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Application of Taguchi Method for Optimization Cadmium Separation by Emulsion Liquid Membrane

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ABSTRACT

A study was carried out to remove cadmium ions from a hydrochloric medium at a concentration of 100 ppm using the emulsified liquid membrane (ELM) technique. Emphasis was placed on assessing process parameters and their effect on changing the concentration of cadmium ions in the hydrochloric solution. To study the performance characteristics of the process, Taguchi method was used with analyzing of signal/noise ratio. Five parameters that affect performance such as (pH of the external phase (1-4), surfactant concentration in the organic layer (4% -10% v / v), carrier concentration in the organic layer (4% -10% v / v), speed of Emulsification (5800-24000) rpm and emulsion volume ratio / outer phase ratio (Eml./Ext ratio) was studied, taking into account the change in the concentration of cadmium ions in the external phase. To obtain the lowest concentration of cadmium ions in the external stage, the values of the optimum parameters were: pH = 3, Surfactant conc. = 4%, Carrier conc. = 8% emulsification speed = 19700 rpm, and Eml./Ext. ratio = 18%. Results of the present work suggested that Eml./Ext. ratio had a major effect on the concentration change, followed by a pH in the outer phase, the emulsification velocity, carrier concentration, and the surfactant concentration respectively.

1. Introduction

The liquid membrane technique is a special type of liquid-liquid extraction, in which the pollutant is extracted by the organic phase, and separated from the organic phase in one –step process Kamiński et al. [1]. Liquid membrane can be expressed as a semi-detachable partition formed by a thin, non-porous, layer of organic solvent. This membrane separates two aqueous phases, which are the source phase (or the feeding phase or the donor phase) and the receiving phase (or the abstraction phase or the stripping phase). The pollutant is transferred from one aqueous phase (External phase) to another phase (stripping phase), according to the difference in concentrations or the extracting effect, through the organic membrane. This transfer process is called "protraction" Kislik et al. [2] The first appearance of the term liquid membrane was in 1902, when it caught the attention of a researcher by chance, while studying the properties of systems consisting of oil layer and electrolytic solutions, the presence of a strong film in the interface of water and oil was observed.

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Nomenclature			
C:	Cadmium ions concentration after t=t	T D.	Taguchi's Design
C0:	Initial concentration of Cadmium ions t=0	n:	is the number of times the experiment was repeated under the same conditions
ELM	Emulsion Liquid Membrane	DF :	Degree of Freedom
Eml./Ext.	Emulsions to external phase ratio.		
v/v :	Volume by volume	D O E :	Design Of Experiments
W/O :	Water in Oil emulsions	y:	response amount.

So much so, that the ring used in the Du Nuoy experiment, to measure the surface tension between liquids, can bind the film and raise it to the oil phase. After that, these films were thought about and how to benefit from them. Therefore, the first experiment in this field was conducted in 1968 by the researcher Lei, who obtained a patent for the separation of hydrocarbons using liquid surface films. Li et al. [3] In the past two decades, this technology has evolved into an accepted separation. Due to the strict environmental legislations and the characteristics that distinguish this technology from the traditional separation processes, the interest of researchers in this field has been increased, where many researches has been done in the field of membrane development, building the unity of the process, the extent of its use in various fields and so on. Román et al. [4] Liquid membrane applications can be implemented using units with different designs of liquid membranes. Therefore, liquid films can be classified according to these designs into Bulk liquid membrane (BLM), supported liquid membrane (SLM), and Emulsion liquid membrane (ELM) Moyo et al. [5].

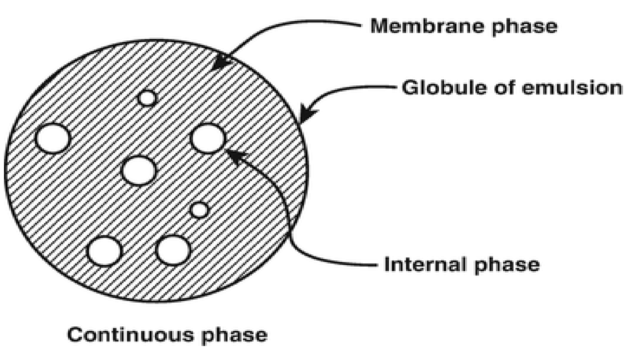

Figure 1. Schematic of ELM Ahmad et al. [7]

The emulsion liquid membrane (ELM) can achieve much higher mass transfer. ELM extraction provides a high ratio of surface area to volume, for high mass transfer, more economy, low energy consumption, and effective for low solubility concentration and small quantity solvent requirements Zaulkiflee et al. [6]. In the liquid membrane design Fig. 1, the ELM unit consists of an internal phase (reception solution), an organic phase (liquid membrane), and an external phase (feeding solution).

