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Abstract of thesis:

On a global scale, out of 80% wastewater generated, about 30% originates from the industrial sources. These effluents are mostly released into the environment without any treatment or recycling, especially in the Asia Pacific region. This unprocessed discharge of industrial wastewater raises significant concerns for both public health and environment. Membrane based separation technology shows potential in tackling such effluents due to its precise control over the separation processes, compact design, better scalability and ability to treat wide range of contaminants. However, these membrane technologies are accompanied by several challenges such as, membrane fouling that require regular cleaning or replacement leading to higher energy consumption. Hence, to mitigate these problems, specialized membranes with better selectivity, higher throughput and low fouling tendency need to be fabricated which is the basic motivation of this work. In this thesis, functionalized ultrafiltration membranes were prepared for specific applications using real life effluent. The detailed modeling was carried out for the process scale up and prediction of performance.

Ethylene diamine tetraacetic acid (EDTA) was immobilized on bentonite clay particles by single step synthesis and the prepared functionalized bentonite (FB) particles were incorporated in polysulfone matrix. The FB particles made the membrane surface negative facilitating adsorption of heavy metals. Among the heavy metals studied, lead showed the maximum retention. The mechanism of lead removal by MMM was identified as adsorption promoted by ion-exchange. The MMM exhibited about 98% lead rejection and breakthrough time of 9 h for 0.07 m² membrane for a battery effluent. A first principle-based modified convection-adsorption model was utilized to predict both the permeate flux and concentration profiles for long term filtration experiment. An in-depth analysis was carried out to establish the inter-relation between various parameters, like, membrane resistance and membrane-solute

interaction variables (adsorption capacity, adsorption kinetic constant and adsorption resistance parameter). Performance curve for the FB incorporated MMM for treatment of actual battery effluent for three different filtration areas, i.e., 10 m², 50 m² and 100 m² was also predicted which is important for the scaling up of the membrane for practical applications. This study elicits the potential of EDTA functionalized bentonite impregnated MMM for heavy metal adsorption and elimination of lead from effluent of a battery plant.

Polythiophene (pTh), an intrinsically conducting polymer, was successfully synthesized and doped in a polysulfone (Psf) matrix to form ultrafiltration (UF) grade blend membranes. Incorporation of pTh particles in the Psf matrix made the blend membranes more hydrophilic and porous with high negative surface charge. The prepared membranes exhibited good adsorption capacities for various heavy metals like, lead, iron, zinc and copper. The potential of the blend membrane was investigated for the reduction of Zn²⁺ and Fe²⁺ ions from an electroplating effluent. Two-stage UF was implemented to the pre-treated effluent to reduce Fe²⁺ and Zn²⁺ concentration below the discharge limit. A two-dimensional multicomponent transient convective-adsorption model was utilized to predict the membrane performance for effective real-life effluent treatment.

Finally, different grades of low cut-off ultrafiltration (LCUF) membranes were prepared through direct modification or interfacial polymerization. A hydrolyzed polyacrylonitrile (PAN) based LCUF hollow fiber membrane using sodium hydroxide having high surface potential was developed. Efficacy of this membrane was demonstrated in treatment of textile effluent. The hydrolysed PAN fibers (HPAN) were dense with 5 kDa molecular weight cut-off (MWCO). The transport of the dyes and the electrolyte through the membrane pores was analyzed using Donnan Steric Poreflow Model (DSPM) for a multicomponent system applicable for LCUF. Contribution of various transport mechanisms, i.e., diffusion, convection and electro-migration was quantified. The membrane pore charge density (X_d) is an effective but non-measurable parameter for determining the performance of low cut-off ultrafiltration (LCUF) membranes. X_d along with the physicochemical properties of the solution determines the membrane zeta potential. These properties include the solution pH, ionic strength as well as the ratio and nature of electrolytes in the solution. Hence, with the prior knowledge of the solution physicochemical properties and the zeta potential, determination of X_d is possible. In the next study, an attempt was made to find

such a correlation between X_d and the measurable quantities for a single electrolyte (NaCl) system. Effects of solution pH and feed electrolyte concentration were included in the measurements of membrane zeta (ζ) potential. Seven membranes were fabricated in the range of molecular weight cut-off between 1 and 5 kDa. A series of monovalent salt rejection experiments were done at three initial feed concentrations of 2 g/l, 5 g/l and 10 g/l, at pH of 3, 7 and 9, at 276 kPa transmembrane pressure and 50 l/h cross flow rate. A map between X_d , ζ -potential and C_0 was generated by solving the DSPM model. In the final study, the correlation was extended for binary electrolyte (NaCl /Na₂SO₄) system. Salt rejection experiments were carried out with the above mentioned combinations of pH and total salt concentration along with different weight ratios of NaCl/Na₂SO₄ namely, 100:0, 90:10, 70:30, 50:50 and 0:100 for six LCUF membranes. The correlation was successfully tested for the commercial membranes in predictive mode. The empirical correlation proposed in this study acts as a useful tool to determine X_d for amine based LCUF membranes. This helps to predict the membrane performance for real life desalination treatment without performing a series of rejection experiments.

Keywords: *Ultrafiltration; Low cut-off ultrafiltration; Mixed matrix membrane; Surface modification; Heavy metal removal; Battery effluent; Conducting polymers; Blend membranes; Electroplating effluent; Multicomponent Langmuir adsorption; Textile effluent; Membrane pore charge density; Donnan Steric Poreflow Model; Zeta potential; Binary electrolyte*