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Recovery of synthetic dye from simulated wastewater using emulsion liquid membrane process containing tri-dodecyl amine as a mobile carrier

N. Othman*, S.N. Zailani, N. Mili

Faculty of Chemical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

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ABSTRACT

The extraction of Red 3BS reactive dye from aqueous solution was studied using emulsion liquid membrane (ELM). ELM is one of the processes that have very high potential in treating industrial wastewater consisting of dyes. In this research, Red 3BS reactive dye was extracted from simulated wastewater using tridodecylamine (TDA) as the carrier agent, salicyclic acid (SA) to protonate TDA, sodium chloride as the stripping agent, kerosene as the diluent and SPAN 80 as emulsifier. Experimental parameters investigated were salicyclic acid concentration, extraction time, SPAN 80 concentration, sodium chloride concentration, TDA concentration, agitation speed, homogenizer speed, emulsifying time and treat ratio. The results show almost 100% of Red 3BS was removed and stripped in the receiving phase at the optimum condition in this ELM system. High voltage coalesce was applied to break the emulsion hence, enables recovery of Red 3BS in the receiving phase.

1. Introduction

Increasing pollutants released to the environment have alerted both public and government since the discharged effluent could destroy the nature we live in. One of the major issues contributing to this crisis is water pollution. The growth in industry and the modification of manufacturing processes may have resulted in an increase in volume, composition and complexity of wastewater discharged to the environment [1]. The discharged wastewater can contain heavy metals, reactive dyes, organic pollutants and suspended solids. Reactive dye is a substance that contains a lot of hazardous chemical compounds such as benzidine structure, halogenated organics, toxic, carcinogenic and mutagenic organic compounds [2,3] exhibiting colours in water body and had become a very important environmental issue. Practically, it has been recorded that almost 125–150 l of water is used for every kilogram of textile product in the textile processing including bath residues from preparation, dyeing, washing, soaking, finishing and slashing [4].

The selection of separation method strongly focuses on the nature of the dye, operation treatment cost and composition of waste product. In some cases, the use of primary technique may not be sufficient to achieve complete decolourization, therefore dye removal strategies could consist of a combination of different techniques [5]. The treatment for removal of dye has been developed since the last two decades with the progress in adsorption separation technique to remove basic violet 10 and acid red on sulphonated coal and Ganoderma Lucidum [6]. Meanwhile, a simulated reactive dye was experimented by Irena et al. [7] using nanofiltration membrane. Combination system to treat synthetic dye wastewater also has been proposed by Panswad and Luangdilok [8] using both anaerobic and aerobic simultaneously. Electrochemical oxidation of dyestuffs wastewater was studied by Jia and Yang [9] and Pelegrini et al. [10]. Removal and recovery of dye using ion exchange method was proposed by Mona and Yehia [11] whereas Snider and Porter [12] introduced ozonation treatment based on the composition of textile dyeing wastewater. Photocatalysis process was investigated [13] though Fenton method was also reported for degradation of textile dyes [14]. Coagulation–flocculation method was addressed as an alternative to the more conventional processes such as adsorption [15]. Liquid–liquid extraction (LLE) also has significant potential as an effective method for treatment of removal dyes [16–20]. However, membrane technology such as ELM, bulk liquid membrane (BLM) and supported liquid membrane (SLM) could be a greatly capable method for both removal and recovery of dye stuffs [21–23].

Among the techniques, ELM could be competitive when the targeted species is present at low concentrations in the aqueous solution. The novelty of ELM also is very promising and practicable for purification and recovery of targeted solute [24]. ELM separation process constitutes an emerging technology with a wide variety of applications, such as the removal, recovery, and purification of

* Corresponding author. Tel.: +60 75535486; fax: +60 75581463.
E-mail address: norasikin@cheme.utm.my (N. Othman).

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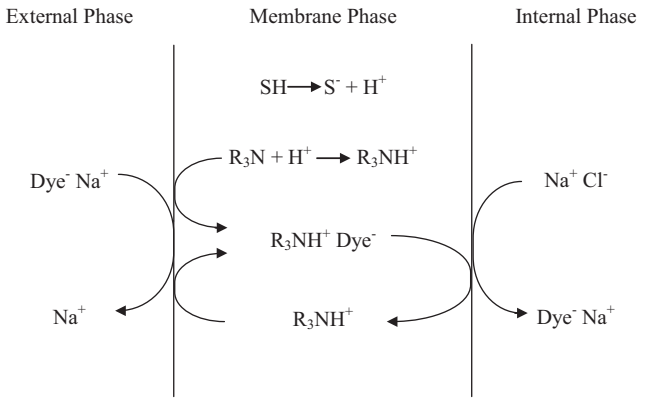


Fig. 1. Facilitated transport mechanism for reactive dyes transfer across a liquid membrane.

many organic and inorganic compounds from dilute solutions of industrial interest [25]. However, stability of the membrane is the major problem associated to this technique. The challenges in a membrane system are due to swelling and breakage effect that could initiate an unstable emulsion resulting in a decrease in the degree of concentration of solute attained in the internal phase. This problem can be solved by choosing suitable parameters through an investigation on the effect of different factors on membrane stability.

The objective of this ELM separation technique is to separate solutes into receiving phase through a very thin layer of liquid membrane phase. The recovery of solute using ELM is very significant since the permeable barrier in emulsion is very selective, thus only targeted solute is allowed to pass through the barrier, whereas the rejected components stay as a raffinate in the solution and then discharged [26]. This method is proven to have several advantages over other physicochemical methods due to its ability to concentrate the pollutant up to 10–100 times [27].