LEMs are made by forming emulsions from the inner phase and the organic phase, then dispersing these emulsions in the outer phase (feeding solution). In LEM extraction, extraction and abstraction operations are combined into one-step process Muesli et al. [8]. .In a typical arrangement, the strip solution and the organic phase are emulsified to form very fine droplets of the dispersed inner solution in the organic phase. The organic phase may contain a conventional solvent recovery reagent to facilitate the transport of the pollutants through the organic membrane. Although this method is very effective, its commercial and industrial applications are still limited so far due to "Emulsion Instability", this term means membrane leakage, fusion, and emulsion swelling. The instability of the emulsion globules will reduce the extraction efficiency. On the other hand, the highly stable emulsion causes new problems during sedimentation and de-emulsification Ahmad et al. [7]. The efficacy of the membrane on extraction and the stability of the emulsion are essential criteria for evaluating the performance of the emulsion membrane. These two criteria are affected by several factors, including factors related to the installation of the membrane and others related to the operational conditions.

1.1 Removal of heavy Cadmium ions by ELM:

One of the well-known toxic heavy metal ions is cadmium ion. This ion can accumulate through the food chain and seriously affect the health of living organisms. Cadmium is discharged at high concentrations in wastewater from the nickel-cadmium battery manufacturing plants, cadmium alloys, iron processing plants, etc. Therefore, the process of separating cadmium has taken great care in the field of research to find a feasible and effective method to purify industrial water Renieri et al. [9]. Among these studies is the field of ELM performance improvement, which is considered as a promising and cheaper separation method of cadmium .. Kumbasar et al. [10] studied the removal of cadmium from a solution resulting from the filtering of the zinc cake with sulfuric acid.by using LEM technique. The effect of acid concentration in outer solution, type of stripping solution, concentration of stripping solution, mixing speed in feed solution, surfactant concentration, carrier concentration, cadmium concentration in the extraction, and phase ratio on the rate of cadmium removal was studied. The ELM consists of kerosene as an economical organic solution and contains Aliquat336 as a carrier and Span80 as a surfactant. A different stripping agent was examined, it was found that ammonia solution is more favorable than Na_2CO_3 , $(NH_4)_2CO_3$ and NaOH. Solutions. It was also concluded that the use of a sufficient quantity of the carrier had a positive effect on increasing the efficacy of pollutant extraction and the speed of recovery, but in any case the amount of extracts used in this technique remains generally low.

Ahmad et al. [11] studied the application of green liquid emulsion membrane technique to remove cadmium by using vegetable oil as a diluent, which contained Span 80 as a surfactant and different types of carrier. They studied the stability of green emulsions in front of several variables, including Carrier type and concentration, Surfactant Concentration, Emulsification time, Internal phase concentration, and Stirring speed. According to the results reached in this study, the use of high concentrations of the carrier and the surfactant in the membrane layer increases the possibility of membrane fracture. Although the use of a high-viscosity emulsion layer causes a high resistance to mass transfer, the results showed that the emulsion was more stable and the fraction ratio reached 0.05% after improving all parameters of the process.

Benderrag et al. [12] studied the recovery of cadmium from stream water using ELM consists of kerosene as an organic solvents; Triton X-100 as a stabilized biodegradable surfactant and di-(2-Ethylhexyl) phosphoric acid (D2EHPA) as carrier. Cd (II) extraction yield, Y (%), quantifying the efficiency of the process, was considered as a function of three parameters: D2EHPA/Triton X-100 ratio ranging from 0.5 to 3.5, initial feed phase concentration between 300 and 500 ppm, and feed phase pH from 5 to 9. At the optimized conditions ([Cd] =500 ppm, stirring speed=200–300 rpm, t=20 min and pH=7.6), Cd (II) ions extraction was recorded more than 98% of efficiency.

This study by Binnal et al. [13] This study was distinguished from the previous two by reviewing the effect of temperature on cadmium extraction by the ELM method. They explained that the extraction reaction of the Cd(II) is favored by a relative decrease in the temperature.

