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A NOVEL METHOD FOR THE TREATMENT OF ESHIDIYA INDUSTRIAL WASTEWATER

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ABSTRACT

The aim of this project was to remove chloride ions from Eshidiya industrial waste water to be reused in the flotation cells. The industrial wastewater was treated by passing it through ion exchange column. During the experiments, two types of resins were used: anion resin and mixed resin (cation / anion).The selectivity coefficient and the separation factor were calculated in those experiments and were found to be within the theoretical limits.

The highest chloride ions removal efficiency which was reached in this process was 96.4% when the height of resin in the column was equal to 40 cm and the flow rate was equal to 0.12 liter/min. It was evident that this treated wastewater can be recycled to the flotation cells in the Jordan Phosphate Company, and the blow down water can be used for agricultural purposes.

Keywords: Wastewater, Mixed resin, Selectivity coefficient, Separation factor, Chloride ions, Efficiency, Chloride ions, Flotation cells.

1. INTRODUCTION

1.1. Eshidiya Wastewater

In Eshidiya phosphate mines more than 500,000 cubic meters of water per month are disposed from the beneficiation plant. These losses represent more than one million dollar per year to Jordan phosphate mines company JPMC [1]. Beneficiation is a plant with an output capacity of two million metric ton per year comprising four washing lines of which two lines are devoted for flotation. The flotation section comprises two lines for fine phosphate ore and one line for coarse phosphate ore [2, 3].

Jordan is a country of severe water stress. Projections show that by 2020, Jordan will have a major deficit in water. Many regions of the country already exhibit shortages and rationing. While industry's demand on renewable water resources is only 5%, and every day we have an industry sector that requires water for manufacturing purposes [4].

1.2. Effects of the Chlorides

1- In phosphate plants, when the chloride ions are found in water, they are associated with other cations (sodium, magnesium and calcium, etc) and form deposits on the flotation cells and cause a blockage [5].

2- Steel reinforcement embedded in concrete is inherently protected against corrosion by passivation of the steel surface due to the high alkalinity of the concrete. When a sufficient amount of chlorides reaches the steel reinforcement it permeates the passivating layer and increases the risk of corrosion. The resistivity of concrete can also be reduced, affecting the corrosion rate of the steel.

3- Road salt ends up in fresh water bodies and could harm aquatic plants and animals by disrupting their osmo regulation ability. The omnipresence of salt posts a problem in any coastal coating application, as trapped salts cause great problems in adhesion.

2. THEORY

2.1. Efficiency of Resin

If the concentration of the solution entering the ion exchanger is equal to C_o, and concentration of the solution that comes out of the exchanger is equal to C_f, the efficiency of this exchange is equal to:

$$\text{Efficiency} = \frac{(C_o - C_f)}{C_o} * 100\% \quad \text{---(1)}$$

It is known that the efficiency of ion exchanger decreases with time, as the resin tends to saturation with time.

2.2 Selectivity Coefficient:

The selectivity is a widely used characteristic of ion exchange systems. It indicates the preference of the material to one ion in comparison with another ion; but it is not yet fully understood.

$$A^{\pm n} + nRB \underset{K_B}{\overset{K_A}{\rightleftarrows}} AR_n + nB^{\pm} \quad \text{--(2)}$$

Where:

- $A^{\pm n} \equiv$ Cation or anion.
- $B^{\pm} \equiv H^+$ for cation exchange or OH^- for anion exchange.
- $K_A \equiv$ relative molar selectivity coefficient of the ion$A^{\pm n}$.
- $K_B \equiv$ relative molar selectivity coefficient of$B^{\pm}$.
- $R \equiv$ resin.

The selectivity sequence will change with the use of different resins, for the use of weak acid resins and weak base resins, the sequence will remain similar, but the values of the coefficients will change. For weak acid resins the most selective ion is the hydrogen ion, while for weak base resins the most selective ion is the hydroxide ion. Strong acid / base resins are the most commonly used in commercial applications and therefore will be the focus in module [6-8].

2.3. Capacity of Resin

The actual capacity of a particular ion exchange resin is less than the total capacity and depends on the operating conditions of the column. It is often difficult to predict because the actual capacity depends on several design parameters including concentration, pH and temperature. Also, the actual capacities of ion exchange resins must be determined experimentally by titration. Plots of the data usually start with small slopes that increase as more titrant is added. The actual capacity of the resin occurs when the pK_a equals the pH, according to the Henderson-Hasselback equation:

$$pH = pK_a + \log\frac{[OH^-]}{[H^+]} \text{ --------------------(3)}$$

If the pH and pKa are equal, then the logarithmic term must be zero. This can only happen when the concentrations of acid and base are the same, which occurs precisely when the resin's capacity is completely exhausted [9, 10].

3. PROCEDURE & RESULTS

3.1. Procedure of the Process

1- The solution was prepared by dissolving (24 & 32)g of NaCl in 20L of water to get (1200 & 1600) ppm respectively.
2- Solution was passed through the column that contains the resin by flow rate of 0.12 L/min.
3- During the process, the ions of Cl^- transferred from the solution to the resin and hydroxyl ion (OH^-) transferred to the opposite direction.
4- Sample of outlet solution was taken every five minutes.
5- 20 ml of the sample was titrated with silver nitrate ($AgNO_3$).
6- The process was finished when the resin exhausted (reach the saturation point).

