



Amine-modified silica-cellulose acetate nanofiber membranes for effective removal of hardness and heavy metals in drinking water

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Introduction

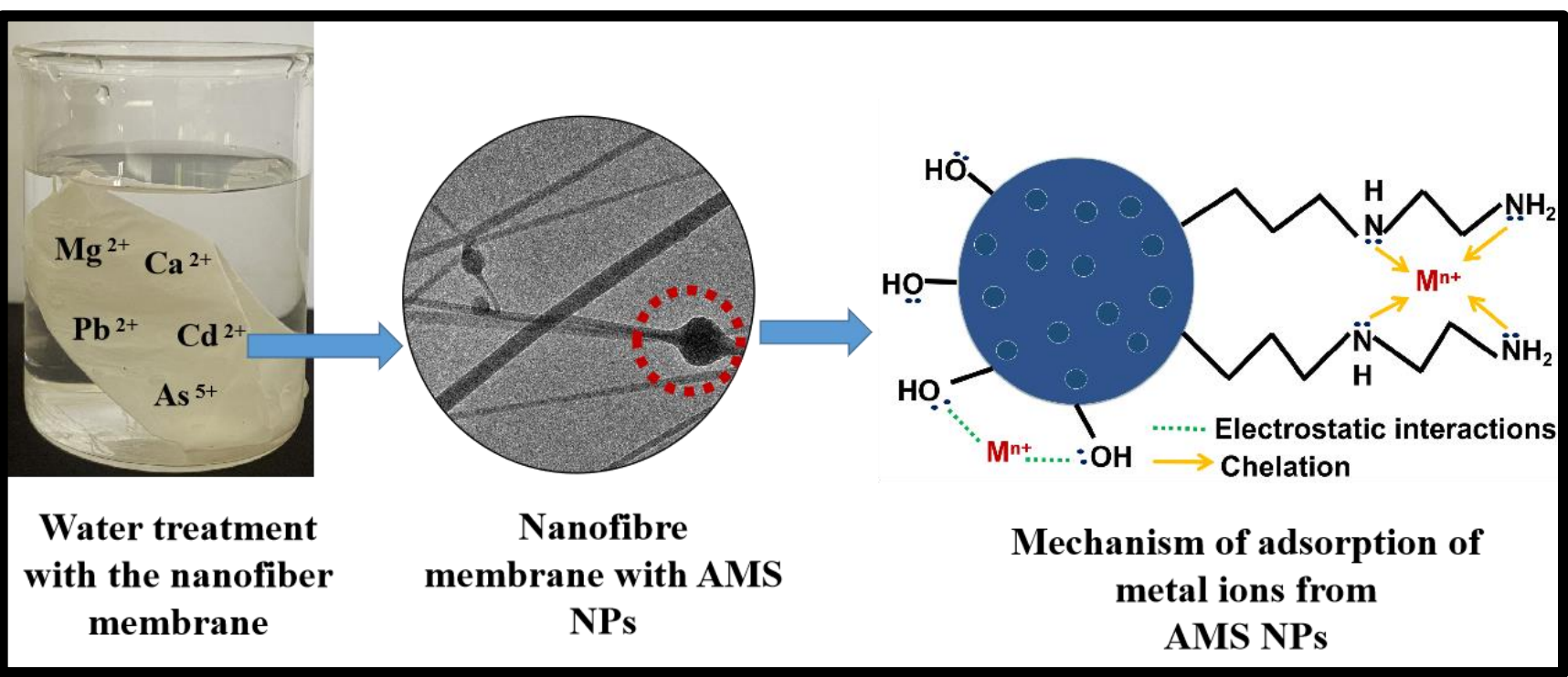
With the increasing urbanisation and population growth, the water scarcity has become a global challenge. Water hardness and heavy metal pollution are important factors that influence water quality.

Silica nanoparticles have gained the interest of researchers for their multidisciplinary role due to the presence of high surface area, high porosity, nanoscale features and ability for facile functionalization. Amine functionalized Silica Nps (AMS) have an unwavering capability to purify water by adsorbing ion contaminants due to the synergistic effect of its high surface area, porosity and the presence of amine functional groups.