In this study, a Taguchi method was adopted to explain the change in the concentration of cadmium ions in the outer phase, where the effect of five variables (pH of external phase, Carrier concentration, Surfactant concentration, Emulsification speed, and Emulsion to External phase ratio) on the process were investigated.

Table 1. Required Materials

Materials	Specifications	Suppliers
Kerosene	MW. =51.5 g/mol Purity ≥ 99% Density = 0.8 g/cm^3	Dwaniyah Refinery
Aliquat 336 (Methyltri-octyle Ammonium Chloride	MW. =404.16 g/mol Purity ≥ 97% Density = 0.884 g/cm^3	Sigma Aldrich
Span 80	MW. =428.62 g/mol Purity ≥ 60% Density = 1.06 g/cm^3	Thomas Baker
Sodium hydroxide (NaOH)	MW. =40 g/mol Purity ≥ 97.5%	Thomas Baker
Cadmium Chloride	MW. =201.32 g/mol Purity ≥ 99%	Central Drug House
Hydrochloric acid	MW. =36.46 g/mol Concentration ≥ 36%	ReAgent

2. Experimental work:

2.1 Required materials :

Table 1 includes the materials used in the present work with their specifications and the companies supplying them. These materials were used without further purification.

2.2 Required Equipment :

- Mixer (BENSONMOOTH /Standard-Germany)
- Homogenizer (OM-TOPS)
- Syringe Filter (CHMLAB Group)
- Atomic Absorption Spectrophotometer (SHIMADZU).

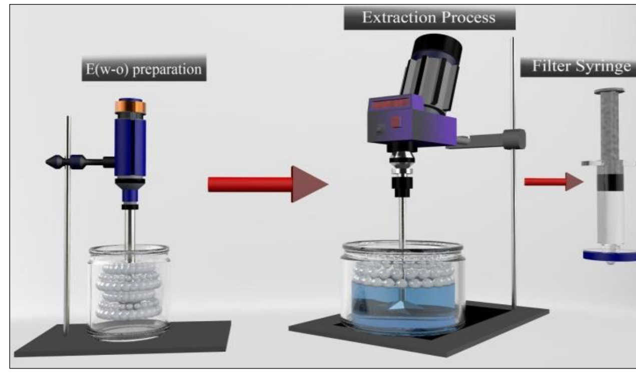

Figure 2. General description of experimental work.

2.3 Experimental procedure :

The method of work includes four steps Hussein et al. [14] that can be summarized as follows :

1. Preparation of solutions step :

Three required solutions were prepared:

- The organic solution: is prepared by dissolving the carrier(Aliquat 336) and surfactant (Span80) in a kerosene solvent according to the certain determined as variables.
- External solution: prepared by dissolving a specific amount of Cadmium Chloride in distilled water to obtain aqueous cadmium solutions at a concentration of 100ppm. The pH value of this solution is controlled using hydrochloric acid & NaOH solution.
- Stripping solution: It is prepared by dissolving a specific amount of NaOH to obtain a basic solution at a concentration of 0.1 M.

2. Emulsification Step (W/O) :

In order to obtain stable emulsions, a stripping solution was added gradually to the organic solution in ratio 1:1 (v/v). This mixture was then emulsified by using the Homogenizer at different mixing speeds according to the conditions of each experiment. Mixing was continued until a steady milky emulsion is obtained. This process is taken about 12min, and the emulsifying cup is placed in a cold water bath to avoid overheating of the emulsion during preparation.

3. Extraction step:

The prepared emulsions were gradually added to 400ml of the 100 ppm Cadmium aqueous solution. This system was mixed using a mixer at a speed of 250rpm for a period of 10min. Samples were taken after every 3min and 10min, the external solution of the sample is separated from the emulsions using a filter syringe.

4. Sample analysis:

The concentration of cadmium in the samples was measured using Atomic Absorption Spectra-photometer. These concentrations were then used to determine the cadmium concentration change in the external phase.