To the best of our knowledge, no work has been conducted on the recovery of reactive dyes from aqueous phase by ELM. Therefore, in this study experimental works have been carried out to remove and further recover anionic reactive dyes, Remazol Red 3BS (R3BS), from simulated wastewater by ELM with the objective to determine the efficiency of the removal and recovery of the dye. The ELM technique was carried out with tridodecylamine (TDA) as a carrier agent with the presence of salicyclic acid (SA). The process parameters investigated include carrier concentration, stripping agent concentration, SA concentration, surfactant concentration, extraction time, agitation speed, homogenizer speed, emulsifying time and treat ratio. The focus is to optimize the process in order to give the optimum condition for the best recovery of reactive dyes from aqueous solution.

Mechanism of carrier facilitated transport extraction and stripping process of reactive dye by TDA is shown in Fig. 1. Mass transfer is assisted by a carrier present in the membrane phase as well as ion concentration gradient between the two sides of the membrane phase. This mechanism is for the recovery and enrichment of dye ions in receiving phase.

2. Experimental

2.1. Chemicals and reagents

Kerosene as diluents was obtained from Acros Organic, TDA as carrier from Merck Schuchardt OHG Germany, Salicyclic acid (SA) from Fisher Chemical, sodium chloride (NaCl) and sodium salicate (normally use in batik industry) from Merck Schuchardt OHG Germany and SPAN 80 from Fluka. R3BS reactive dye was obtained from Nozi Batik Industry from Kuala Terengganu, Malaysia. The chemical structures of R3BS dye is shown in Table 1. The operation equipments are agitator IKA C-MAG, homogenizer Heidolph Silent Crusher M, UV/VIS Spectrophotometer model Jenway 6305 and high voltage coalescer.

2.2. Experimental procedures

A primary emulsion was prepared by emulsifying an equal volume of aqueous solution (stripping phase) with formulated organic phase (diluents, surfactant and carrier) using homogenizer. Stability test of the emulsion was conducted on different concentration of surfactant, homogenizer speed, emulsifying time and agitation speed. The optimum ranges were applied in extraction study. Reactive dye solution was prepared by dissolving desired amount of dye concentration with distilled water. An equal volume of 5 ml portions of organic solution and an aqueous strip solution was stirred continuously at 12,000 rpm using motor driven homogenizer for 5 min to attain a stable primary emulsion system. The emulsion must be freshly prepared each time before the experiments. Then, the emulsion was dispersed into the agitated vessel of 50 ppm reactive dye solution (external phase) with appropriate treat ratio.

The double emulsion of water in oil in water (W/O/W) was mixed using magnetic stirrer at 250 rpm in a conical flask to allow the extraction and stripping process to occur. The three-phase dispersion was stirred for 10 min. After that, the samples were quickly introduced into a separation funnel and left for phase separation in half an hour. Two layers were formed in the separating funnel; upper layer is W/O emulsion, while bottom layer is aqueous treated phase. Then, the water in oil (W/O) emulsion was separated from the aqueous phase. For recovery purpose, this emulsion was demulsified using a high voltage coalescer to obtain the receiving phase/internal phase. The external and internal aqueous phase were analysed to determine the percentage of extraction and stripping recovery of reactive dye. The same procedures were repeated for different condition and formulations.

2.3. Determination and calculation

The quantitative evaluation of reactive dyes was conducted using a UV–vis spectrophotometer at a suitable maximum wavelength. The concentration of dye ion is determined spectrophotometrically by absorbent of light through the dye solution. The percentage of removal efficiency, R is calculated using the following equation:

$$R = \frac{[\text{Dye}]_i - [\text{Dye}]_f}{[\text{Dye}]_i} \times 100\% \quad (1)$$

where $[\text{Dye}]_i$ is the initial dye concentration (ppm) and $[\text{Dye}]_f$ is the final dye concentration (ppm).

3. Results and discussions

3.1. Reactive dye removal and stripping efficiency

The experimental results for reactive dyes removal and stripping efficiency are shown in Table 2. The experiments were carried out in duplicates and the investigation and optimization was carried out one factor at a time and the best condition in each investigation was used in the conservative experiments that follow.

3.1.1. Salicyclic acid concentration

Fig. 2 shows the effect of SA concentration on the percentage of extraction and stripping of reactive dye. The results show that 0.001 M SA is adequate to enhance the extraction process which is almost 100% of dye was extracted. This is due to the hydrogen

Table 1
Chemical structure of R3BS reactive dye.

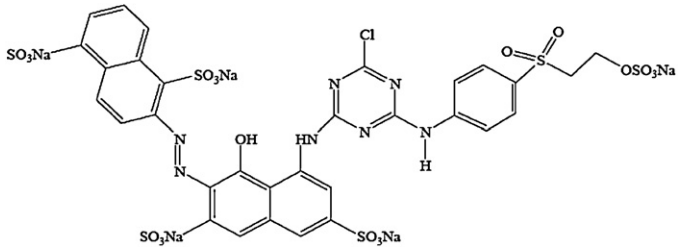
Anionic reactive dye	Chemical formula	λ_{max} (nm)
Remazol Red 3BS (MW = 1085 g/mol)		511

Table 2
Results of parameters of ELM study.