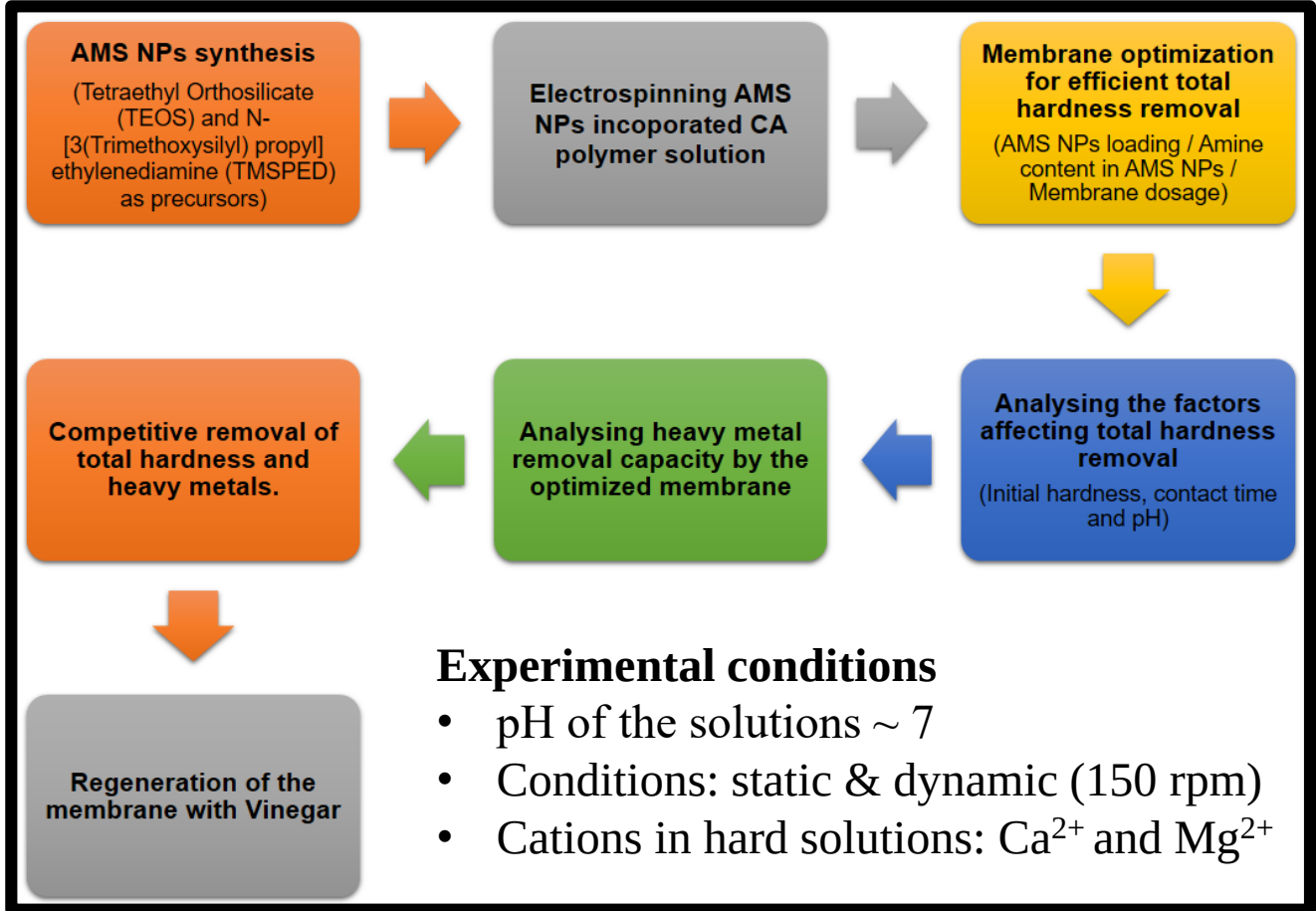
Electrospinning the nanoparticles into the biodegradable nanofibers prevents aggregation of NPs and thus increases interaction with ions, resulting in improved removal. The high aspect ratio of the nanofibers allows the accommodation of a higher number of functionalized nanoparticles blended into the polymer leading to enhanced adsorbent sites. Furthermore, it facilitates the recovery of nanoparticles from water samples and synergistically improves ion adsorption via electrostatic interactions with its functional groups.

Contributing to the UN's 6th sustainable goal of clean water and sanitation, this work involves the development of efficient and convenient approach of water purification by integrating amine-functionalized silica nanoparticles (AMS NPs) into cellulose acetate (CA) electrospun nanofiber membranes.