2.4 Transport mechanism:

The general steps of the ions transport process between the three phases of the emulsion liquid membrane unit (external phase, organic phase, and internal phase in series) are as follows Koter et al. [15]:

(1) diffusion of metal ions from the depth of the feed phase to the surface where the feed phase meets the organic phase,

(2) The complexity of metal ions with the carrier on the convergence surface to form mineral complexes dissolved in the organic phase,

(3) These complexes diffuse through the organic layer in addition to the confluence of the organic phase with the inner phase,
(4) dissociation of the mineral organic complexes on this side, as mineral water complexes form, then spread throughout the inner phase.
Aliquot 336 is one of the quaternary ammonium halides more efficient for extracting metal ions from an aqueous halide medium. The extraction mechanism is an ion bonding mechanism to produce neutral types, whereby quaternary ammonium compounds balance the charge of ionic mineral complexes, and thus the process is called enhanced extraction. The proposed general extraction mechanism is as follows Kumbasar et al. [10]:

$$nR_4N^+A_{(org)} + (MB_x)^{n-}_{(aq)} \leftrightarrow (R4N^+)_n(MB_x)^{n-}_{(org)} + nA_{(aq)} \quad (1)$$

Where :
nR_4N^+A = Quaternary ammonium halides ,
(MB_x)= Ionic groups are in the external phase ,
$(R4N^+)_n(MB_x)$ = Carrier-ion complex.
In this study (cadmium extraction), an ion exchange reaction with Aliquat 336 (R_4NCl) occurred on the surface of the membrane to form an ion pair ($(R_4N)_2CdCl_4$) that then enters the emulsified liquid membrane layer.
For the feed solution, cadmium ions interact with chlorine ions (Cl^-) in proportion to the following equation He et al. [16]:

$$2H^+_{(aq)} + Cd^{2+}_{(aq)} + 4Cl^-_{(aq)} \leftrightarrow H_2CdCl_{4(aq)} \leftrightarrow 2H_{(aq)} + CdCl^{2-}_{4\,(aq)} \quad (2)$$

The process of forming complexes on the side of the confluence of the outer phase with the organic phase can be described by the following chemical reaction Juang et al. [17] :

$$2R_4NCl_{\,(org)} + CdCl^{2-}_{4\,(aq)} \leftrightarrow (R_4N)_2CdCl_{4\,(org)} + 2Cl^- \quad (3)$$

Where In this reaction, Cl^- is interchanged with the $CdCl_4^{2-}$ anion in the acidic feed solution–membrane interface.
The compound formed as above is dispersed through the membrane towards the abstraction side, and *when* there is NaOH there, the next reaction is expected to occur on the membrane face on the side of the internal solution :

$$(R_4N)_2CdCl_{4\,(org)} + 2NaOH_{\,(aq)} + 2(R_4N^+OH^-)_{(aq)} + 2Na_{\,(aq)} + CdCl^{2-}_{4\,(aq)} \quad (4)$$

In this reaction, $CdCl_4^{2-}$ is interchanged with the OH−anion in the basic stripping solution–membrane interface.
Then the carrier complex ($R_4N^+OH^-$) is returned to spread in the organic layer where the exchange reaction between the sides of the extract and the abstraction takes place as follows:

$$2(R_4N^+OH^-)_{(org)} + 2H_{(aq)} + CdCl^{2-}_{4\,(aq)} \leftrightarrow (R_4N)_2CdCl_{4\,(org)} + 2H_2O_{(aq)} \quad (4)$$

Where Aliquat 336 turns into a hydroxide in a certain ratio by contacting with stripping NaOH solution Bhowal et al. [18].

3.Design of experiments (DOE) :

This work includes five variables (pH of external phase, Surfactant to kerosene ratio (v/v), Carrier to kerosene ratio (v/v), Emulsification speed, and Emulsions to External phase ratio (v/v)). Each variable was taken at four levels, as shown in **Table 2.**

Table 2. Work's variables

No.	Variables	Level 1	Level 2	Level 3	Level 4
1	pH of External phase	1	2	3	4
2	Span 80 Ratio (v/v)	4%	6%	8%	10%
3	Carrier Ratio (v/v)	4%	6%	8%	10%
4	Emulsification Speed (rpm)	5800	12700	19700	24000
5	Eml./Ext. Ratio (v/v)	6/100	10/100	14/100	18/100

One common method of designing experiments is the Taguchi approach to reducing the number of experiments needed to work, and to illustrate the impact of each factor. Taguchi Design (TD) Experiment Method is a very popular method due to its high applicability and ease of use with limited knowledge of the basics of statistics. This method was developed by Dr. Genichi Taguchi based on the design principles that emerged in the fifties and sixties, this method can be defined as "an engineering methodology to improve productivity during research and development so that high-quality products can be produced quickly and at low cost." It can be used in various research fields. Menten et al. [19]**.** Essentially, the Taguchi method is characterized by Dar et al. [20]:

- Its ability to study all process parameters using a few number of experiments.
- Finding the parameter that most influences the response rate.

