

Effect of Coagulants on Electrochemical Process for Phosphorus Removal from Activated Sludge Effluent

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Abstract

According to Environmental Protection Organization of Iran, maximum permissible concentration of residual phosphorus in treated municipal wastewater is 1 mg/l-P. The total average phosphorus concentration in raw municipal wastewater is about 8 mg/l; about 70 percent of the incoming phosphorus normally is discharged with secondary treatment plant effluents. In this research, the role of adding different kinds of coagulants on phosphorus removal efficiency of an electrochemical process was investigated. The research is a bench scale experimental type using batch system for elec. process with direct current. Samples were collected from an extended aeration effluent. The used electrode was steel type and its total effective area was 336 cm². In each run 1500 ml of sample was placed in an electrolytic cell equipped with magnetic stirrer. The results show that phosphorus removal efficiency increases by increasing of DC and reaction time. Minimum rate of current/percentage of removal was obtained for 0.6amp current and under the same conditions minimum rate of reaction time/percentage of removal was provided in 15 min. In 6min reaction time and 0.6amp current, adding poly aluminum chloride (PAC) up to about 27 mg/l could improve the efficiency up to about 50%. But under the same condition, similar results were not observed in 12min reaction time. Besides, adding alum or ferrous sulfate showed similar behavior to PAC.

Electrochemical treatment without addition of coagulants and thereby without any changes on the primary characteristics of the sample can remove the phosphorus up to about 93%. But in the case of sufficient reaction time for electrochemical process, adding coagulants can not improve the efficiency and in comparison to a chemical precipitation alone, the use of electrochemical treatment can not reduce the required doses of coagulants in short reaction time.

Keywords: *Phosphorus, Electrochemical process, Wastewater, Coagulants, PAC*

Introduction

According to Environmental Protection Organization of Iran, maximum permissible concentration of phosphorus in treated municipal wastewater for discharge is announced to be 1mg/l (1). Like nitrogen, P is a nutrient for micro and macroscopic plants thus it has important role in creating eutrophication of surface waters (2). The average concentration of total P in raw municipal wastewater is 8mg/l, about 10% of it, is removed in primary sedimentation and the other 10-20% in biological treatment, so the remainder 70% is often discharged by secondary effluent (3). Common forms of P in

wastewater are orthophosphate (PO₄⁺³), polyphosphates and phosphates bonded to organic compounds. The last compounds release orthophosphate in aqueous solution too (4). Nearly all the P-content of wastewater and natural waters may appear as phosphate (5). It is obvious that advanced wastewater treatment facilities have to be employed to meet the discharge standard of P. The number of these facilities has increased considerably from the beginning of 1970s (6). There are various methods for P-removal but electrochemical method that is a valuable alternative has been used less. Indeed, this method has been used successfully in the treatment of phenol

containing wastewaters, rinse water of electroplating, Cr & Zn removal from water destined for cooling towers and destabilization of colloidal suspensions (7-10). Also, this method has proved to have good efficiency in electrochemical reduction of halogenated compounds by using graphic electrode (11). In the treatment of wastewater from olive oil factories, E oxidation can reduce both the COD and sodium chloride to 500mg l^{-1} from the initial concentrations of 20000 and 7000 mg l^{-1} and thereby decrease the dilution ratio about 40 times (12). This method is also very effective in color and CODs removal from textile wastewater in 8-10 min reaction times and with less pH dependency (13). Another study indicates that the efficiency of this system is about 85-92% for COD and 85% for DOC removal from textile wastewater (14). Besides, it has reported for a novel electrolytic process using ionic electrode to be effective for phosphate recovery on anode surface (15). In this study, the role of coagulant addition on electrochemical p – removal from effluent of an activated sludge system has been investigated.

Materials and Methods

This research is a bench scale experimental type study, using a batch system of electrochemical process with direct current electricity. Cathode and anode were each made of 4 steel pieces, 1.5 cm apart and submerged in wastewater sample.

An ammeter and a voltmeter controlled the power input for this system. In each run, 1500 ml sample was poured in the electrolytic cell equipped with magnetic stirrer. The total effective area of used electrodes was 336 cm^2 . (Figure 1) shows the sectional view of the electrolytic cell and other equipment used in this study as follows:

1. Adjustable D.C. power supply in the range of 0-40 ampere coupled with an A.C. /D.C adaptor
2. Industrial type digital ammeter/voltmeter
3. Paraleled anodes (steel pieces)
4. Paraleled cathodes (steel pieces)
5. Magnetic bar stirrer
6. Mechanical sampling valve
7. P.G. vessel (3 litter max)
8. Digital magnetic stirring controller 0-300 rpm

Fig. 1: Sectional view of the employed electrolytic cell

For avoid adjust, pH, temperature and electrical conductivity of effluent, the initial values of these parameters were not changed. The total phosphorous of all samples has been determined according to the ascorbic acid method as outlined in Standard Methods (5). The reaction time was at first 10 min and steel electrode had been employed for optimum electrical current determination. For the second stage, the effect of reaction time on P- removal had been examined using the determined optimum current (0.6 amp). Besides, the effect of coagulant

addition [$\text{Al}_2(\text{SO}_4)_3$, $18\text{H}_2\text{O}\text{-FeSO}_4$, $7\text{H}_2\text{O}$] and PAC (poly aluminum chloride) had been investigated separately for reaction times of 6 and 12 minutes.

Results

Concentrations of total Phosphorus after electrochemical processes on different electrical currents presented in table 1. In this step the other conditions were same for all runs.

