# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Fig. 1.1:</th>
<th>A membrane as a selective barrier between two homogeneous phases</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 1.2:</td>
<td>Symmetrical and asymmetric membranes</td>
<td>16</td>
</tr>
<tr>
<td>Fig. 1.3:</td>
<td>Porous membranes</td>
<td>16</td>
</tr>
<tr>
<td>Fig. 1.4:</td>
<td>“Size based” fractionation processes</td>
<td>17</td>
</tr>
<tr>
<td>Fig. 1.5:</td>
<td>Types of ideal continuous flow used in membrane based separation</td>
<td>22</td>
</tr>
<tr>
<td>Fig. 1.6:</td>
<td>Stirred Cell module</td>
<td>24</td>
</tr>
<tr>
<td>Fig. 1.7:</td>
<td>Schematic Flat sheet tangential flow (TF) module</td>
<td>25</td>
</tr>
<tr>
<td>Fig. 1.8:</td>
<td>Schematic of Spiral wound module</td>
<td>26</td>
</tr>
<tr>
<td>Fig. 1.9:</td>
<td>Schematic drawing illustrating the tubular membrane module</td>
<td>27</td>
</tr>
<tr>
<td>Fig. 1.10:</td>
<td>Schematic drawing illustrating the construction of a hollow fiber module</td>
<td>28</td>
</tr>
<tr>
<td>Fig. 1.11:</td>
<td>Different membrane separation process relative to size</td>
<td>31</td>
</tr>
<tr>
<td>Fig. 1.12:</td>
<td>An example of diffusion of adsorbed particles (o) through a membrane of varying pore (Dp) sizes. Effective separation for Dp &lt; 2p.</td>
<td>33</td>
</tr>
<tr>
<td>Fig. 1.13:</td>
<td>Schematic representation of vapour condensation and transport through a Microsporus membrane.</td>
<td>35</td>
</tr>
<tr>
<td>Fig. 1.14:</td>
<td>Simplified schematic of cross flow a membrane filtration module.</td>
<td>36</td>
</tr>
<tr>
<td>Fig. 1.15:</td>
<td>Schematic representation of concentration polarization and the concentration profile during membrane filtration</td>
<td>40</td>
</tr>
<tr>
<td>Fig. 2.1:</td>
<td>Solute Concentration Ranges for Separation Technology</td>
<td>50</td>
</tr>
<tr>
<td>Fig. 2.2:</td>
<td>Liquid membrane configurations</td>
<td>51</td>
</tr>
<tr>
<td>Fig. 2.3:</td>
<td>Bulk liquid membrane systems</td>
<td>51</td>
</tr>
<tr>
<td>Fig. 2.4:</td>
<td>Schematic of liquid supported membrane</td>
<td>53</td>
</tr>
<tr>
<td>Fig. 2.5:</td>
<td>Schematic of Supported liquid membrane</td>
<td>53</td>
</tr>
<tr>
<td>Fig. 2.6:</td>
<td>Different configuration of Liquid emulsion system</td>
<td>54</td>
</tr>
</tbody>
</table>
Fig. 2.7: A schematic diagram of mixer-settler extraction using in emulsion liquid membrane

Fig. 2.8: Emulsion liquid process.

Fig. 2.9: Schematic of benzoic acid extraction by Type I ELMs.

Fig 2.10: Schematic of zinc extraction by Type II ELMs

Fig. 2.11: The structure of surfactant.

Fig. 2.12: Molecular structure of Span 80

Fig. 4.1: Carrier facilitated mechanism

Fig. 5.1(a): Effect of sonicator speed with percentage removal at pH 2.4

Fig. 5.1(b): Effect of sonicator speed with percentage removal at pH 6.5

Fig. 5.1(c): Effect of sonicator speed with percentage removal at pH 10.45

Fig. 5.2: Ratio of Membrane volume / Feed volume ratio with percentage of removal chromium Sonicator 100% amplitude, Stripping agent 1(N) NaOH

Fig. 5.3: Effect of change of internal stripping phase concentration, Sonicator 100% amplitude

Fig. 5.4: Effect of change of carrier concentration at different pH

Fig. 5.5: Effect of change of surfactant conc. with organic membrane (V/V)

Fig. 5.6: Effect of feed concentration with % removal of Chromium

Fig. 5.7: Effect of metal ion Copper (+2) in feed solution

Fig. 6.1: Transport of Cr\textsubscript{4}O\textsubscript{7}\textsuperscript{2-} and H\textsuperscript{+} through the ELM

Fig. 6.2: Effect of different 1 (N) acid in feed solution with time, Speed of Sonicator : 30000 Hz, Carrier : Aliquot 336, NaOH as stripping agent

Fig. 6.3: Effect of different pH of feed solution with time, Speed of Sonicator : 30000 Hz, Feed with 1 (N) HCl, Carrier : Aliquot 336, NaOH as stripping agent
Fig. 6.4: Effect of different pH of feed solution with time, Speed of Sonicator: 30000 Hz, Feed with 1 (N) HCl, Carrier D2EHPA, NaOH as stripping agent

Fig. 6.5: Change of Flux at different pH of feed solution, Speed of Sonicator: 30000 Hz, Feed with 1 (N) HCl, Carrier: D2EHPA, NaOH stripping agent.

Fig. 6.6: Effect of temperature in presence of different carriers, Speed of Sonicator: 30000 Hz, Feed with 1 (N) HCl, Carrier: Aliquot 336 & D2EHPA, NaOH stripping agent.

