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Investigation of Interaction of Effecting Factors in Phosphate and Nitrate Removal from Municipal Wastewater by Electrocoagulation Process with RSM Approach

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ABSTRACT: One of the environmental problems of wastewater is the presence of micro and macronutrients, the most important of which is phosphorus and nitrate. Hence, in this study removal of phosphate and nitrate from aqueous solution was conducted using electrocoagulation (EC) processes with Al electrodes. In the present study, an electrocoagulation reactor was used in a laboratory-scale with a volume of approximately 1200 ml equipped with 3 Al-electrode in a size of 5 × 12 cm2 to remove phosphate and nitrate. The effects of operating parameters such as applied voltage, initial pH of the solution, the value of $FeCl_2$ and reaction times were evaluated. The effect of pH and $FeCl_2$ parameters in inlet and facultative ponds were also studied. Also, pH changes in the oxidation process were investigated. Finally, it can be said that phosphate was completely eliminated in facultative and outflow ponds, but due to the low initial concentration of phosphate in the outlet, less voltage (10 V), less time (about 3 minutes), low FeCl2 dosage (0.2 mg/l) and original pH of the solution were applied compared to the facultative pond., 100 % of nitrate in optimum condition (pH=5.5, applied voltage=25 V, FeCl2=0.65 mg/l, time=11.50 min) in output pond has been removed. In the EC process, the electrocoagulation process using an aluminum electrode, as well as it's relatively low cost and simplicity, has a good effect on phosphorus and nitrate removal compared to other methods.

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1. INTRODUCTION

The increase of industrial and agricultural activities and discharging wastewater into the surface water receptor sources leads to a decrease in the quality of these resources [1]. The use of water containing nitrate over allowable levels can lead to problems such as blue baby syndrome, methemoglobinemia in children and the incidence of cancer in adults [2]. In recent years, electrocoagulation has been successfully used in wastewater treatment. Asheesh Kumar et al. [3], in their study, showed that it is possible to remove the various pollutants from combinatory wastewater with the mentioned method. The purpose of this research is to investigate the efficiency of electrocoagulation process to remove phosphate and nitrate as water pollutants from urban wastewater in Sabzevar city.

2. MATERIALS AND METHODS

Electrolysis is carried out in a glass container of 1200 ml volume using three aluminum electrodes with 5×12 cm^2

Table 1- Equations for the percent of phosphate and nitrate removal in the effluent

Response	Modified equations or meaningful variables	R^2	adjusted-R^2	Predicted-R^2	Adeq. Precision	Std.Dev	Mean	C.V%
Percentage of Phosphate removal	+99.91+3.06A+2.70B +5.14C -4.84D+1.36AB +1.29AC-2.84AD-5.08BC +4.79BD+4.72CD-6.13A $-0.028B^2-2.45C^2+1.73D^2$	0.648	0.32	-1.2792	5.845	11.6	94.6	12.27
Percentage of nitrate removal	+97.15 -4.11 A -4.13 B +4.79C+8.56 D -4.98 AB +3.59AC9.33AD+4.57BC+1.07BD-0.12CD+0.52$B^2$23.66C^2-3.87D^2	0.9242	0.8484	0.3028	11.696	7.59	81.59	9.3

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dimensions connected to the power supply in parallel (with the positive electrode at the center and the negative electrodes at the sides). The effective contact of each electrode with the wastewater and the distance between electrodes were 50 cm^2 and 4 cm respectively. The variables involved in the experiment and the range of their values are determined by independent tests and introduced to the Design Expert software. According to the data, the software has suggested 30 runs. After the runs, the responses are re-entered into the software and the software performs the statistical analyzes and interactions of the variables. By calculating the percentage of removal for each test at a specified equilibrium time, values were entered into the software to provide statistical analysis and optimization of the observations. Finally, as seen in Table 1, modeling of the variables and modified equations was performed by the software to determine the amount of phosphate and nitrate removal.

3. RESULT AND DISCUSSION

3.1. Effect of pH, contact time, $FeCl_2$ and voltage on removal of phosphate in the effluent pond using electrocoagulation method

As Fig. 1 shows, the efficiency of removal is increased by increasing the input voltage. In the electrocoagulation method, the best results are obtained to remove nitrate in the pH range of 5.5, but increasing the pH to a range of 8 (initial pH of the wastewater) reduced the removal rate (figure not shown).