Parameters	Variables	Percentage removal of reactive dye (%)	Percentage stripping of reactive dye (%)	Percentage recovery of reactive dye (%)
Salicyclic acid (M)	0.0001	100	10.68	10.68
	0.01	100	40.12	40.12
	0.05	100	37.48	37.48
	0.1	99.8	45.42	45.34
	0.3	98.6	26.56	26.18
	0.5	85.8	27.34	23.45
Extraction time (min)	3	99.9	37.70	37.67
	5	99.4	52.85	52.55
	7	100	50.09	50.09
	10	100	42.83	42.83
	15	100	40.90	40.90
	20	100	31.46	31.46
SPAN 80 (%w/v)	1	99.5	37.86	37.67
	3	100	58.17	58.17
	5	100	52.64	52.64
	7	100	43.57	43.57
	10	100	42.42	42.42
NaCl (M)	0.01	100	27.08	27.08
	0.1	100	77.70	77.70
	0.3	100	96.83	96.83
	0.5	100	86.15	86.15
	1	100	71.12	71.12
	2	100	58.07	58.07
	3	100	40.99	40.99
	4	100	32.11	32.11
	5	100	30.43	30.43
TDA (M)	0.0001	11.8	62.99	7.45
	0.001	11.7	91.57	10.68
	0.01	18.4	69.81	12.86
	0.1	100	74.35	74.35
	0.3	99.6	58.69	58.45
	0.5	97.6	46.15	46.15
Agitation speed (rpm)	125	77.5	48.89	37.89
	250	100	73.29	73.29
	350	100	81.37	81.37
	450	100	60.87	60.87
Homogenizer speed (rpm)	8000	100	56.29	55.59
	10,000	100	63.31	62.73
	12,000	100	80.75	80.75
	14,000	100	69.56	69.44
	16,000	100	69.59	69.13
Emulsifying time (min)	3	100	61.80	61.80
	5	100	69.88	69.88
	7	100	71.12	71.12
	10	100	81.37	81.37
	15	100	69.94	69.94
Treat ratio (emulsion:dye solution)	1:3	100	36.94	36.94
	1:5	100	64.00	64.00
	1:7	100	65.77	65.77
	1:10	100	72.17	72.17
	1:15	100	82.78	82.78
	1:20	90	65.51	58.96

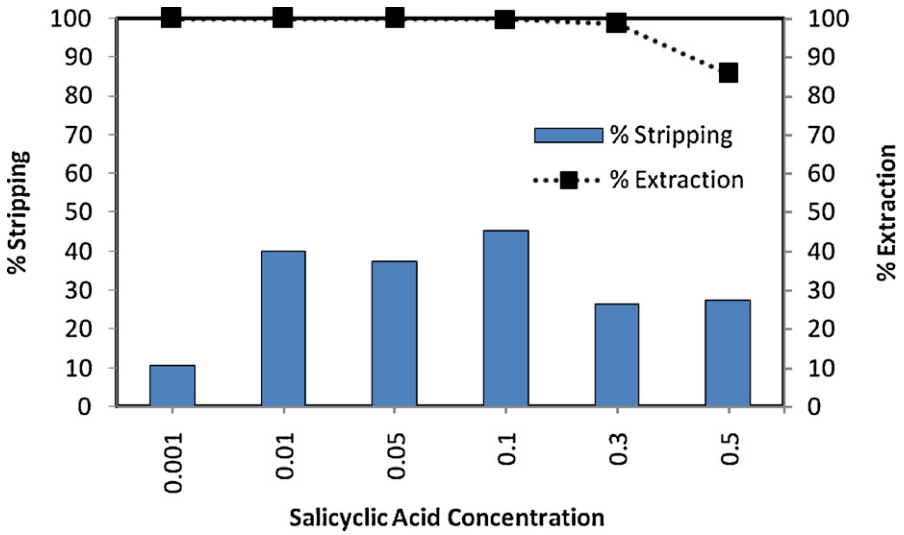


Fig. 2. Effect of salicyclic acid concentration on percentage of extraction and stripping of reactive dye.

ion, H^+ derivative from dissociation of SA, protonates the non-ionic tertiary amine (R_3N) and promotes this basic carrier to undergo extraction process.

Protonated TDA, (R_3NH^+) raises up the formation of TDA–dye complex formed at the external-membrane interface causing an increase in the concentration gradient meaning that, increases the permeation of dye through the membrane layer [28]. In view of the fact that anionic reactive dyes contain Na^+ attached at the dye component Dye^- therefore, positively charged R_3NH^+ cation is necessary to extract the anionic dyes (with negatively charge ion) [18]. The formation of complex TDA–dye with the presence of SA at membrane-internal interface continues to the stripping process using NaCl as a stripping agent. Too high of SA concentration in organic phase however initiate the decrease in both extraction and stripping processes because higher H^+ to protonate R_3N is not favourable to extract dye efficiently.

The results also show that further increase the concentration of SA does not make any advantages because the only function of salicyclic is to protonate the carrier. The highest percentage of stripping is only 45% compared to the extraction efficiency of 100%. It is due to the other parameters affecting the ELM system have not been completely experimented to achieve the optimum condition for the stripping process although the result of extraction is proven to be very excellent.

3.1.2. Extraction time

Table 2 illustrated that the extraction time of 5 min yielded the highest stripping percentage and recovery of reactive dyes and the extraction efficiency of the reactive dye is in fact almost 100 percent. By utilising the optimum parameter of SA (0.1 M) in membrane phase, the effect of extraction time of reactive dye is presented in Fig. 3. Reactive dye was removed rapidly once it comes in contact with the carrier in ELM system. It seems that the extraction kinetics of reactive dye by ELM is very fast because the removal efficiency is almost 100% after 3 min extraction time. Fig. 3 also shows that treatment time of 3 min is adequate for satisfactory extraction efficiency but not for stripping. The different rate of extraction and stripping is because the formation of complex dye-carrier in membrane is enormously robust hence accelerates the extraction efficiency even in a short contact time. But this phenomenon has not enhanced the stripping efficiency.