Fig. 6.7: Effect of change of stripping agent to remove Cr (VI) with time, Carrier = Aliquot 336,

Fig. 6.8: Effect of change of stripping agent to remove Cr (VI) with time, Carrier = D2EHPA, pH 5.0

Fig. 6.9: Effect of change of carrier concentration (volume % with Membrane volume) with removal efficiency of Cr (VI), Sonicator 30000 Hz, Time 20 minutes, pH = 5.0

Fig. 6.10: Effect of change of surfactant concentration (Span 80) with Cr (VI) removal efficiency for two different carriers, Sonicator 30000 Hz, Time 20 minutes, pH = 5.0

Fig. 6.11: Effect of change of salt concentration (NaCl) with Cr(VI) removal efficiency, Carrier: Aliquot 336, Sonicator 30000 Hz, Time 20 minutes, pH = 5.0

Fig.7.1: Span 80 (Sorbitan monooleate)

Fig. 7.2: Schematic of Emulsion Liquid Membrane process

Fig. 7.3: Effect of mixing speed (Sonicator speed) on different Surfactants, Time = 20 minutes, pH= 6.0, carrier: 10% (V/V), temperature = 34 deg C,

Fig. 7.4: Effect of pH on different Surfactants, Time = 20 minutes, Mixing speed = 100 % (30000 Hz), carrier: 10% (V/V), temperature = 34 deg C
Fig. 7.5: Effect of different concentration of Span 80 to remove Cr(VI) with time, Mixing speed, = 100% (30000 Hz), carrier : 10% (V/V), temperature = 34 deg C

Fig. 7.6: Effect of different concentration of SDS to remove Cr(VI) with time, Mixing speed, = 100% (30000 Hz), carrier : 10% (V/V), temperature = 34 deg C

Fig. 7.7: Effect of different concentration of CPC to remove Cr(VI) with time, Mixing speed, = 100% (30000 Hz), carrier : 10% (V/V), temperature = 34 deg C

Fig. 7.8: Effect of different feed concentration with different Surfactants, Mixing speed, = 100% (30000 Hz), carrier : 10% (V/V), temperature = 34 deg C

Fig. 8.1: Effect of Sonicator speed (100% amplitude = 30000 Hz) in removal of Cu(II) at pH 2.0

Fig. 8.2: Effect of Sonicator speed at 100% (amplitude = 30000 Hz) in removal of Cu(II) at pH 4.0

Fig. 8.3: Effect of Sonicator speed (100% amplitude = 30000 Hz) in removal of Cu(II) at pH 6.0

Fig. 8.4: Percentage of removal of Cu (II) from feed with time at different pH of feed solution in presence of acetate buffer. Sonicator speed at 100%

Fig. 8.5: Effect of change of concentration of surfactant (change of ratio of SPAN 80 / Membrane v/v) at pH 4 & buffer concentration :20 (buffer volume / feed volume) and 1 (N) HCl as stripping agent.

Fig. 8.6: Effect of change of concentration of carrier (change of ratio of D2EHPA / Membrane v/v) at pH 4 & buffer concentration 1:20 (buffer volume / feed volume) and 1 (N) HCl as stripping agent.

Fig. 8.7: Effect of change of buffer volume with feed volume after 20 minutes of run at different pH, stripping Agent 1.0(N) HCl,

Fig. 8.8: Effect of change of strength of stripping solution (HCl) to removal Cu(II) at different pH of feed solution after 20 minutes and 5% (V/V) D2EHPA
Fig. 8.9: Effect on change of stripping agent at different pH after 20 minutes of run and 100% amplitude of sonicator with buffer concentration 1:20 (buffer volume / feed volume)

Fig. 9.1: Single Module Operation of Viva flow Cross-flow module

Fig. 9.2: Variation of permeate flux with time at different operating pressure at 0.88 mM CPC Concentration. MWCO = 10 kD, Temperature = 34°C

Fig. 9.3: Variation of permeate flux with time at different Surfactant concentration (CPC Concentration) at constant operating pressure 1.0 bar. MWCO = 10 kD, Temperature = 34°C

Fig. 9.4: Variation of permeate flux with different Surfactant concentration (CPC concentration) at Different electrolyte concentration at constant operating pressure 1.0 bar. MWCO = 10 kD, Temperature = 34°C, Salt concentration in mM

Fig. 9.5: Effect of electrolyte at different pH in removal of Chromium, Nacl = 0 mM, CPC = 0.88 mM, MWCO = 10 kD, Temperature = 34°C

Fig. 9.6: Effect of electrolyte at different pH in removal of Chromium, Nacl = 5 mM, CPC = 0.88 mM, MWCO = 10 kD, Temperature = 34°C

Fig. 9.7: Effect of electrolyte at different pH in removal of Chromium, Nacl = 10 mM, CPC = 0.88 mM, MWCO = 10 kD, Temperature = 34°C

Fig. 9.8: Removal efficiency of chromium ion through ultra filtration without surfactant in presence of 10 mM of Nacl in feed and at constant operating pressure 1.0 bar and 6 pH of feed, MWCO = 10 kD, Temperature = 34°C

Fig. 9.9: Effect of surfactant in removal of chromium ion through ultra filtration at 10 mM Nacl in feed at constant operating pressure 1.0 bar at 6 pH of feed. MWCO = 10 kD, Temperature = 34°C

Fig. 9.10: Removal efficiency of Cr (VI) at different concentration of Nacl (electrolyte) after 20 minutes at 0.88 mM Surfactant concentration (CPC). MWCO = 10 kD, Temperature = 34°C

Fig. 9.11: Concentration of Surfactant (CPC concentration) in permeate at different concentration of Nacl. Surfactant concentration 0.88 mM in 200 ml feed solution with 50 ppm Cr (VI) concentration. MWCO = 10 kD,