Research approach

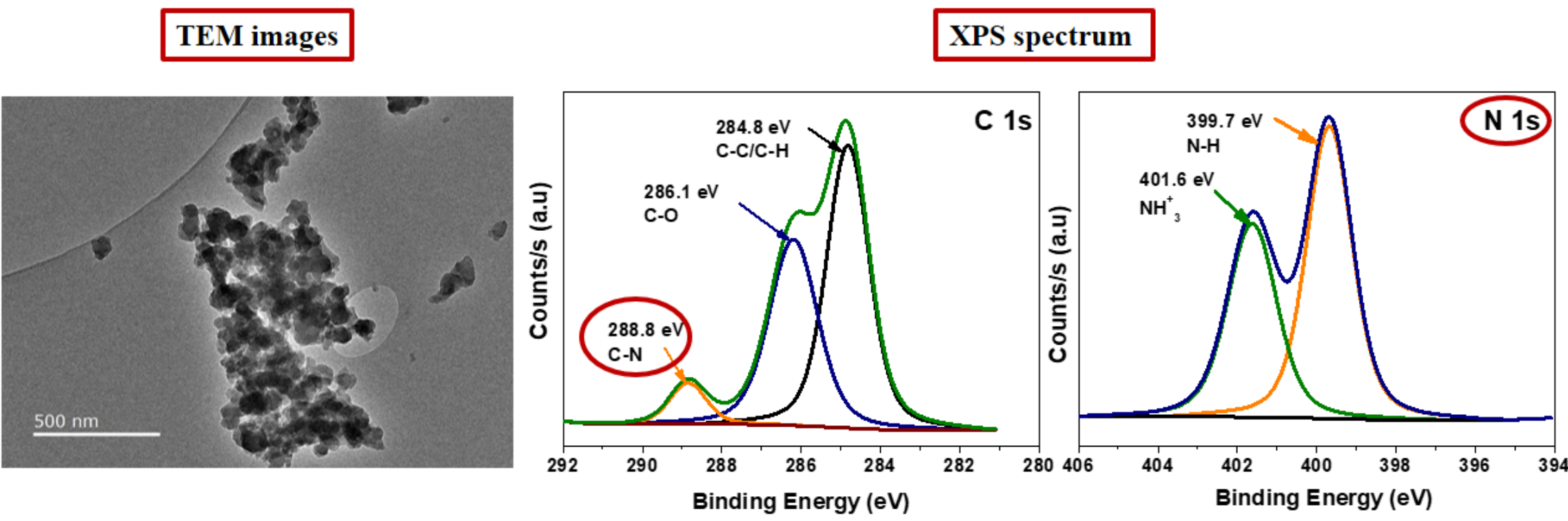


Methodology



Results and Discussion

AMS NPs characterisation

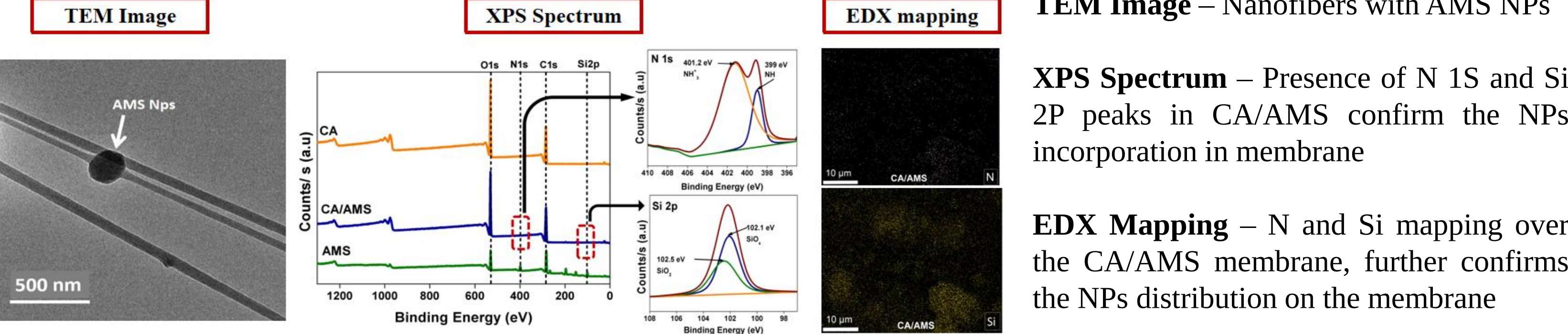


TEM images – Spherical NPs with an average diameter of 56±14 nm

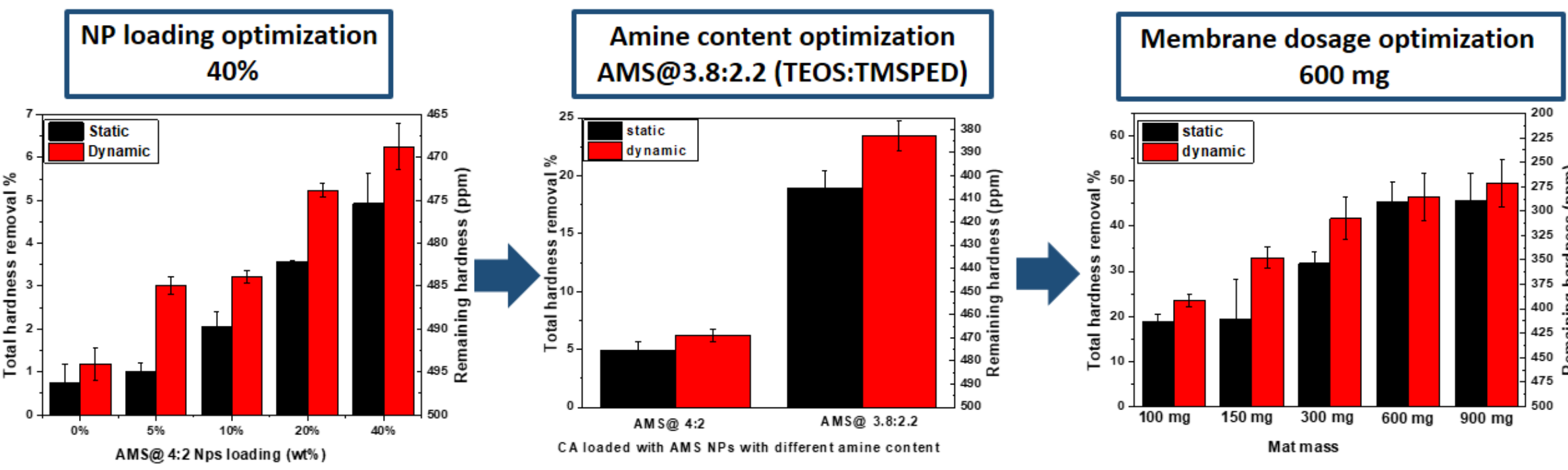