At the same time 40% of dye was stripped and increased as the extraction time increases. After 5 min extraction, the rate of stripping begins to decline but contradictory to the rate of extraction; which remains almost 100%. It is to be noted that the percentage removal of reactive dye is higher compared to the rate of stripping at this certain extraction time. This is due to re-extraction of the dye into the internal phase, also correlated with stripping agent concentration, membrane thickness and ionic strength of reactive dye ion. The decreasing stripping performance may due to the swelling effect which resulted in dilution of the stripped dye in the internal phase. Thus, the best condition of ELM system is at 5 min extraction time.

3.1.3. Surfactant concentration

The effect of surfactant concentration on extraction and stripping of the reactive dye was investigated in the concentration range of 1–10% (w/v). From Table 2 it is evident that the concentration of 1% (w/v) shows the lowest stripping efficiency. Increasing concentration of SPAN 80 offers different results on stripping process. At 3% (w/v) SPAN 80, percentage of stripping has increased to more than 58% but when the concentration was further increased up to 10% (w/v) the stripping efficiency declined to 42%. Manipulation of the concentration of SPAN 80 however has not affected the extraction of reactive dye significantly because the efficiency remained constant.

Fig. 4 depicted the effect of surfactant concentration on the reactive dye transport. Low concentration of SPAN 80 resulted in low stripping efficiency. This indicates that the break-up of emulsion is most likely the contributing factor [29] retarding the transportation of reactive dye from membrane phase into receiving phase. The stability of emulsion has improved with increasing concentration of SPAN 80. Nevertheless, further increase in the SPAN 80 in water in oil (W/O) emulsion has promoted a drop in the rate of stripping due to the swelling effect occurring during extraction stage.

Swelling associated with excess presence of surfactant and with entrainment at low membrane viscosities is also being reduced. Swelling is the incorporation of some continuous phase into the emulsion globules [30]. Fig. 4 exhibits that too high of an increment in the concentration of surfactant will strongly encourage the swelling of emulsion because the hydrophilic part of SPAN 80 will serve as water carrier for internal phase hence diluting the concentrated dye ion in receiving phase.

Higher concentration of SPAN 80 also exhibits increasing viscosity and thickness of liquid membrane and resulted in difficulty of dye ion to diffuse through membrane into receiving phase. This justification is sequential to the finding shown in Fig. 4 that increasing the SPAN 80 concentration above

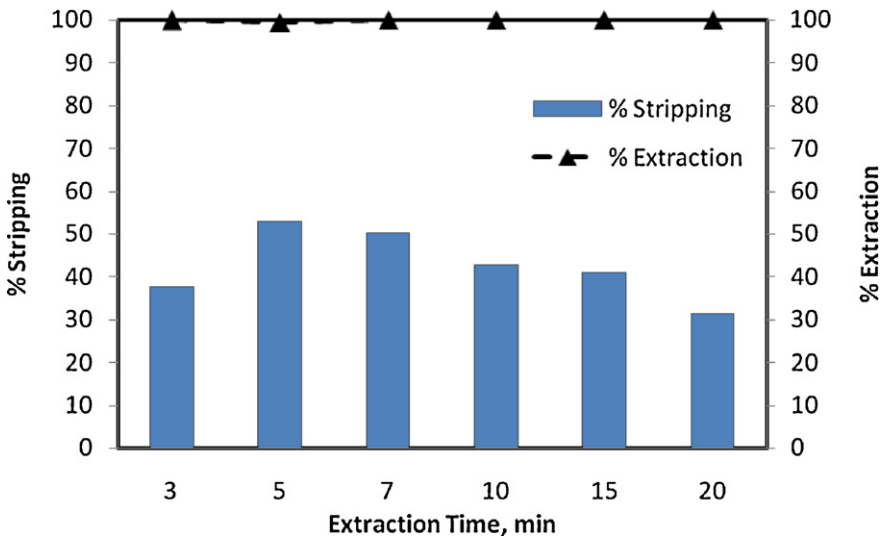


Fig. 3. Effect of extraction time on percentage of extraction and stripping of reactive dye.

the limit will reduce the performance of the stripping process. Therefore, 3% of SPAN 80 was selected for the tests that follow to obtain other optimum parameters of ELM system.

3.1.4. Stripping agent concentration

The effect of stripping agent on both extraction and stripping of reactive dye is shown in Fig. 5. Different concentrations of NaCl ranging from 0.01 to 5 M were used to verify the optimum value for stripping process. Fig. 5 reveals that higher NaCl concentration has given better rate of stripping however, raising NaCl beyond 0.3 M causes stripping efficiency to begin decreasing. The rate of stripping increases with increasing NaCl concentration in the internal aqueous phase ranging from 0.01 M to 0.3 M. This may due to the increase in the ability of the internal phase for stripping which delays the accumulation of TDA–dye complex in the membrane layer [28].

Although excess NaCl in the internal phase increases the permeation rate of solute, it also invites more water transfer and encourages instability of emulsion and swelling of dominated membrane phase [31]. It is observed that the maximum rate of stripping takes place at NaCl concentration of 0.3 M showing nearly 100% stripping affiance. Changes in the stripping agent concentration has not influenced the extraction so as the removal of reactive dye, which is 100%.