As this can be due to the presence of anionic compounds in the wastewater, which will be more soluble in acidic pH. Anionic compounds transformed into the negative ions in the higher pH values and can be deposited more. By increasing the pH to 10.5, the increase in alkalinity of the medium causes the sediment of $Al(OH)_3$ to be soluble and the efficiency of removal decreases [2].

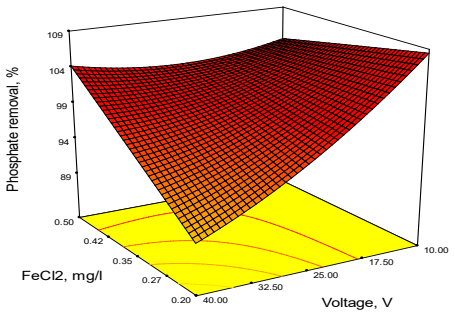

Fig. 1. The effect of the interaction of $FeCl_2$ and voltage (A) and the interaction of time and voltage (B) in the removal of phosphate from effluent pond

3.2. Effect of pH, contact time, $FeCl_2$ and voltage on removal of nitrate in the effluent pond using electrocoagulation method

According to Fig. 2, the increment of phosphate removal efficiency occurs at higher voltages and reaction times so that the maximum removal efficiency in removing 100% phosphate has been obtained in reaction time of 3 minutes, an input voltage of 10 V, pH of 8 and $FeCl_2$ of 0.2 mg/l and the maximum removal efficiency has been obtained in reaction time of 11.51 minutes, voltage of 25 V, pH 5.5 and $FeCl_2$ of 0.65 mg/l for removal of 100% of nitrate.

3.3. Effect of pH and $FeCl_2$ on phosphate and nitrate removal in an anaerobic and facultative pond by electrocoagulation method

The best removal efficiency in an anaerobic pond for phosphate in pH=5.5, $FeCl_2$ dosage of 0.5 mg/l with removal percentage of 98.93% and for nitrate in pH=5.5, $FeCl_2$ dosage of 0.35 mg/l with removal percentage of 91.43% has been obtained. Also, the best efficiency in facultative pond has been achieved for phosphate in pH of 5.5 and $FeCl_2$ dosage of 0.35 mg/l with the removal of 100% and nitrate in pH value of 5.5 and $FeCl_2$ dosage of 0.35 mg/l with removal of 97.44%.

4. CONCLUSION

With increasing the input voltage, the removal efficiency is increased. The most important reason for the further removal of nitrate and phosphate by increasing the input voltage intensity can be attributed to the increase in the amount of oxidized iron in the electrochemical process and the further production of $Fe(OH)_3$ hydroxide sediments and flocks to remove pollutants. Also, the high efficiency of the

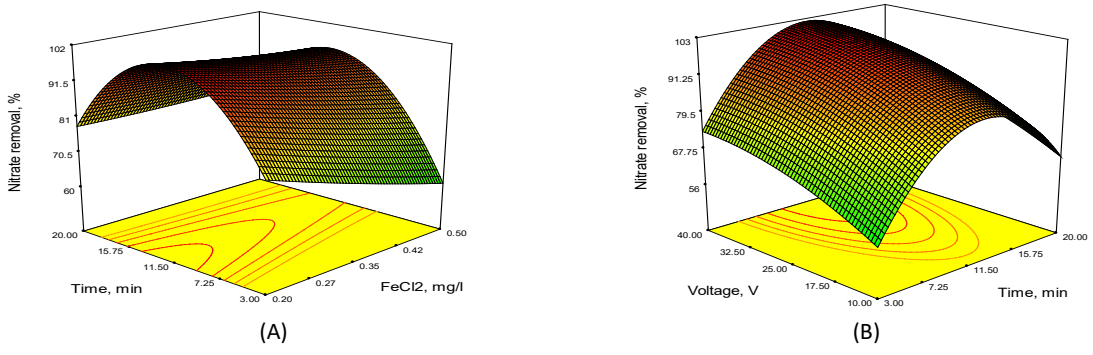

Fig. 2. The effect of the interaction of $FeCl_2$ and time (A) and the interaction of time and voltage (B) in the removal of nitrate in the effluent pond

electrocoagulation process in alkaline media can be assigned to the reaction between iron metal and hydroxide ion. The results of this study and similar researches indicate that it is possible to use the electrochemical methods to design wastewater treatment systems.

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