XPS spectrum – Presence of N peaks confirm the successful functionalization of NPs with amine groups

Results and Discussion

CA/AMS nanofiber membrane characterisation

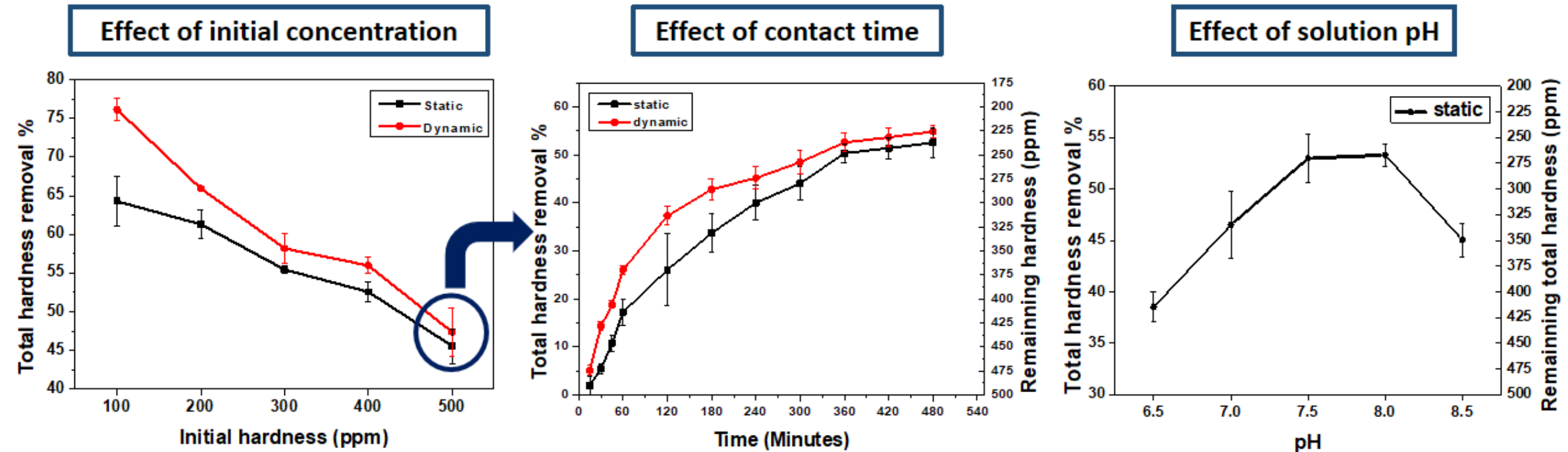


Membrane optimization for efficient total hardness removal (Initial concentration of 500 ppm)