3.1.5. Carrier concentration

The concept of carrier facilitated transport is such that the diffusing species is carried across the membrane phase from external-membrane interface to internal-membrane interface by incorporating a carrier compound. The effect of carrier concentration in the organic phase on the extraction and stripping of reactive dye is shown in Fig. 6. The changes in concentration of TDA from 0.0001 to 0.1 M presented a significant increase in the permeation of reactive dye ion through external-membrane interface. Higher TDA concentration accelerates the migration of the dye ions towards the oil phase interface promoting excellent extraction process [32].

However, the enhancement is less pronounced when TDA is increased beyond 0.1 M as it illustrated lowered rate of extraction and stripping. This is because more TDA would result in an increase in the membrane thickness hence resisting the reactive dye ion to permeate through external-membrane interface to perform extraction process and permeate through membrane-internal interface

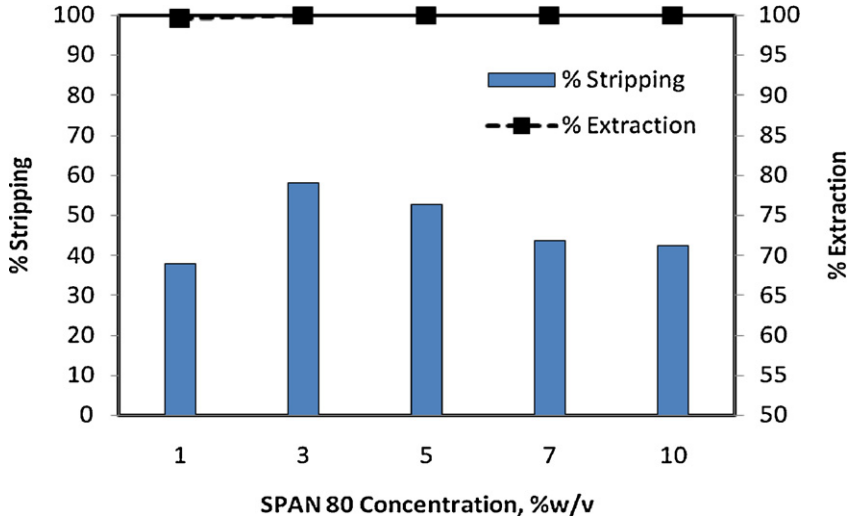


Fig. 4. Effect of SPAN 80 concentration on percentage of extraction and stripping of reactive dye.

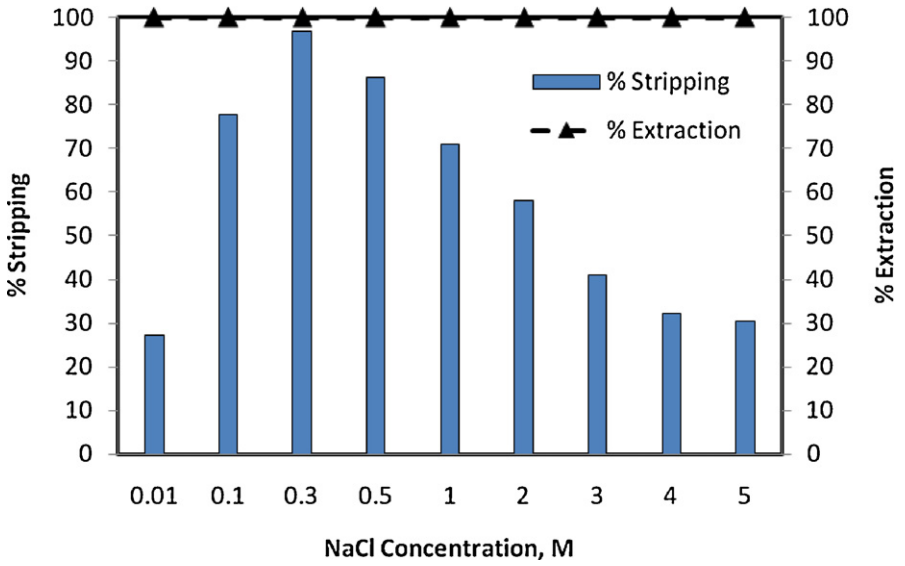


Fig. 5. Effect of NaCl concentration on extraction and stripping of reactive dye.

to carry out stripping process [22]. Both properties of membrane viscosity and interfacial tension between membrane and external phase increases dominated by the formation of larger globules thus lowering the diffusivity of the complex dye-carrier in membrane phase [33].

As also depicted in Fig. 6, the best efficiency of stripping process takes place at 0.001 M concentration of TDA which has reached 91.57%. This is because a lower transport of reactive dye which is only 11% was extracted into the membrane phase facilitating the stripping of the internal phase, thus resulting in poor recovery of reactive dye. The best concentration of TDA to promote the optimum ELM parameter is 0.1 M.

3.1.6. Agitation speed

Table 2 shows the influence of agitation speed on the extraction and stripping rate. It shows the highest percent of stripping and recovery is at 350 rpm which is more than 81% and further increase significantly drops the both percentage to 60%. As illustrated in Fig. 7, better extraction and stripping of reactive dye occurs at higher agitation speed. This is because higher agitation speeds lead to the formation of increasing number of smaller emulsion globules hence favouring higher interfacial area for mass transfer of reactive dye through membrane layer into receiving phase [23,28,32,34]. Interaction between emulsion and external phase is enhanced at higher speed of agitation therefore producing better extraction and stripping process. 100% extraction of reactive dye is achieved above 250 rpm of agitation speed.