The first step in this method is to determine the controllable factors (factors & there levels mentioned in **Table 2)** and the factors that cannot be controlled (response). In this method, orthogonal matrices are used to calculate the number of experiments and rely on the results of these experiments to analyze the data. Calculating the number of trials using the Taguchi method depends on the degree of freedom (DF). In this study there are five variables and four levels, DF= (1 + 5 * (4-1)) = 16. Therefore, when selecting the orthogonal matrix L16, the number of experiments will be 16. Sulaymon et al. [21]. **Table 3** represents orthogonal matrices are used to calculate the number of experiments based on TD method in coded form using Minitab v 17.0.
So that the experiments were conducted in the same sequence shown in **Table 4** in terms of real values.
In TD the data is analyzed using the following analysis methods provided by this method Design-of-experiments et al. [22]:

- The Signal / noise ratio indicates parameters of quality features for testing. Average Analysis,
- ANOVA variance analysis to determine the effect of each factor.

Table 3. Orthogonal matrices of L16 in terms of coded values.

NO.	A	B	C	D	E
1	1	1	1	1	1
2	1	2	2	2	2
3	1	3	3	3	3
4	1	4	4	4	4
5	2	1	2	3	4
6	2	2	1	4	3
7	2	3	4	1	2
8	2	4	3	2	1
9	3	1	3	4	2
10	3	2	4	3	1
11	3	3	1	2	4
12	3	4	2	1	3
13	4	1	4	2	3
14	4	2	3	1	4
15	4	3	2	4	1
16	4	4	1	3	2

Table 4. Orthogonal matrices of L16 in terms of real values.

NO.	pH of external phase	Surfactant conc. v/v %	Carrier conc. v/v %	Emulsification speed	Eml./Ext. ratio %
1	1	4	4	5800	6
2	1	6	6	12700	10
3	1	8	8	19700	14
4	1	10	10	24000	18
5	2	4	6	24000	18
6	2	6	4	19700	14
7	2	8	10	5800	10
8	2	10	8	12700	6
9	3	4	8	24000	10
10	3	6	10	19700	6
11	3	8	4	12700	18
12	3	10	6	5800	14
13	4	4	10	12700	14
14	4	6	8	5800	18
15	4	8	6	24000	6
16	4	10	4	19700	10

4. Results and Discussion :

4.1 Effect of process parameters on C/C0

4.1.1 Effect of pH of External phase :

The effect of each pH level on the extraction process is shown in **Fig. 3** As shown in the graph, the highest Cd^{+2} extraction is the value of pH = 3, that is, the lowest value of the remaining Cd^{+2} ions in the External solution. According to the chemistry of extraction by basic carrier (Aliquat 336) that was used in this study, it can be explained that at very low pH values there is difficulty in separating $CdCl_4^{2-}$ complex from $CdCl_4$ stable complex. Increasing the value of pH more than 3 (decrease in the amount of hydrochloric acid) causes a decrease in the transmission rate due to a decrease in the number of halide (Chloride) ions that are needed to form the complex $CdCl_4^{2-}$ [10],[16].

4.1.2 Effect of Surfactant Concentration:

The effect of each level of the surfactant factor concentration on the extraction process is shown in **Fig. 4**. It can be deduced from the graph that the lowest value of the remaining Cd ions in the External solution occurred at the concentration = 0.04. Increasing the concentration of the surfactant from the required limit leads to an increase in the viscosity of the organic layer, which leads to a high resistance to the mass transfer process due to the difficulty of spreading complexes through the organic layer. Also increasing the viscosity causes the formation of large-size pellets during the dispersion phase, which causes a reduction in the moving area Naim et al. [23].

4.1.3 Effect of Carrier Concentration:

Fig. 5 shows the effect of each level of the carrier concentration on the extraction process. The concentration of the remaining Cd ions in the outer solution decreases gradually until it reaches the carrier concentration = 0.08. Then increase slightly when the focus = 0.1.

Increasing the concentration of the carrier leads to an increase in the number of complexes present during the organic membrane, which may lead to swelling of the emulsion pellets, then reducing the transfer area, as well as swelling of the pellet to reduce the organic membrane, which makes it susceptible to fracture and the internal phase leakage outward Ahmad et al. [11].