Optimum NP loading is 40 % and optimum amine content is when TEOS:TMSPED ratio is 3.8:2.2. No statistically significant difference between the removal percentages when using 600 mg and 900 mg membrane dosages. Therefore 600 mg was chosen as the optimum membrane dosage

Factors affecting total hardness removal



Removal efficiency decreases with increasing concentration

Equilibrium time – 8 Hrs

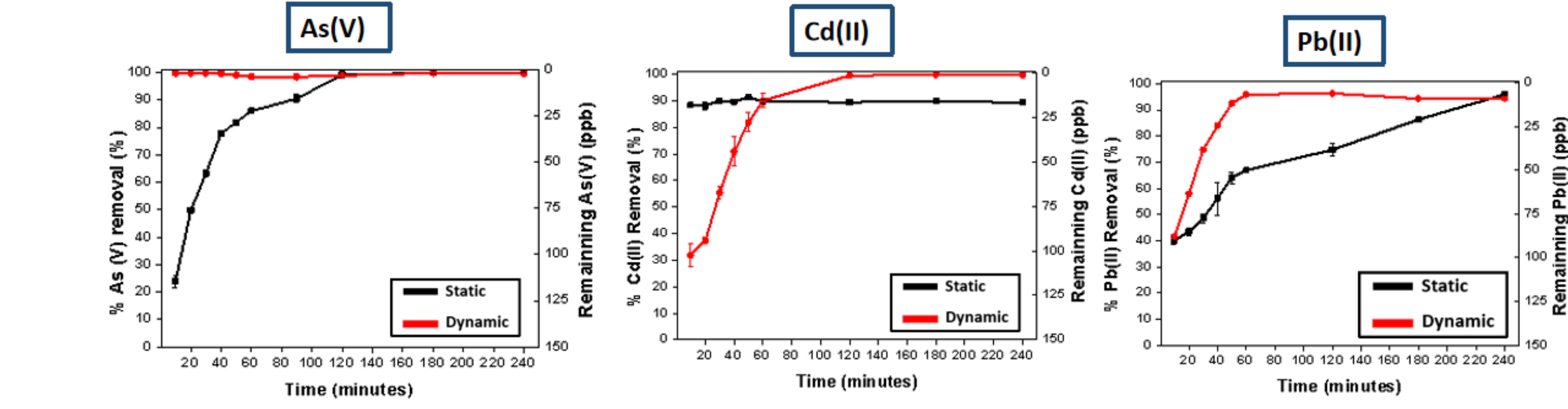
pH_{pzc} of the adsorbent membrane is 7.5

solution pH < pH_{pzc} → Net positive adsorbent surface charge
solution pH > pH_{pzc} → Net negative adsorbent surface charge

Therefore when solution pH decreases removal efficiency decreases. At higher solution pHs (above 8.3) Ca²⁺ and Mg²⁺ start depositing resulting in decrease of removal efficiency.