Fig. 7 also depicts that the findings on of stripping efficiency is parallel with the previous researches which have claimed that agitation speed above 450 rpm would cause decreasing value of concentrated reactive dye in the internal phase. Increasing the agitation speed to a higher limit offers larger energy to rupture the emulsion drops compared to lower agitation speed [34,35]. Higher shear force is available and subsequent higher rate of breakage of globules allows more leakage of concentrated reactive dye in the internal phase to diffuse back into the external phase [36]. In addition, this deleterious phenomenon is particularly influenced by the impact of the tips of impeller blade or a wall of contactor which

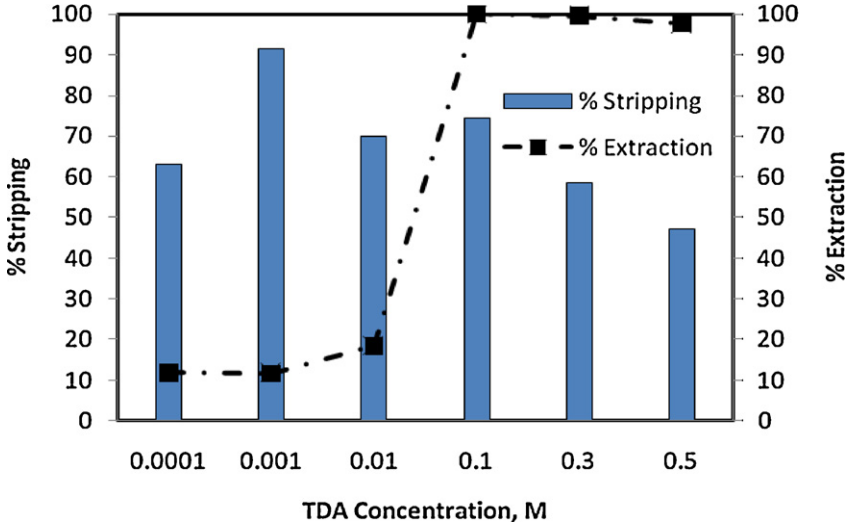


Fig. 6. Effect of TDA concentration on extraction and stripping of reactive dye.

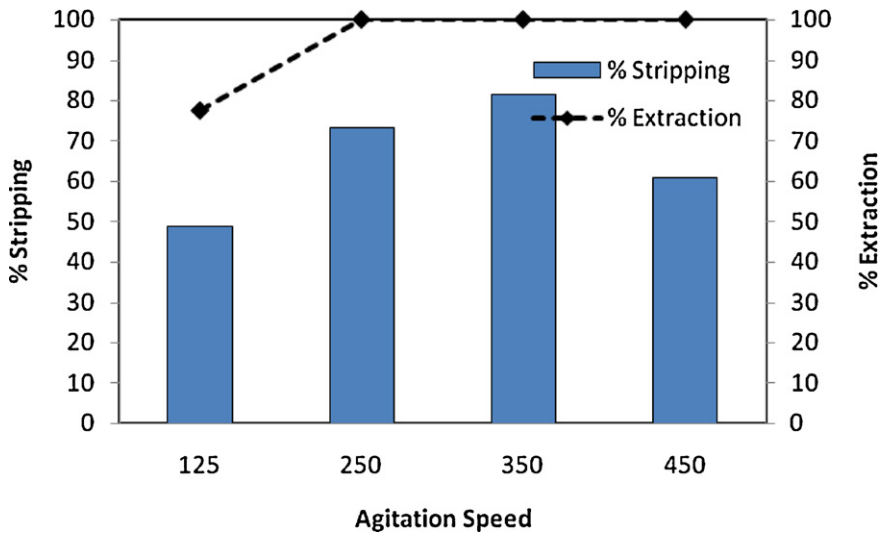


Fig. 7. Effect of agitation speed on extraction and stripping of reactive dye.

imposes the turbulent effect on the ELM system. Agitation speed hence plays a major role in the mass transfer of reactive dye through liquid membrane.

3.1.7. Homogenizer speed

Table 2 also shows the percentage of extraction, stripping and recovery of reactive dye as affected by homogenizer speed. Excellent extraction process was discovered, shown by nearly 100% extraction of reactive dyes as displayed in Fig. 8. It is hence proven that the alteration of homogenizer speed does not affect the extraction performance. However, the rate of stripping is not as good as the extraction process. Emulsion stability increases with increasing homogenizer speed up to a particular speed. Thus, it is crucial to obtain the allowable lower and upper limit of homogenizer speed during the emulsification process.

Homogenizer speed of 8000 rpm has shown lowest stripping performance because the formation of larger globules simply promotes swelling effect on aqueous phase of emulsion and finally dilutes the concentrated dye ion in internal phase. Increasing homogenizer speed yielded smaller size of emulsion droplets while dispersing in the reactive dye solution thus offering better extraction process [37]. Perfect execution of emulsification process gives better dispersion of the internal phase to membrane phase. Therefore, it precisely affects the rate of stripping of reactive dyes from the membrane peripheral [22,38].

Fig. 8 also displays a decreasing of stripping percentage as altered by the homogenizer speed beyond 12,000 rpm. A previous argument has stated that higher homogenizer speed above 12,000 rpm favours breakage of emulsion hence decreases the extraction performance, but it is not valid to be justified in from this finding as no clear and major reduction can be observed in Fig. 8. 12,000 rpm homogenizer speed is found to be the best condition to give excellent extraction (100%) and a good stripping process and recovery of reactive dye with approximately 81%.