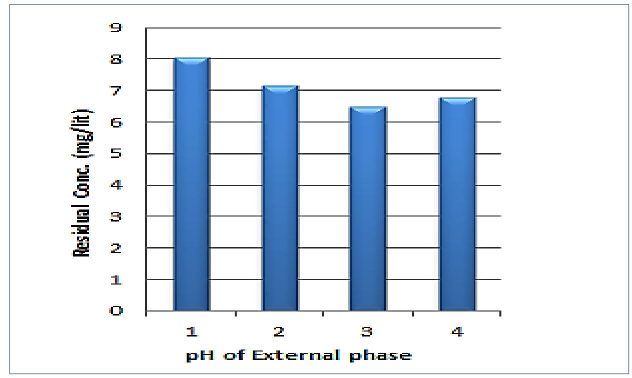

Figure 3. Effect of pH of the External phase.

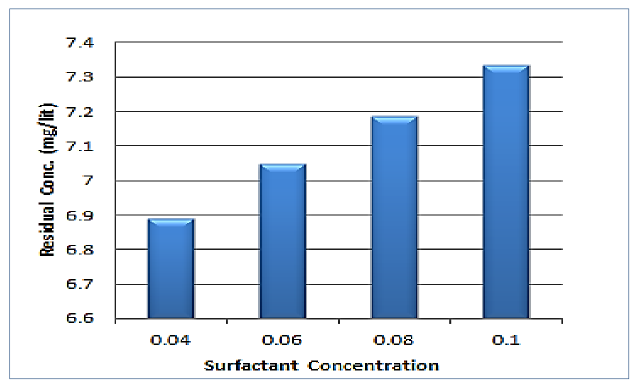

Figure 4. Effect of Surfactant Concentration.

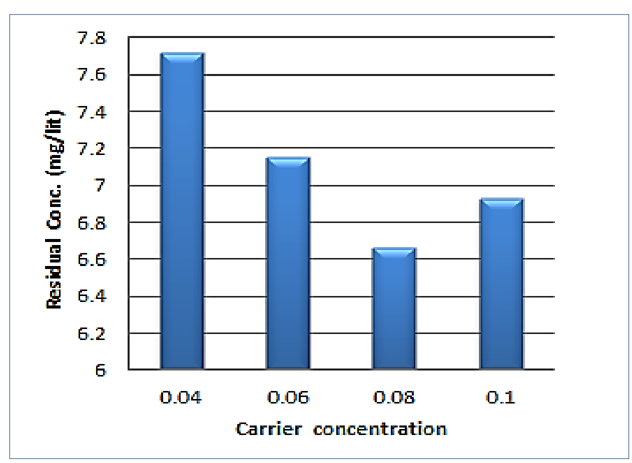

Figure 5. Effect of Carrier Concentration.

4.1.4 Effect of Emulsification speed:

As shown in **Fig. 6** the amount of cadmium ions remaining in the outer phase decreases with increasing emulsification speed, i.e. the separation efficiency increases. Increasing the speed of emulsification provides more homogeneity between the organic membrane and the internal phase. This homogeneity provides more stable dispersible pellets of an appropriate size so that it can provide sufficient transport space to obtain the largest value of the mass transfer coefficient during the work. Dong et al. [24].

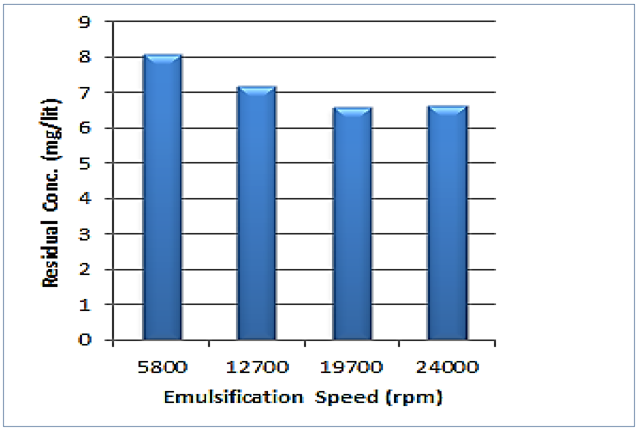

Figure 6. Effect of Emulsification Speed .