For mixed resin:

Saturation point was reached when two layers formed as shown in the figures below:

3.2. Results

Common data for all runs:

Sample of outlet water is used in titration= 20 ml,Molecular weight of NaCl (M_w) = 58 g/mole.

Density of resin= 0.0645 g/ml = 0.0645 kg/l, Diameter of column= 3cm.

Flow rate of inlet water = 0.12L/min, $N_{AgNO_3} = 0.2$ N

Figure- 3.1. Mixed resin at the beginning of the process.

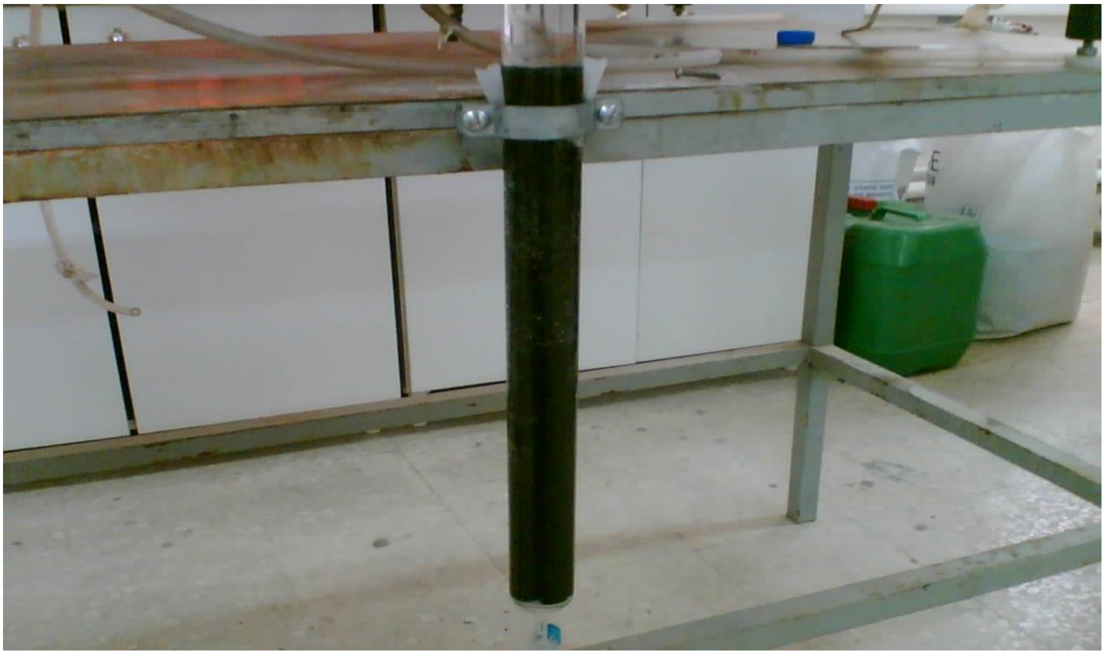

Figure- 3.2. Mixed resin at the end of the process.

Mixed bed:

Figures (3.4) to (3.9) are not shown here, as they belong to very specific details of the process.