3.1.8. Emulsification time

Fig. 9 has shown that the emulsification time is not affected by the extraction efficiency because 100% extraction was achieved along the experiment. In contrast the stripping is not as good as the extraction efficiency. The finding shows that extremely short emulsifying time (3 min) leads to swelling effect because less creamy emulsion would disperse in reactive dye solution thus, facilitates entrainment of water from external phase into internal phase. Insufficient extraction time leads to formation of larger size of emulsion globules serving the same effect of swelling on emulsion.

Also, at 15 min a decrease in stripping percentage is shown because too long of emulsifying time enhances the viscosity of emulsion which begins at this point. Therefore, this situation leads to difficulties in the transfer of extracted dye ion at membrane layer into receiving phase. Emulsifying time of 10 min is selected as an optimum condition for a good extraction and recovery of reactive dye.

3.1.9. Treat ratio

Table 2 represents the effect of treat ratio on extraction, stripping and recovery of reactive dye. The volume of emulsion remains constant along the experiment which is 10 ml. External phase was manipulated from 30 to 200 ml and the result of extraction and stripping efficiency is shown in Fig. 10. Treat ratio plays a vital role of controlling the interfacial mass transfer across liquid membrane layer. Larger external phase to emulsion ratio value interprets to a lower contact area of emulsion to the reactive dye solution hence less emulsion is required to extract the solute.

However, a previous research has shown lower external phase to emulsion ratio offers better extraction performance of solute in external phase [39] but at the expense of higher emulsion volume. On the other hand, a further increase in treat ratio decreases the extraction and stripping efficiency. These findings are parallel with the results depicted in Fig. 10. Increasing emulsion to dye solution ratio resulted in decreasing of both stripping and extraction processes (1:20). Fig. 10 also illustrates that the extraction performance significantly decreases after an increase in the upper limit of treat ratio (1:15).

3.1.10. Effect of sodium salt in dye solution

The function of sodium salicate (Na_2SiO_3) in batik industry is to make colourfastness on the fabric by soaking the fabric for several hours. Na_2SiO_3 solution is used as a fixative agent for hand dyeing with reactive dyes that require a high pH in order to react with the textile fibre. Thus, the colour will be durable and will not fade easily. The waste of Na_2SiO_3 in the batik processing is from fixation is about 2.05×10^{-5} M [40]. Fig. 11 illustrates the extraction and recovery performance on R3BS from various concentration of Na_2SiO_3.

Different concentrations of Na_2SiO_3 were employed for this study; 0.00001, 0.001, 0.01 and 0.1 M. The results show that R3BS reactive dyes performed an excellent extraction around 90% with

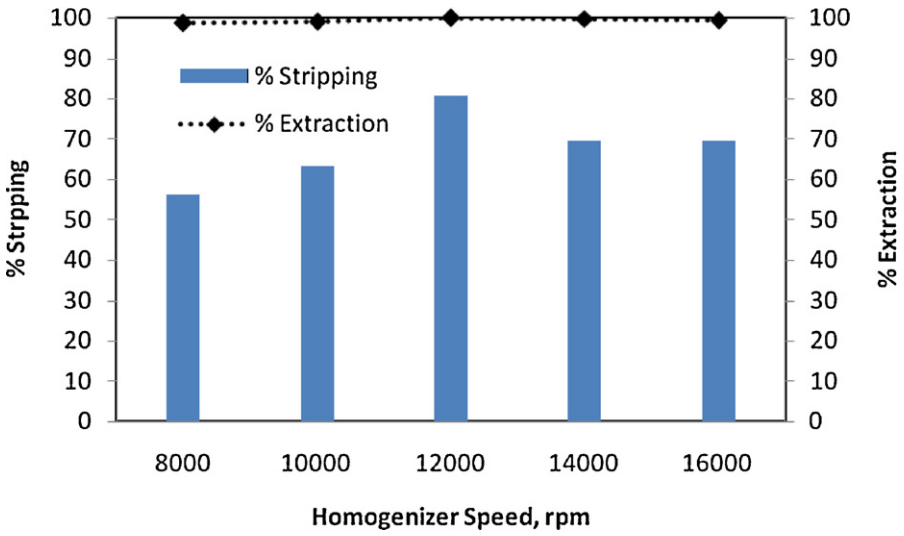


Fig. 8. Effect of homogenizer speed on extraction and stripping of reactive dye.

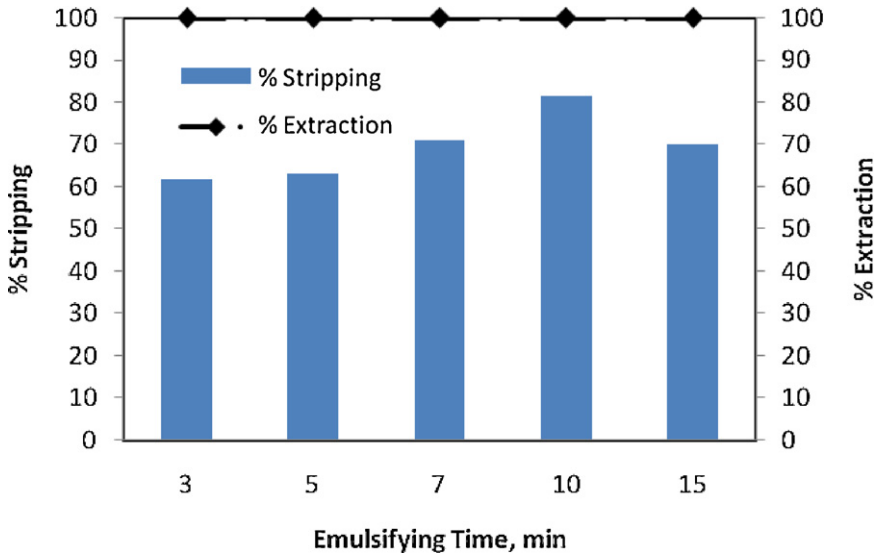


Fig. 9. Effect of emulsifying time on extraction and stripping of reactive dye.