4.1.5 Effect of Eml./Ext. Ratio :

From **Fig. 7**, it can be concluded that the concentration of the remaining cadmium ions is completely inversely proportional to the Eml./Ext. Ratio, meaning that the efficiency of cadmium ions extraction using ELM technique increases with this ratio. This can be attributed to the increase in the contact area between the external phase and the emulsions and thus increasing the area of the mass transfer. In addition to the increase in the amount of abstraction phase, it can also lead to preventing the occurrence of the reverse transition resulting from the accumulation of complexes traveling in the organic phase, which leads to the emulsion being swollen and broken. Zaheri et al. [25].

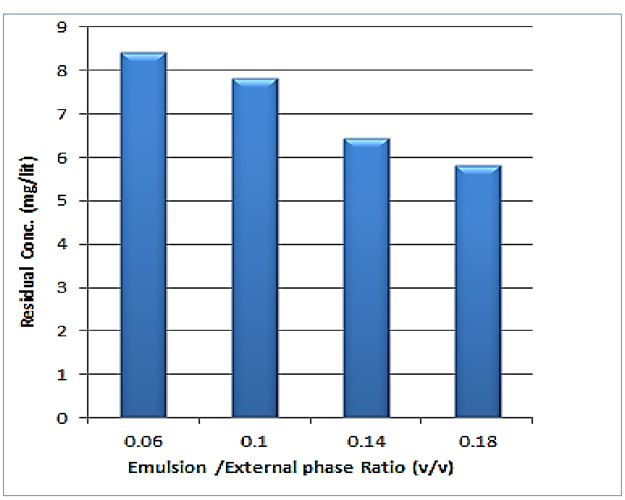

Figure 7. Effect of Eml. / Ext. Ratio.

4.2 Sign /Noise Analysis:

In Taguchi method for determining process quality, the signal-to-noise ratio is used. Where the signal represents a desirable value (average response value), while noise is undesirable values (the square deviation of the response from the desired value). There are three possible signal/noise ratios, which depend on the system quality improvement standard. These ratios are divided into Larger Is Better (LIB), used when the largest value of a response is needed without compromising the reliability of the process. Small Is Better (SIB), used when the goal is to get the lowest value of the response. Nominal value Is Better (NIB) and, used when the response value needs to be around a certain value Pundir et al. [26].

In this study, to find out the main effects of the variables and levels mentioned in **Table 2**, the "Smaller Is Better ", represented by the Equation (6), was used to calculate the signal-to-noise ratio.

$$Signal/Noise = -10 \log \left(1/n \left(\sum y^2\right)\right) \quad (6)$$

Since the SIB used, the highest S / N ratio is required to obtain the lowest concentration of cadmium ions in the External phase Fouad et al. [27] shown in **Fig. 8** and **Table 5**. Where the effect is chosen that achieves the smallest value from the mean of **C/C_0**. Calculations were performed using the program "Minitab® 17.1.0", knowing the effect of each factor on the response represented by **Table 5**, and **Fig. 8.**

Table 5. Response Table for Signal to Noise Ratios 'Smaller is better'

Level	pH	Surfactant conc.	Carrier conc.	Emulsification speed	Eml./Extr. Ratio
1	22.09	23.61*	22.48	22.08	21.6
2	23.12	23.14	23.07	23.01	22.24
3	23.77*	22.96	23.61*	23.73*	23.87
4	23.47	22.74	23.29	23.63	24.74*
Delta	1.67	0.87	1.13	1.65	3.14
Rank	2	5	4	3	1

*Optimum Level

As shown from **Table 5** Signal /Noise Ratio ranged from 21.6 - 24.74, The table includes ranks of the variables based on delta values, which compare the extent to which each variable affects the response (represented by the ***C/C_0***) Dar et al. [20]. Therefore, the order of the variables in terms of the magnitude of the effect in a descending form is as follows: Eml./Extr. Ratio > pH of external phase > Emulsification speed Carrier Conc. >Surfactant Conc.

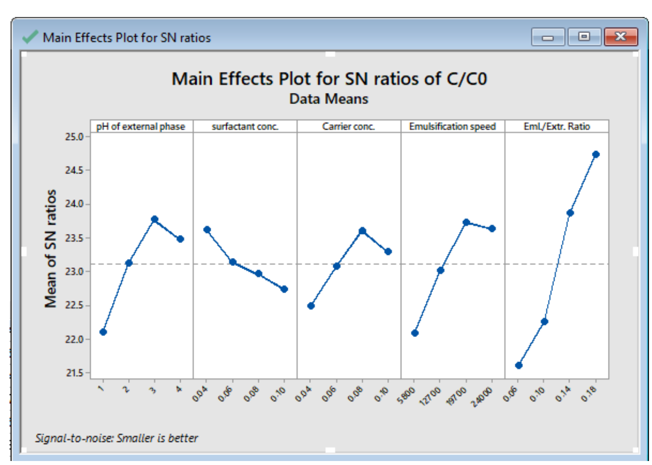

Figure 8. Main Effects Plot for SN ratios of C/C0.