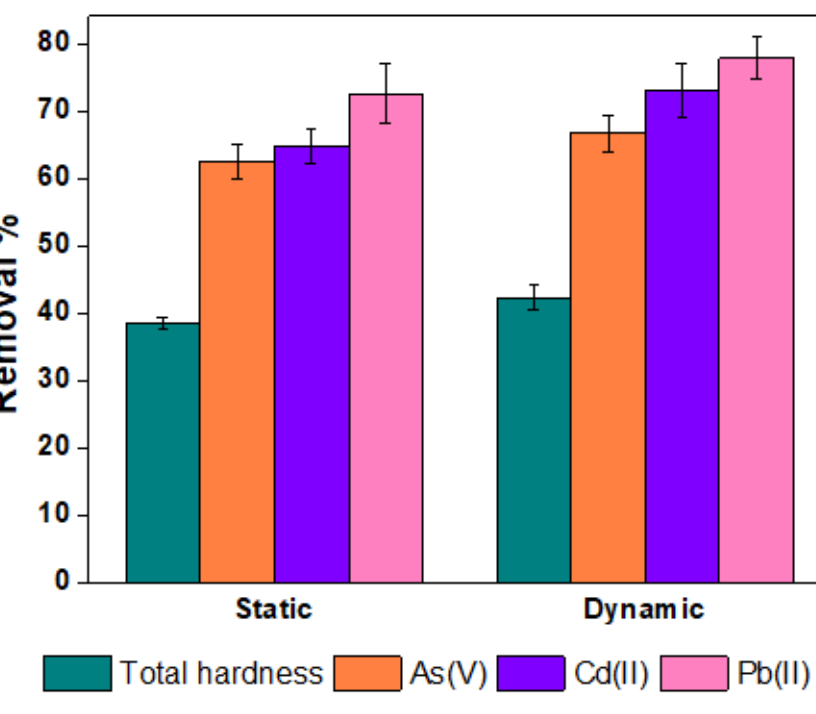
Results and Discussion

Heavy metal removal by the optimized membrane



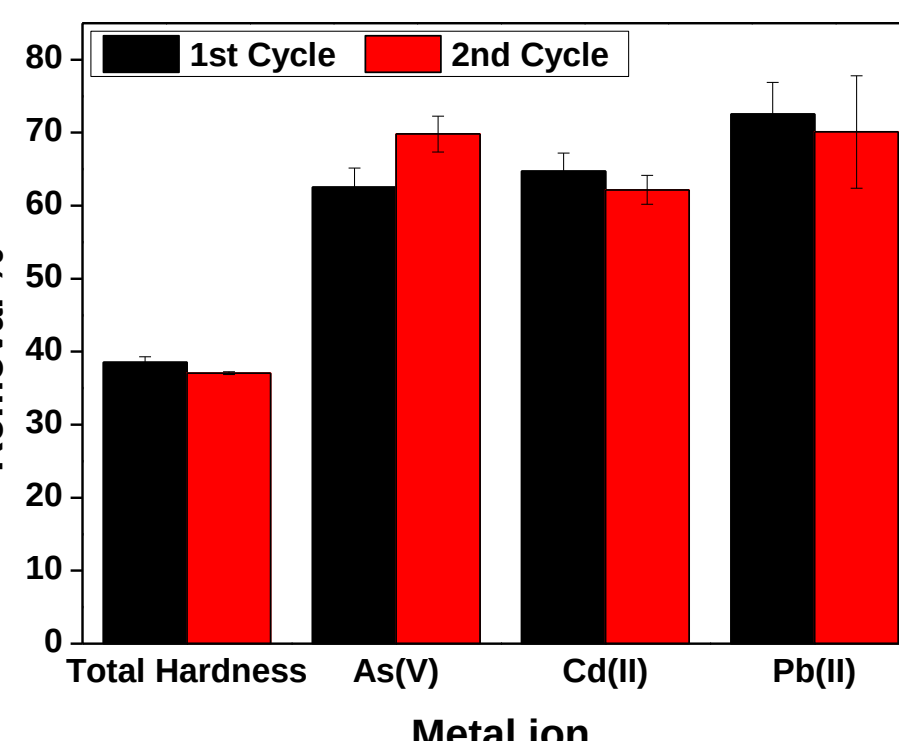
More than 90% removal for As(V), Cd(II) and Pb(II) within 4 Hrs at an initial concentration of 150 ppb

Competitive removal of cations



A slight decrease in removal efficiency due to competition was observed.

Regeneration of the membrane



The used membrane was dipped in **food grade vinegar** for 1 Hr, washed with DI water, air dried and reused.

Both hardness and heavy metal removal followed Pseudo-second order kinetics and Freundlich Isotherm

Conclusion

The findings demonstrated that AMS/CA nanocomposite membranes have a high potential for water softening and heavy metal removal in contaminated drinking water with an approximately 50% hardness removal (500 ppm) and more than 90% heavy metal removal (150 ppb).

Acknowledgement

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References

Boretti, A.; Rosa, L., Reassessing the projections of the world water development report. NPJ Clean Water 2019, 2 (1), 1-6.
Munaweera, I.; Koneru, B.; Patel, A.; Dang, M.; Balkus Jr, K.; Di Pasqua, A., Nitric oxide-and Cisplatin-releasing amine-modified mesoporous silica nanoparticles for the treatment of non-small cell lung cancer. 2016.