ± 0.96 and 81.97 ± 0.39 mg/g for Cu²⁺, Pb²⁺, Cd²⁺ and Zn²⁺ ions, respectively. Equilibrium data fitted the Freundlich isotherm and pseudo second order kinetics. Thermodynamic parameters, ΔG° (-13.72 ± 0.20 to -5.45 ± 0.35 kJ/mol), ΔH° (95.10 ± 14.33 to 162.4 ± 27.17 J/K.mol), and ΔS° (22.81 ± 4.50 to 39.12 ± 8.70 kJ/mol) showed that the adsorption process of Cu²⁺, Pb²⁺, Cd²⁺ and Zn²⁺ ions onto AC-Ag-SiO₂ composite was spontaneous, endothermic and physical in nature. Regeneration studies suggested that AC-Ag-SiO₂ composite could be reused effectively with no statistical significance among the cycles (p > 0.9 for all the four metal ions).

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Contact Details: nyirendaj@unza.zm, jamesn7414@gmail.com, jnyire2@uic.edu

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