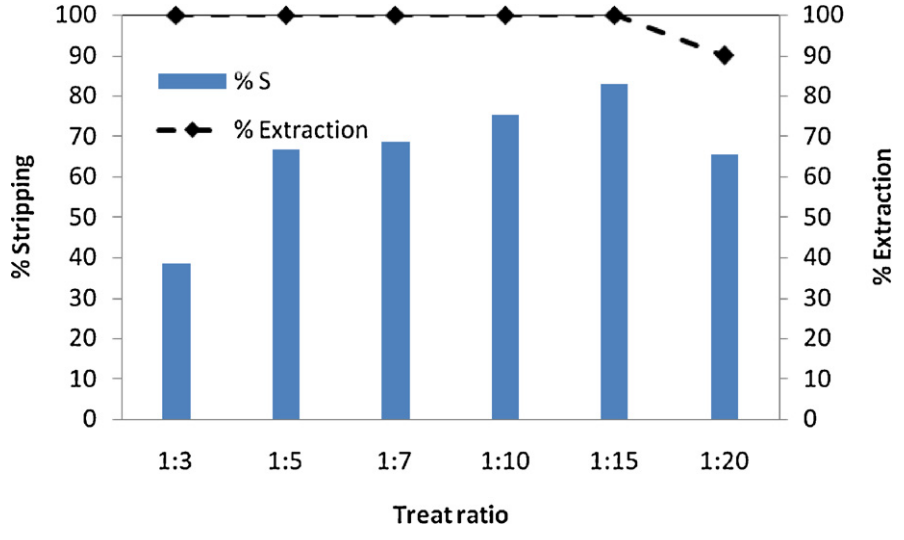


Fig. 10. Effect of treat ratio on extraction and stripping of reactive dye.

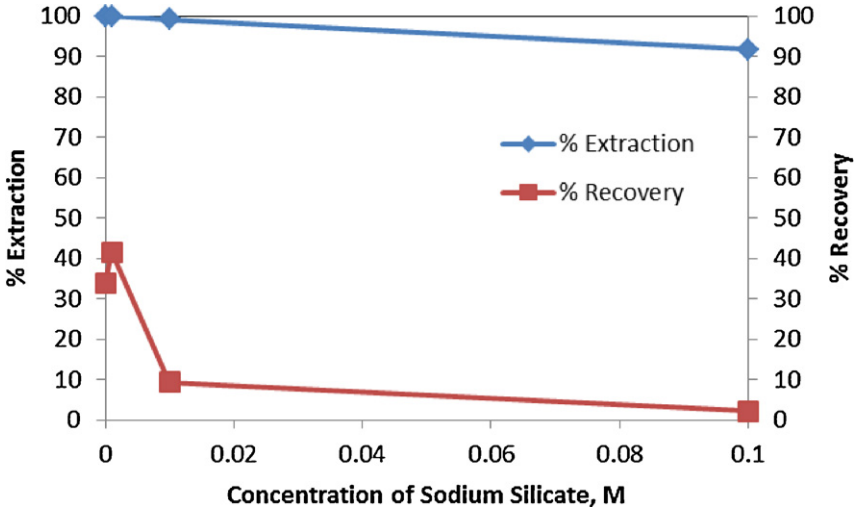


Fig. 11. Effect of Na_2SiO_3 on extraction and recovery of reactive dye.

slightly decrease of extraction efficiency with the increasing of Na_2SiO_3 concentration. On the other hand, the efficiency of recovery relies on the both performance of extraction and stripping process of reactive dye. By increasing the concentration of Na_2SiO_3 in the solution, it will decrease the percentage of recovery. The presence of Na_2SiO_3 in external dye feed solution interrupted the performance for both process. The performance of dye recovery was not results as good as extraction performance. It is due to the increase in the basicity/alkalinity and ion competency hence affecting the formation of TDA–dye complex to facilitate the transportation of dye ion through membrane layer to continue releasing the dye ion into receiving phase. Higher Na_2SiO_3 concentration may form different type of reactive dye. By owing to the nature of Na_2SiO_3, the colour of reactive dye solution was changed depends on the concentration of Na_2SiO_3 in the solution. Ability of Na_2SiO_3 to change the colour of reactive dye is very significant thus influenced the extraction and stripping efficiency.

4. Conclusions

It is demonstrated that the ELM technique is very promising in extracting reactive dye from simulated wastewater. In order to achieve the objective several parameters have been studied such as concentration salicyclic acid, extraction time, concentration SPAN 80, concentration of NaCl, concentration of TDA, agitation speed, homogenizer speed, emulsifying time and emulsion to reactive dye solution ratio in ELM system. The most suitable parameter conditions are at 0.1 M salicyclic acid, 5 min extraction time, 3% (w/v) concentration of SPAN 80, 0.3 M concentration of NaCl, 0.1 M concentration of TDA, 350 rpm agitation speed, 12,000 rpm homogenizer speed, 10 min emulsifying time and 1:15 emulsion to reactive dye solution. Investigation of the optimum condition of ELM system is necessary in order to realise the intention of ELM in removal of reactive dye.

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