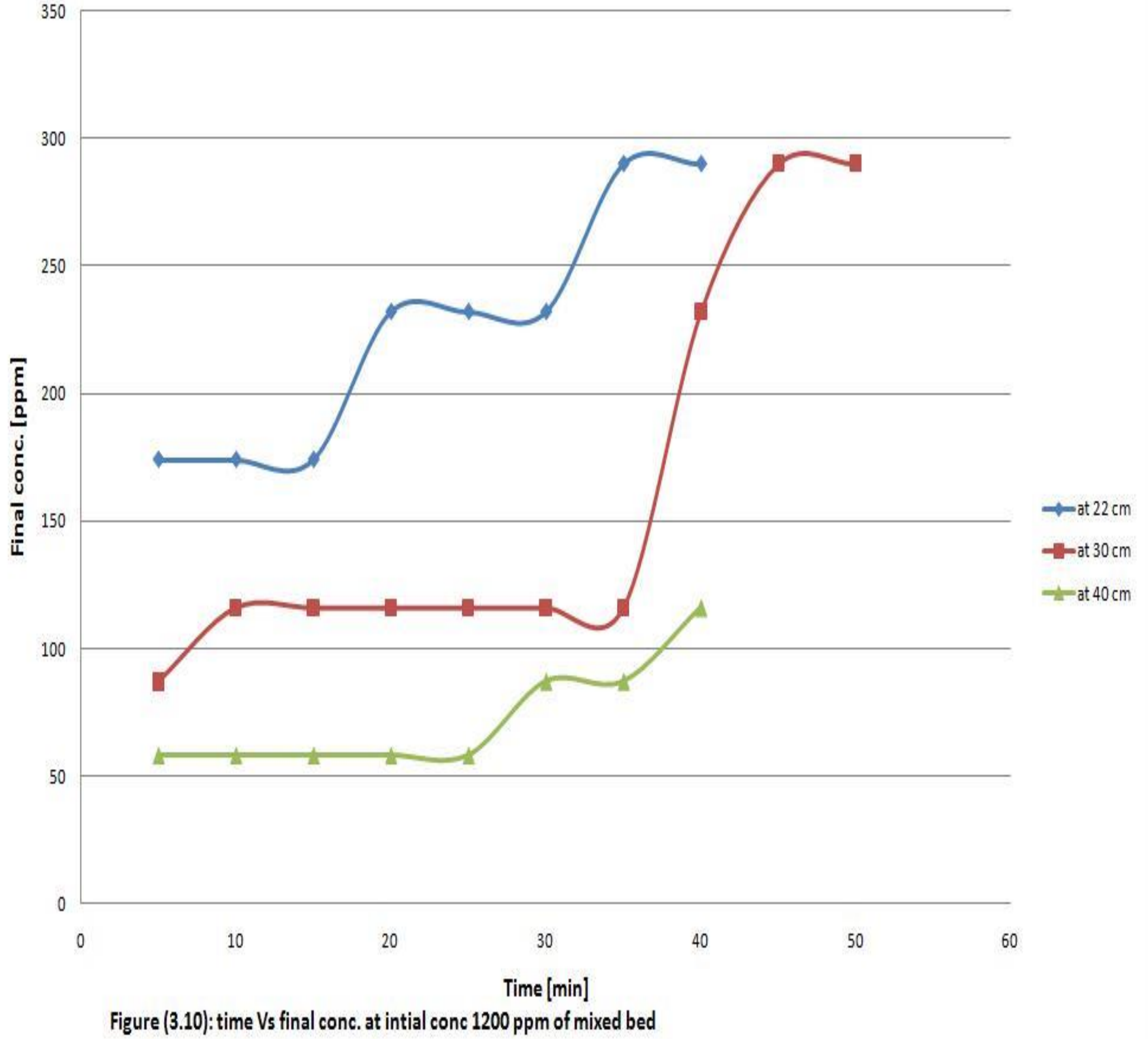

Figure (3.10): time Vs final conc. at intial conc 1200 ppm of mixed bed

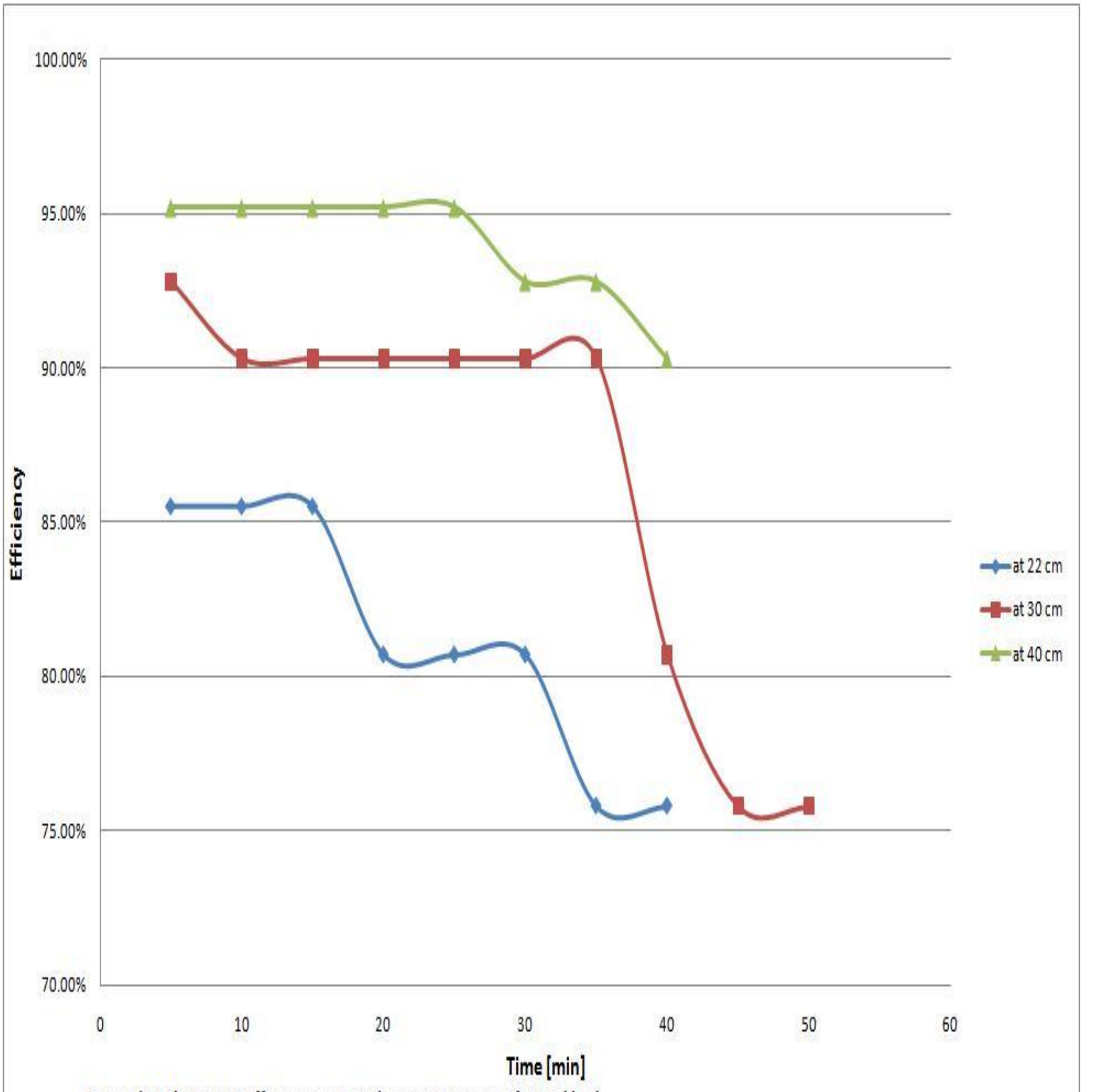

Figure (3.11): time Vs efficiency at initial conc. 1200 ppm of mixed bed

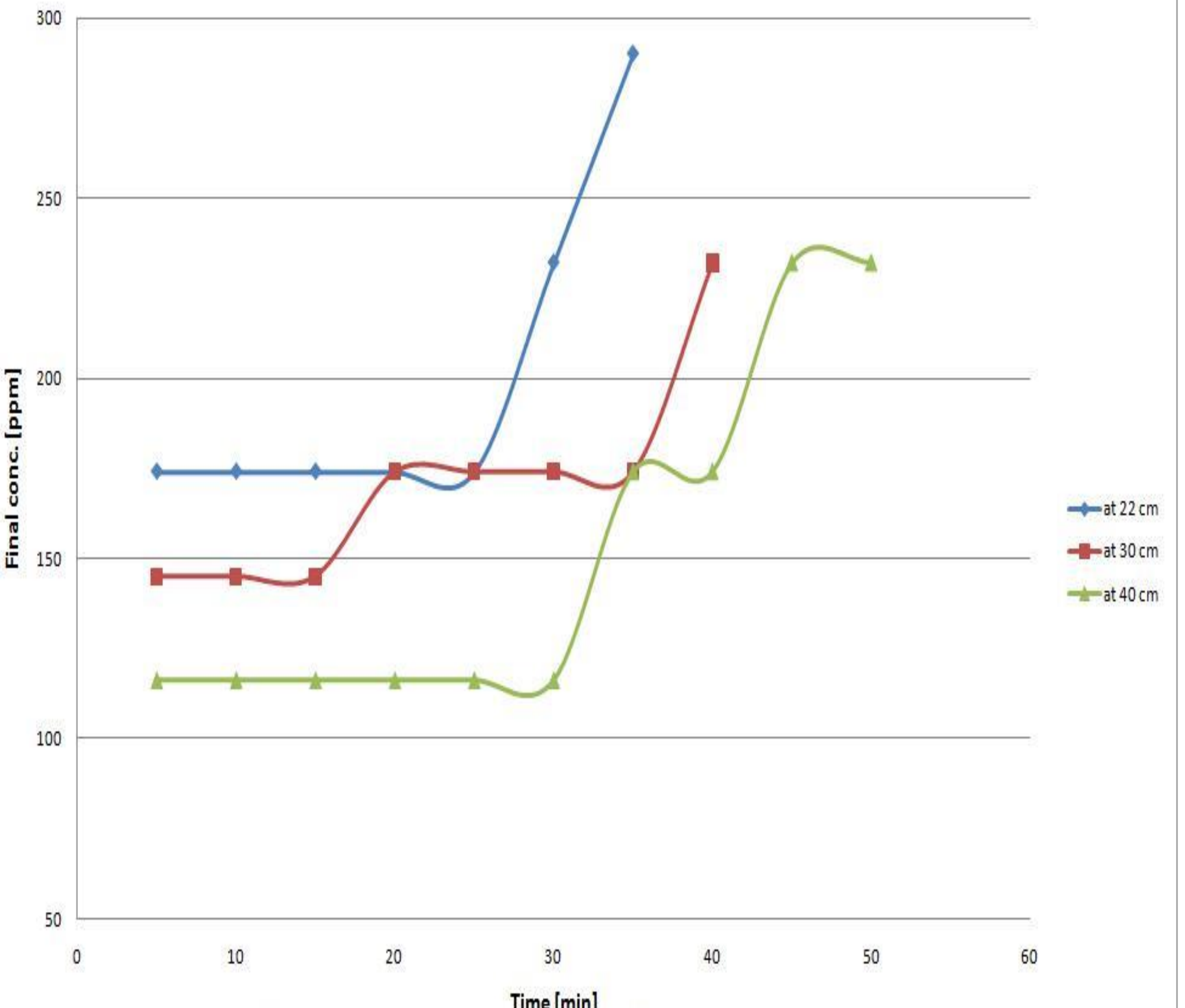

Figure (3.12): time Vs final conc. at initial conc. 1600 ppm of mixed bed

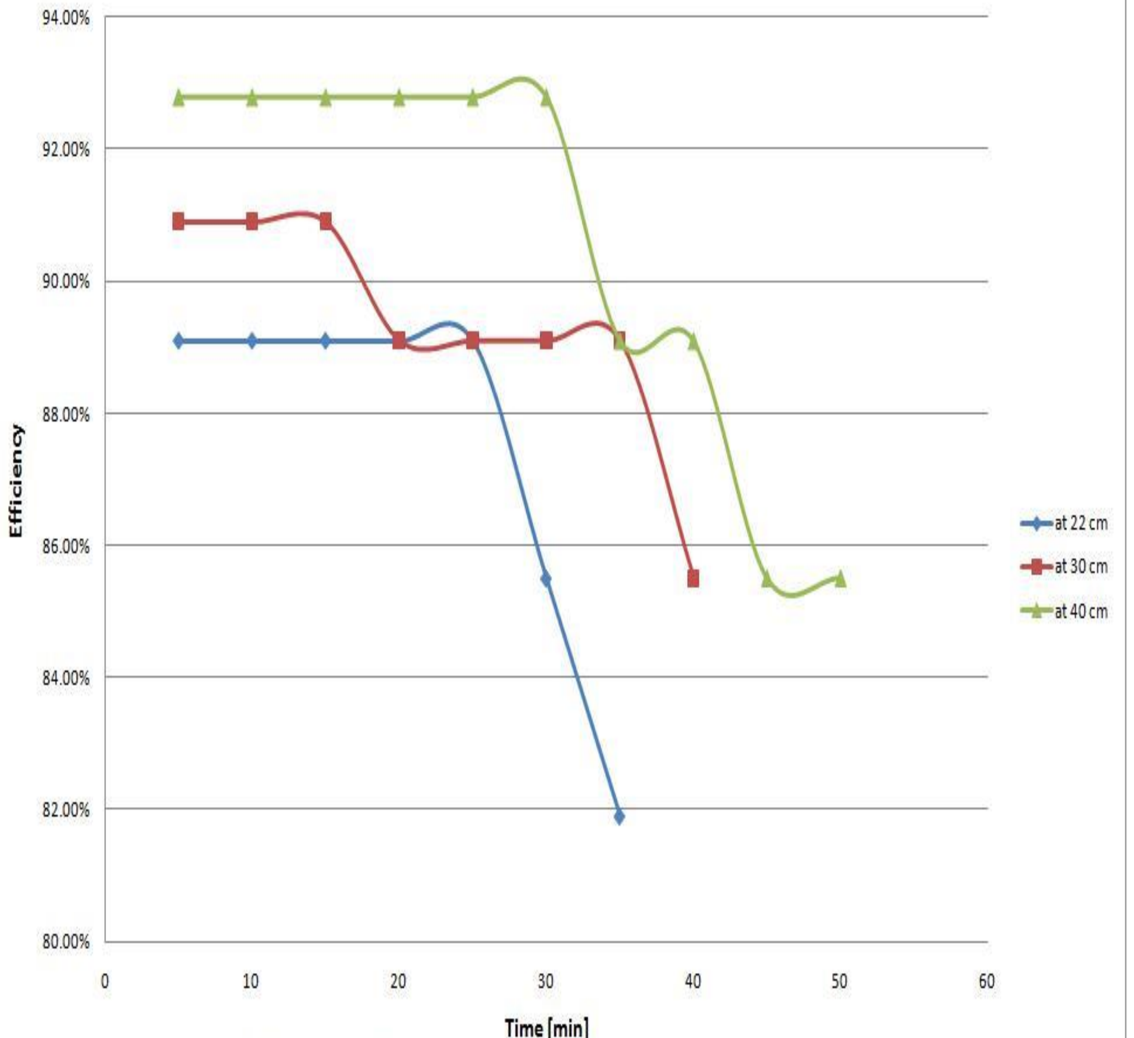

Figure (3.13): time Vs efficiency at initial conc. 1600 ppm of mixed bed

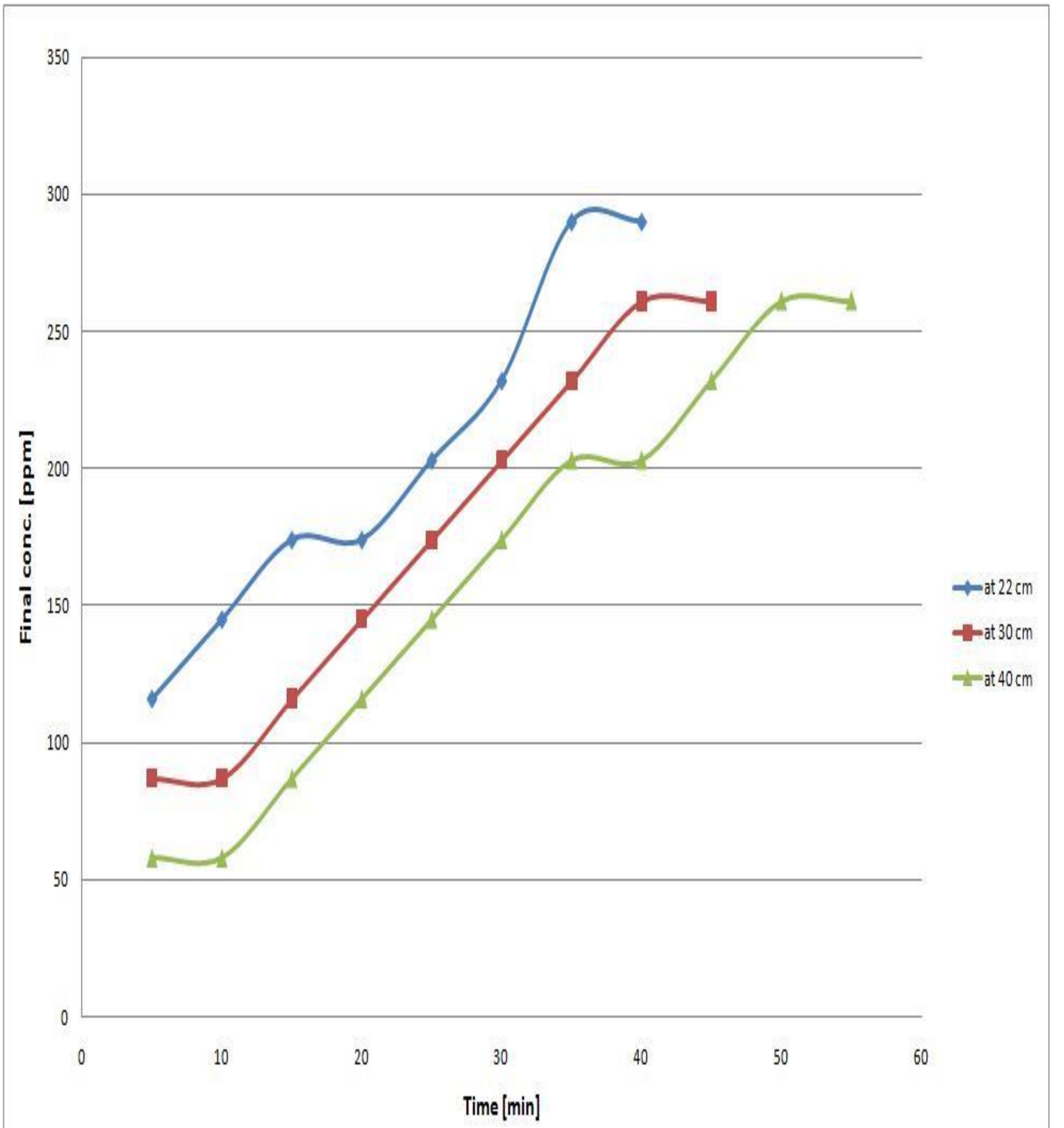

Figure (3.14): time Vs final conc. at initial conc. 1200 ppmof anion

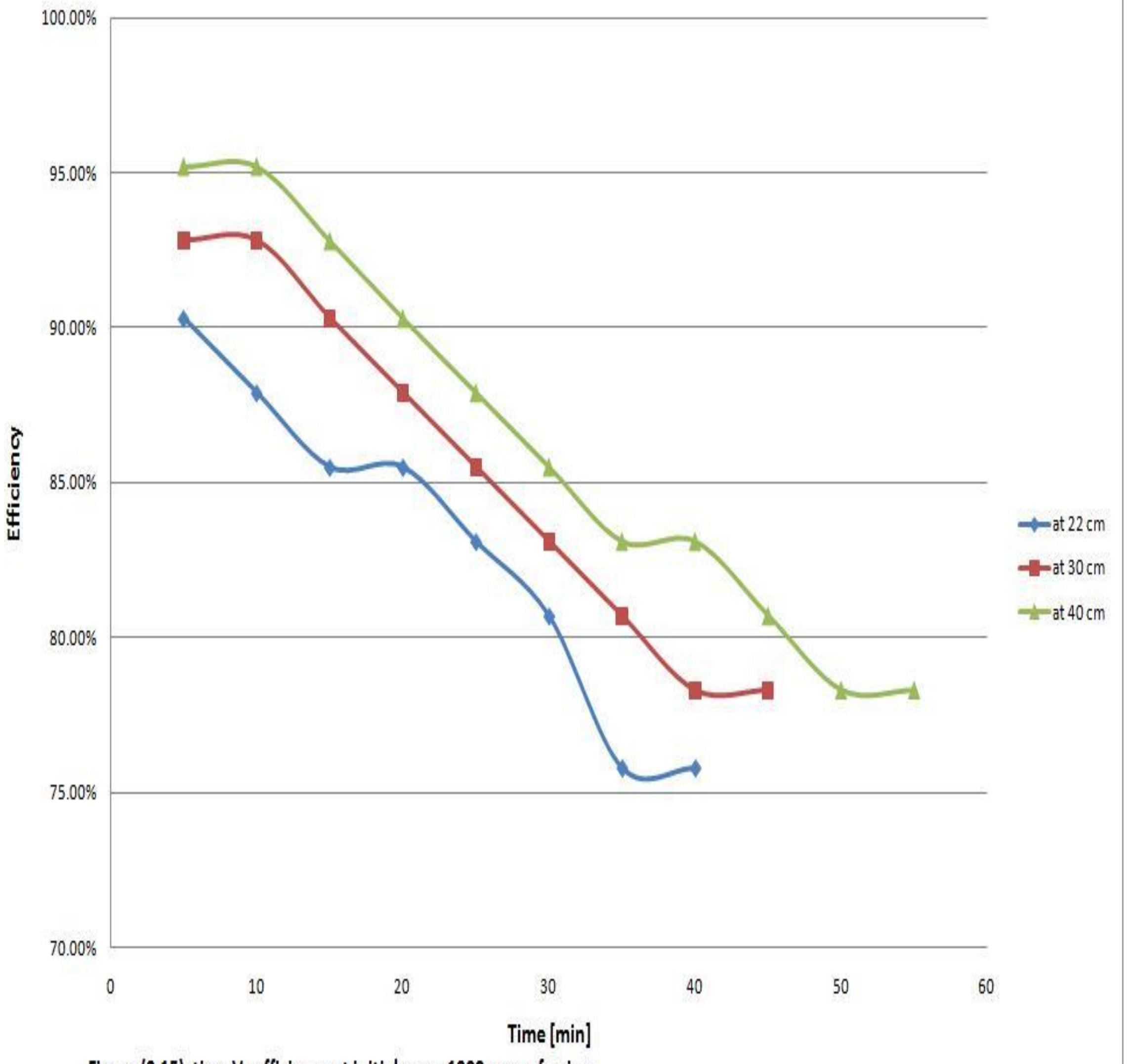

Figure (3.15): time Vs efficiency at initial conc. 1200 ppm of anion

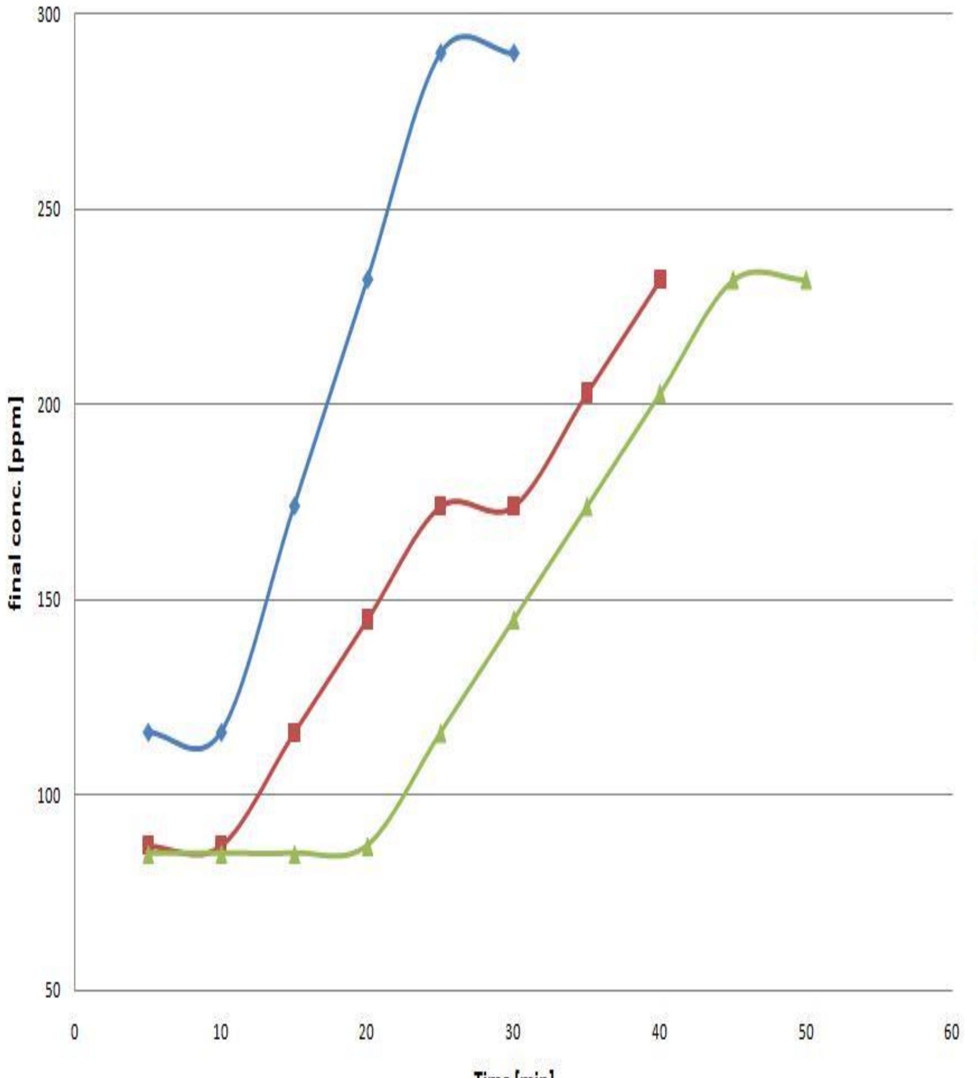

Figure (3.16): time Vs final conc. at initial conc. 1600 ppm of anion

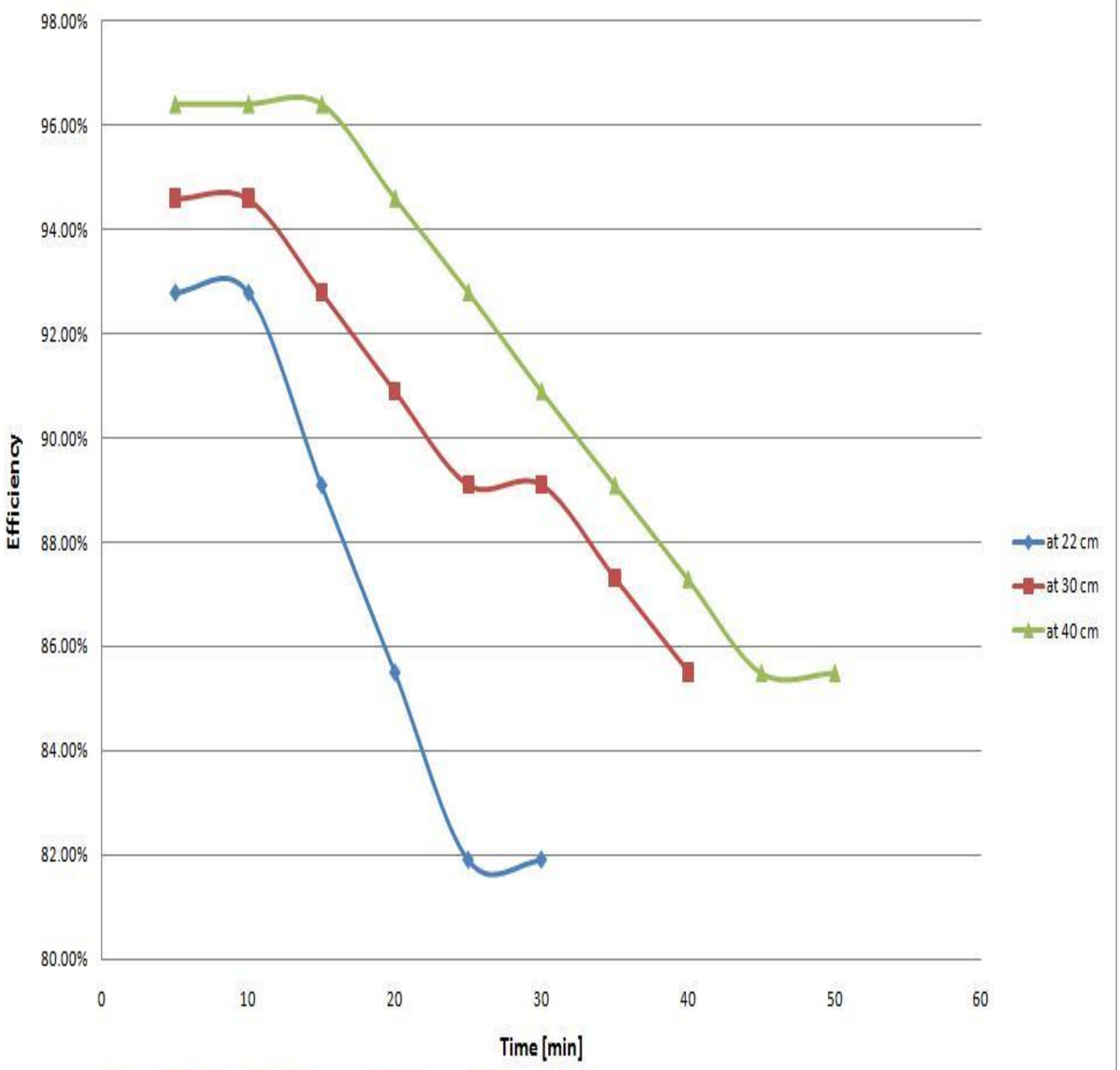