So the optimum level of effectors that achieves the smallest value of C/C_0. will be:, Eml./Extr. ratio = 18/100, pH value =3, emulsification speed = 19700 rpm , and surfactant concentration = 4%, and the carrier concentration = 8% .

From Fig. 9, which represents the mean of C/C0. for each influencing factor. If the line is not horizontal, it means that the factor has a significant impact on the response rate, and also means that the effect of the levels varies with the different factor. Where the effect of the factors can be compared by comparing the slope of the lines represented by them. In the event that the lines are parallel to the X-axis, this means that all levels of factors affect the same way and also have no significant impact on the response rate. Hameed et al. [28]

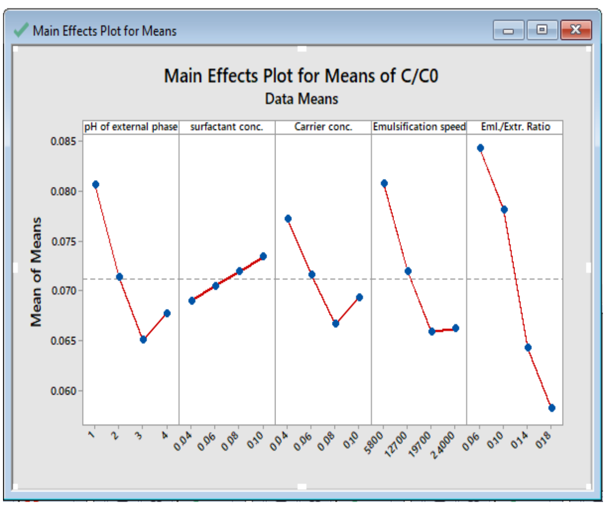

Figure 9. Main Effects Plot for means of C/C0.

4.3Analysis of variance (ANOVA) :

ANOVA is a statistical technique that can draw some important conclusions based on empirical data analysis. This method is very useful for detecting the effect of each factor on the response value. **Table 6** includes the most important elements of the analysis of variance.

Table 6. Analysis of variance for Cadmium extraction by ELM.

Response	Source	Contribution %	F-Value	P-Value
	pH	12.77%	12.54	0.005
	Surfactant conc.	1.34%	1.31	0.279
C/C_O	Carrier conc.	5.14%	5.05	0.048
	Emuls. Speed	16.90%	16.59	0.002
	Eml./Ext. Ratio	53.68%	52.71	0.000

These elements include: the percentage of contribution (**Contribution%**) which gives the percentage of each factor's contribution to affecting the response value. As for the work variables, it can be noted that the Eml./Ext. ratio has the greatest effect on changing the response rate, It has 53.6% of the effect of **C/C_O**. F-value indicates that the change in the value of the factor causes a significant change in the response value, and on it, the same result for the regression contribution was obtained as the Eml./Ext. ratio, with a 95% confidence level, is still with the highest effect. p-value determines the importance of each factor (with a level of confidence 95%) where p-value >0.05 indicates that the influence of workers is not important for the model, and thus we conclude that the most important factor is the Eml./Ext. ratio. , while surfactant conc. is less important factor with P-value = 0.279 Pundir et al. [26].

5. Conclusions

Successful recovery of cadmium ions from a hydrochloric aqueous solution was performed using ELM technique. The results of improving study of changing the concentration of cadmium ions in the external stage were using ELM technique with variation in process parameters in order to obtain the highest extraction efficiency (the minimum concentration of cadmium ions in the external stage). In this study Eml./Ext. ratio was found to be the dominant factor in extraction efficiency while the Span 80 concentration was found to be the least influencing factor. Optimal emulsion liquid membrane conditions were determined to maximize extraction efficiency (reduce the concentration of cadmium ions).They were pH = 3, surfactant conc. = 4%, Carrier conc. = 8% emulsification speed = 19700 rpm and Eml./Ext. ratio = 18%.

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