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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Wastewater treatment

Improved membranes for wastewater treatment

A completed Water Research Commission (WRC) research project saw the development of nano-composite polysulphone membranes with reduced fouling properties for use in wastewater treatment.

Background

Many studies have been conducted to increase the hydrophilic properties of the polysulphone membrane surface. In recent years, various metal nanoparticles have been used in wastewater treatment technology with varied success. These metal centres act as redox mediators to reduce hydrophobicity of the membrane.

Nanocomposite membranes are attractive for the purpose of creating new materials with enhanced properties, such as high perm selectivity, good hydrophilicity and excellent fouling resistance. Nanocomposite membranes can remediate two types of fouling: membrane fouling due to organic matter and biofouling.

Study rationale

Polysulphone (PSF) membranes are the most common membranes used in ultrafiltration of wastewater due to its mechanical robustness and structural- and chemical stability. Unfortunately PSF is a hydrophobic material, making its surface prone to fouling due to adsorptive mechanisms.

Many studies have been conducted to increase the hydrophilic properties of the polysulphone membrane surface. Hydrophilicity of membranes refers to the charge-polarised properties of the membrane material and its capacity for hydrogen bonding.

In this project, two divergent approaches in materials synthesis were incorporated to produce polysulphone membrane materials that would be suitable for membrane development and water treatment applications. The first strategy involved the preparation of well defined; metal nanoparticle modified homogenous polysulphone membranes, based on dispersion of chemically synthesised metal nanoparticles within polysulphone thin films. The metal nanoparticles used in the study were selected for their documented catalytic properties.

However, since there is a strong awareness of the need to assess the ecotoxicity of any method or technology that may release nanoparticles into the environment, a second synthetic strategy was identified. This strategy involved the chemical synthesis of chemically cross-linked hydrogels with improved hydrophobicity for improved separation as well as the necessary mechanical strength for membrane development and application.

General outcome

The study demonstrated the successful synthesis of hydrophilic polysulphone derivatives from simple chemical precursors commercially available from local chemical suppliers. Two approaches for synthesis of reproducible thin films of hydrophilic polysulphone have been analysed in detail in order to understand the underlying mechanisms that govern the improvement in surface mass transport properties.

The hydrophilic polysulphone materials have been characterised extensively in an attempt to verify structure, physical and chemical properties of the novel polysulphone composite materials. Spectroscopic investigation was used to characterise the structure of the product and verify the efficiency of chemical modifications employed.

Surface morphology analysis and electron microscopy was used to evaluate pore size and shape distribution of polysulphone composites. Calculate size and shape of metal nanoparticles and confirm homogeneous incorporation of modifier in metal nanoparticle and hydrogel modified polysulphone materials.

Electrochemistry was used to evaluate diffusional properties associated with conductivity of the polysulphone materials as thin film electrodes, evaluate their sensitivity towards selected analyte moleculates and calculate their sensitivity to fouling at very low analyte concentrations.

The polysulphone materials displayed improved mass transport properties in aqueous solutions and produced good linear response as chemical sensors to tannic acid and alginic acid in the micro molar concentration range. This sensitivity made it possible to determine the reaction mechanisms involved in mass transport of the model compounds in the presence and absence of convection, in a closed reaction vessel.

Conclusions

Polysulphone modified with selected catalytic metal nanoparticles was successfully achieved. The polysulphone composite based on homogeneous incorporation of Ni nanoparticles, before film casting, was observed to have the smallest pore size and highest pore distribution per unit area.

The Ni nanoparticles adopted the hexagonally close packet unit arrangement with packing efficiency up to 74%. In the analytical evaluation of PSF/Ni composites drop coated to form thin film chemical sensors, a good sensitivity towards tannic acid and alginic acid was observed with a linear response in the micro molar concentration range.

One of the drawbacks of using metal nanoparticles in environmental applications relates to potential environmental health-related issues as a result of metal nanoparticles leaching into the environment. Hence a second synthetic approach was evaluated that does not involve metal nanoparticles, based on chemical crosslinking of polysulphone with a hydrophilic polymer to produce mechanically stable hydrophilic hydrogels.

Polysulphone and polyvinyl alcohol were chemically cross-linked using a short chain di-aldehyde to produce hydrogels with greatly reduced hydrophobicity, irrespective of the ratio of the starting polymers.

All hydrogels showed similarities to the metal nanoparticle modified polysulphone in terms of surface morphology and electrochemical evaluation of mass transport properties to the thin film hydrogel surface in a three electrode arrangement.

All hydrogel materials showed very good sensitivity and linear response to tannic acid and alginic acid at micro molar concentrations.

Overall, the project has been successful in achieving all its objectives for materials design, development and testing at a laboratory scale..

The research results show great promise for the utilisation of hydrophilic polysulphone derivatives for improved separation efficiency in aqueous media.

Further reading:
To order the report, ***The development of nano-composite polysulphone membranes with reduced fouling properties for use in wastewater treatment*** (**Report No. 2006/1/14**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.