Figure (3.17): time Vs efficiency at initial conc. 1600 ppm of anion

5. DISCUSSIONS

- Figure (3.10) shows that:

When a mixed resin was used at height of 40 cm gave a minimum final concentration during 25 minutes at initial concentration of 1200ppm.

- As can be seen from Figure (3.11):

When a mixed resin was used at height of 40 cm, the efficiency was equal to 95.2% during 25 minutes at initial concentration of 1200ppm.

- Figure (3.12) shows that:

When a mixed resin was used at height of 40 cm, it gave a minimum final concentration during 20 minutes at initial concentration of 1600ppm.

- As can be seen from Figure (3.13):

When a mixed resin was used at height of 40 cm, the efficiency was equal to 92.8% during 25 minutes at initial concentration of 1600ppm.

- Figure (3.14) shows that:

When an anion resin was used at height of 40 cm, it gave a minimum final concentration during 10 minutes at initial concentration of 1200ppm.

- As can be seen from Figure (3.15):

When an anion resin was used at height of 40 cm, the efficiency was equal to 95.2% during 10 minutes at initial concentration of 1200ppm.

- Figure (3.16) shows that:

When an anion resin was used at height of 40 cm, it gave a minimum final concentration during 10 minutes at initial concentration of 1600ppm.

- As can be seen from Figure (3.17):

When an anion resin was used at height of 40 cm, the efficiency was equal to 96.4% during 10 minutes at initial concentration of 1600ppm.

- When a comparison between the different heights of the resin, it is clear that:

The greater the height of the resin, the greater the efficiency of the ion exchange process.

- When a comparison between different concentrations within the ion exchange column, it is clear that:

