



GUJARAT TECHNOLOGICAL UNIVERSITY

(Established by Government of Gujarat under Gujarat Act No. : 20 of 2007)

ગુજરાત ટેકનોલોજીકલ યુનિવર્સિટી

(ગુજરાત સરકારના ગુજરાત અધિનિયમ ક્રમાંક : ૨૦/૨૦૦૭ દ્વારા સ્થાપિત)

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Abstract of the Thesis



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Faculty: Engineering

Discipline/Branch: Chemical Engineering

Title of the Thesis: Separation of organic dye compounds by emulsion liquid membrane

Abstract

Water is Earth's essential resource for sustaining life, but swift industrial growth endangers its quality and availability. Industrial waste often releases complex mixtures of synthetic dyes, introducing toxic, mutagenic, and persistent pollutants into key aquatic ecosystems. These pollutants significantly impair aquatic photosynthesis by hindering light penetration and quickly accumulate through the food chain. Therefore, creating advanced remediation technologies is a crucial ecological priority to protect global water sources and public health.

Water is vital for the existence of living beings. Over the years, developing nations as well as developed nations have been facing the issues of water pollution. Industrialization and urbanization are continuously increasing exponentially due to the rise in population. Clean water resources are polluted by uncontrolled discharge from several sources such as industrial effluents, urban sewage and agricultural waste, landfills leachate, pharmaceutical and personal care products (PPCPs). Moreover, there has been a significant rise in the usage of PPCPs during and after COVID-19. Toxicological effect of PPCPs creates a significant negative effect on the hydrosphere. Among the different treatment techniques, emulsion liquid membrane (ELM) is an emerging technique for wastewater treatment and grabs the attention of researchers due to the independence from the equilibrium conditions, integration of extraction and stripping in a single stage, larger area at interface for the mass transfer, lower energy consumption, and lack of undesired side reactions. The current study addresses the application of ELM for the treatment of wastewater involving PPCPs. Also working, mechanism, importance of influencing factors like concentration of surfactant and carrier, and types of diluents with the latest developments and prospects are also discussed.



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In the era of water scarcity, the uncontrolled discharge of various pollutants into freshwater bodies has become the utmost threat to all living beings. Several traditional separation techniques exist, but these methods have limitations like large usage of costly chemicals, energy consumption, sludge generation, and high utility requirements. The green emulsion liquid membrane (GELM) is a developing and suitable technology that includes the advantages of emulsion liquid membrane (ELM) for separating different pollutants. Nowadays, much attention has been given to applying green solvents produced from vegetables and plants. Such solvents are eco-friendly, less expensive, and when incorporated in ELM, make the GELM process more reliable and convenient. Petroleum-based solvents used in the ELM technique are costly, toxic, volatile, have a high carbon footprint, and have detrimental environmental effects. The current research addresses the mechanism, significance of influencing factors, and application of GELM for wastewater treatment, along with the recent development and scope of future work.

Industrialization and the rise in population have led to the larger utilization of resources which has become the supreme risk for the environment. Different types of pollutants enter the aquatic environment from various sources which create a threat for the aquatic organisms and humans. Many separation techniques like precipitation, adsorption, reactive distillation, ion exchange, electro dialysis, solvent extraction, and ultrafiltration are available, but these techniques have various limitations like the use of excessive and expensive chemicals, high energy requirement, sludge formation, requirement of utilities in large amount and so. The green emulsion liquid membrane (GELM) is an emerging and promising method that incorporates the traits of ELM for the removal of various pollutants, metal ions, acids, and so on. In the present scenario, much focus has been diverted towards the use of green solvents derived from vegetable and plant origin. These solvents are environmentally friendly and economically viable making the ELM process more reliable. The traditionally used petroleum-based solvents for ELM formation are expensive, toxic, volatile in nature, and are detrimental to the environment. The present study tries to address the recent advancement in the field of GELM. The different factors like concentration of surfactant, carrier, types of diluents, effect of volume ratio of external feed phase to emulsion, agitation speed, effect of internal aqueous phase concentration, and emulsification time play a substantial role in the removal of several pollutants from the aqueous streams through GELM have been discussed in detail. The statistical analysis of the operating variables as executed by different investigators is also mentioned.

