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Treatment of acid mine drainage using silica sodalite infused polysulfone composite membrane

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Abstract

Water contamination by Acid Mine Drainage (AMD) has been a challenge in the mining and water treatment industry. This is due to the acidity, alkalinity, high salinity, conductivity and heavy metal toxicity associated with AMD contaminated water. The quality of affected water bodies has negative impacts on the agricultural land, aquatic ecosystem, and on the health of nearby communities. Studies have been conducted on the treatment of AMD using different methods, but there is currently no successful method which has the required combination of scale, resources, affordability, and performance.

Conventional treatment methods which have been explored in the treatment of AMD include but are not limited to wetlands, limestone drains, ion exchange, absorption/adsorption, density sludge plants and membranes. The application of some of these methods is limited by economic viability, effectiveness, and time consuming or sludge production. Membrane technology has drawn the interest of many researchers because of its flexibility, efficiency, selectivity, and reliability. The incorporation of nanoparticles into membranes have improved their mechanical properties and surface chemistry resulting in better performing membranes. Nanoparticles like carbon nanotubes, chitosan, and zeolites have been explored on the treatment of wastewater.

Hydroxy sodalite (HSOD) and silica sodalite (SSOD) are types of zeolites which are explored in this study for the treatment of AMD. HSOD and SSOD synthesized by hydrothermal synthesis and topotactic conversion, respectively, were successfully employed in composite polysulfone (Psf) membrane for the treatment of AMD. SEM analysis revealed that synthesized HSOD nanoparticles possess a thread-ball like morphology with a touch of cubic structures while textural properties show a BET pore volume and surface area of 0.115 cm^3/g and 201 m^2/g, respectively. The morphology of SSOD nanoparticles shows a plate-like structure similar to that of its mother silicate RUB-15, indicating successful topotactic conversion without

structural collapse. A BET pore volume and surface area of 0.242 cm^3/g and 200 m^2/g was obtained for SSOD. The XRD patterns showed a crystalline structure for all the nanoparticles and it matched to that of simulated patterns from the DIFFRAC.EVA software. The SSOD nanoparticles showed high thermal stability with 6% weight loss when compared to 8% and 19% weight loss from fSSOD and HSOD nanoparticles, respectively, on the TGA. The high weight loss from HSOD confirmed the presence of pore occluded with water molecules as described in literature. SSOD nanoparticles were further functionalized to introduce carboxylic functional groups. The functionalization process was able to preserve the physical and chemical structure of SSOD with a slight decrease in BET surface area and pore volume (i.e. 188 m^2/g for BET area and 0.240 cm^3/g for the pore volume).

The synthesized nanoparticles were infused into the Psf at 5wt.% and 10wt.% loadings (10%HSOD/Psf, 10%SSOD/Psf, 5%HSOD/Psf, 5%SSOD/Psf and 10%fSSOD/Psf) and membranes were formed by phase inversion. The SEM images of membranes loaded with HSOD and SSOD show formation of agglomerates, while SEM image of 10%fSSOD/Psf membrane reveals a uniform dispersion of nanoparticles in the polymer matrix. The successful infusion of nanoparticles into Psf enhanced the membrane thermal stability as Psf had 27% residual while 10%HSOD/Psf, 10%SSOD/Psf, 5%HSOD/Psf and 5%SSOD/Psf membranes had 43%, 33%, 32%, and 28% residuals, respectively, after calcination of up to 800°C. The infusion of nanoparticles was also able to improve the membranes mechanical strength from 67 MPa Young modulus for Psf to a maximum of 92 MPa for 5%HSOD/Psf membrane. Nevertheless, the nanoparticles agglomeration at higher loading reduced the membranes mechanical strength.

The performance of the as-produced membranes was evaluated in the treatment of AMD by investigating the membranes permeability and selectivity. The SSOD infused membranes showed good permeability with 10%SSOD/Psf reaching a maximum pure water flux of 2.1

L/m^2.h while 10%HSOD/Psf membranes showed poor permeability of 0.6 L/m^2.h. The fSSOD loaded membrane had negligible effect on the pure water flux as it showed a maximum flux of 2.2 L/m^2. h. HSOD loaded membrane showing poor permeability, was able to produce selectivity above 50% for most metal ions. This indicates a trade-off between membrane selectivity and permeability as the SSOD loaded membranes with high pure water flux presented very poor rejections (2.3-13.3%) which was attributed to nanoparticles agglomeration. Agglomeration reduces the quality of the membrane as it forms sites of nanoparticles concentration, hence increases the surface pore size of the membranes.

The 10%SSOD/Psf membrane was then selected to be evaluated further by modification of SSOD surface chemistry to fSSOD as it presented good permeability. The 10%fSSOD/Psf membrane presented reduced fouling rate with 78.7% reduction in flux over time while the 10%SSOD/Psf membrane showed 90.8% which is even higher than that of pure Psf (87.7%). Functionalization of the SSOD nanoparticles to fSSOD was also able to enhance the membranes selectivity, with most rejections in the range of 51.5%-74.2%, indicating enhanced nanoparticles dispersion.

The successful coating of the membranes was confirmed by the improved reduction of flux over time. The initial flux of 10%fSSOD/Psf/PVA membranes was 4 L/m^2.h, while that of 10%SSOD/Psf/PVA was 3.5 L/m^2.h. This reduced to 1.1 L/m^2.h for both PVA coated membranes after operating for 3 hours, which translate to 68.2% reduction in flux. This indicated an improved reduction in flux when compared to 90.8%, 87.8% and 78.7% for 10%SSOD/Psf, Psf and 10%fSSOD/Psf membranes, respectively. After cleaning the PVA coated membranes with deionized water, a flux of 3.25 L/m^2.h and 1.95 L/m^2.h was obtained, translating to a flux recovery ratio of 81.3% and 55.5% for 10%fSSOD/Psf/PVA and 10%SSOD/Psf/PVA, respectively. The performance shown by the 10%fSSOD/Psf/PVA membrane shows that this membrane can be applied in the treatment of AMD as it was able to

present good selectivity (>50%), membrane flux (4 L/m^2.h), reduced flux decline (68%) and it is able to recover 81% of its initial flux after a simple cleaning process

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