When increasing concentrations of ions in solution exists, the amount of ions that are exchanged decreases and less efficient ion exchange process dominates.

- When a comparison between the anion resin and the mixed resin (cation/anion) is made, it is clear that:

The efficiency of the anion resin is higher than the efficiency of the mixed resin, because the full amount of resin contributes in the process of exchange of the negative ions, while in the mixed resin part of the resin included in the process of exchange of the negative ions, while the other part is not included in this process.

The selectivity coefficient was calculated for the ion exchange process and it was found that the experimental value was within the range of theoretical values, since the experimental value was equal to 14.83 and the theoretical range was in the range (14.29-20), this can be attributed to the accuracy of the calculation of selectivity coefficient.

The separation factor was calculated for the ion exchange process in two methods, in the first method, the value of the separation factor was equal to 0.067 and in the second method, the value was equal to 0.061, the two results were close to each other, as well as the two results were within the range specified in theory, where the theoretical range of this was located between (0.05-0.07).

The Resin capacity was calculated by two methods, as the resin capacity was equal to 4.44eq/kg by the first method and in the second method the resin capacity was equal to 4.1eq/kg, this means that both methods and the two results were quite close to each other.

6. CONCLUSIONS

1. When the volume of resin was increasing the final concentration was decreasing and the efficiency was increasing.
2. The highest efficiency was 96.4% when anion resin was used and the height of resin in the column was equal to 40 cm and the flow rate was equal to 0.12 liter/min.
3. The actual capacity of resin was less than the theoretical capacity.
4. The actual capacity of resin depends on pH, temperature and concentration.
5. Whenever the flow of solution was decreasing to a determined extent; the contact time was increasing, then the efficiency of process was increasing.
6. The selectivity increases generally with higher valence charge.

7. RECOMMENDATIONS

1- Using actual Eshidiya industrial waste water in the experiments.

2- Scale up of the pilot plant to study the fluid dynamics of the process.

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