Malachite green (MG) dye has various applications as a dyeing material, medical disinfectant and biocide but is also recognized as a teratogenic, carcinogenic, mutagenic and respiratory toxic material which creates dire effects on human



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beings, aquatic flora and fauna. Hence, the main objective lies in the removal of MG dye from an aqueous stream. In the current investigation, emulsion liquid membrane (ELM) technique was used and the effect of different factors like concentration of carrier, surfactant, stripping phase and its type and volume ratio of membrane to stripping solution on the removal of MG dye were studied. MG extraction efficiency of 94.99% was achieved using emulsion consisting of 2% w/v Span 80, 2% w/v D2EHPA, 0.1 N HCl and membrane phase to stripping phase volume ratio 1. Microscopic studies of the emulsion revealed the formation of well-defined and large number of globules with very less coalescence which resulted in high removal of MG dye. The physical stability of the emulsion was analyzed and the phase separation was comparatively less at various time intervals suggesting that the conditions used for preparing the emulsions are suitable. Fourier transform infrared spectroscopy established the bonding and presence of various functional groups. The current study intends to fulfill the gap by exploring the removal of MG dye by ELM technique.

Auramine O (AO) dye has various applications as a coloring agent in food, paper, textile, and leather industries but it is also recognized as a carcinogenic, mutagenic and toxic material by the International Agency for Research on Cancer (IARC) for the respiratory system which affects the health of human beings, aquatic flora and fauna. The current investigation focuses on the removal of Auramine O (AO) dye from aqueous solution by emulsion liquid membrane (ELM) method. Effect of different parameters like concentration of surfactant, carrier, and internal aqueous phase were investigated to eliminate the AO dye. ELM comprises carrier (D2EHPA), surfactant (SPAN 80), diluent (n-hexane), and stripping agent (HCl). The optimum conditions for dye extraction were determined and maximum separation efficiency was achieved. Studies on emulsion characterization were conducted using Photomicrographs, Dynamic light scattering, and Turbiscan. In addition, microscopic examination of the emulsion demonstrated the production of well-defined and a large number of globules with very little coalescence, resulting in high removal of AO dye. The physical stability of the emulsion was investigated, and the phase separation was found to be quite low at various time intervals, indicating that the conditions employed for producing the emulsions are appropriate. The current investigation showcased the potential of the ELM for effective AO dye removal and opens the path to explore ELM method for wastewater treatment.

This PhD Thesis would be useful for researchers, environmental engineers, and industries working on wastewater treatment using emulsion liquid membrane (ELM) technique for removal of toxic dyes like Malachite Green and Auramine O. It benefits textile, leather, and pharmaceutical sectors seeking cost-effective, eco-friendly alternatives to



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conventional separation methods, and aids policymakers in controlling dye and PPCP pollution in water bodies. It also serves as a reference for academicians exploring green solvents, surfactant-carrier optimization, and emulsion stability, supporting future scale-up of ELM technology for sustainable water resource management.

List of Publications:

- 1) Raval, A. R., Kohli, H. P., & Mahadwad, O. K. (2022a). A Comprehensive Review on Green Emulsion Liquid Membrane and Its Applicability Towards the Removal of Contaminants from the Aquatic Streams. Water Air & Soil Pollution, 233(9). <https://doi.org/10.1007/s11270-022-05849-6>
- 2) Raval, A. R., Kohli, H. P., & Mahadwad, O. K. (2022b). Application of emulsion liquid membrane for removal of malachite green dye from aqueous solution: Extraction and stability studies. Chemical Engineering Journal Advances, 12, 100398. <https://doi.org/10.1016/j.cej.2022.100398>
- 3) Raval, A., Patel, H., Mahadwad, O. K., & Pal, B. (2025). Novel Zinc Orthotitanate photocatalyst: Synthesis, characterization and photocatalytic degradation of methylene blue dye. Journal of the Indian Chemical Society, 102(11), 102155. <https://doi.org/10.1016/j.jics.2025.102155>
- 4) Raval, A. R., & Mahadwad, O. K. (2025). Emulsion Liquid Membrane for Malachite Green Dye Removal: Emulsion stability Studies and Environmental Impact. International Journal of Scientific Research in Chemistry, 10(5), 23–32. <https://doi.org/10.32628/ijsrch251152>