Table 1: concentrations of T.P after Electrochemical Process on different electrical currents

| E.C. Process Characteristics sample | Reaction time (sec) | Electrical current (mamp) | Residual Phosphorous (mg /l) | Phosphorous removal % |
|--|-----------------------------|----------------------------------|-------------------------------------|------------------------------|
| A.S. effluent | - | - | 5.95 | 0.00 |
| Run 1 | 600 | 300 | 4.14 | 30.42 |
| Run 2 | 600 | 600 | 1.69 | 71.60 |
| Run 3 | 600 | 1200 | 0.88 | 85.21 |
| Run 4 | 600 | 3600 | 0.44 | 92.61 |
| Run 5 | 600 | 5100 | 0.42 | 92.94 |
| Run 6 | 600 | 12000 | 0.41 | 93.11 |

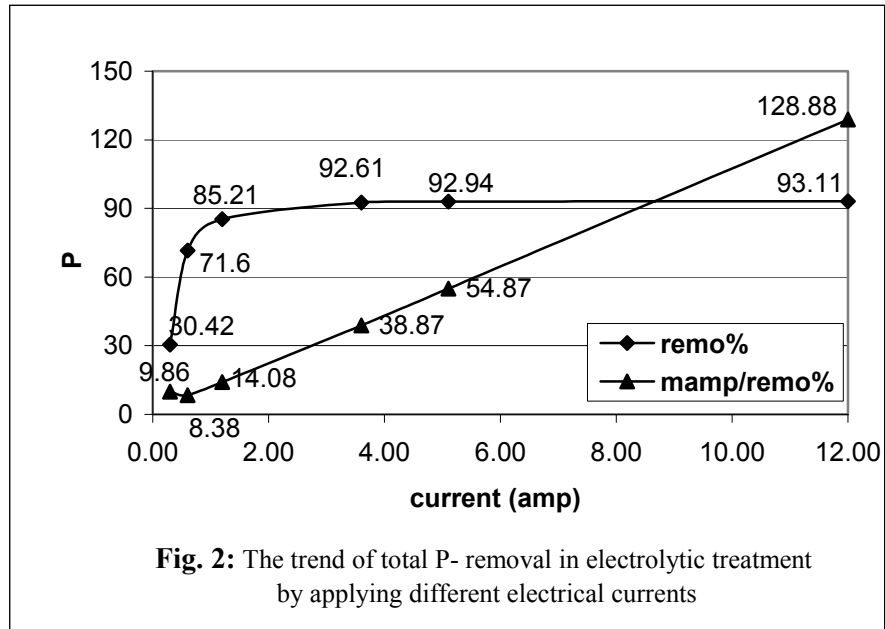


Fig. 2: shows the percentages of P- removal versus electrical current in 10 min reaction time. As it is shown, removal efficiency for phosphorous can be improved by increasing electrical current. The minimum ratio of current to 1% P- removal could be gained by imposing 0.6 amp current.

Table 2: shows concentrations of T.P after electrochemical process on different reaction times.
Table 2-concentrations of T.P after Electrochemical Process on different reaction times

| E.C. Process Characteristics sample | Reaction time (sec) | Electrical current (mamp) | Residual Phosphorous (mg /l) | Phosphorous removal % |
|-------------------------------------|---------------------|---------------------------|------------------------------|-----------------------|
| A.S. effluent | - | - | 5.37 | - |
| Run 1 | 1800 | 600 | 0.65 | 87.90 |
| Run 2 | 1500 | 600 | 1.60 | 70.20 |
| Run 3 | 1200 | 600 | 1.90 | 64.62 |
| Run 4 | 900 | 600 | 1.93 | 64.06 |
| Run 5 | 600 | 600 | 3.43 | 36.13 |
| Run 6 | 300 | 600 | 5.34 | 0.56 |

The changes in total P- removal efficiency versus reaction time can be seen in figure3.

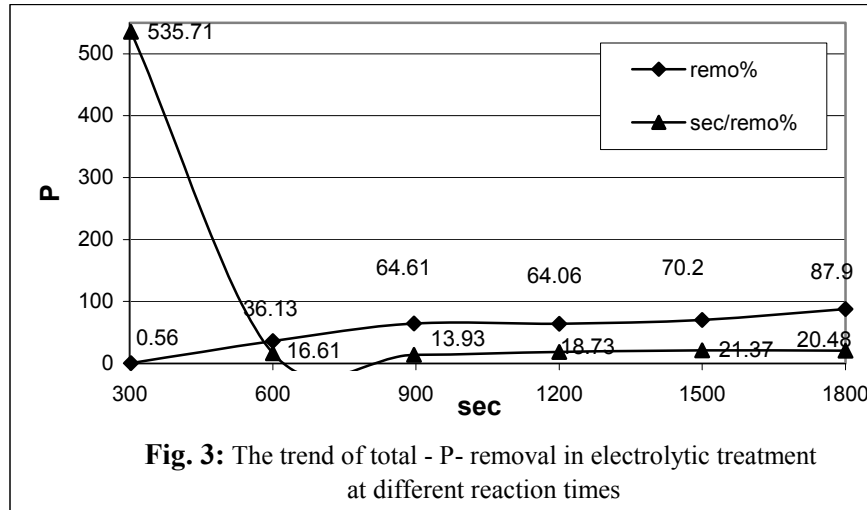


Fig. 3: The trend of total - P- removal in electrolytic treatment at different reaction times

According to this figure, the minimum ratio of reaction time to 1% P- removal is belonging to 15 min reaction time. Besides, P-removal efficiency is improved by increasing the time of reaction and about 88% removal could be achieved in 30 minutes. (Table3) represents

concentrations of T.P after electrochemical process on different PAC doses for two reaction times of 6 and 12 minutes. The effect of increasing PAC dose on P- removal efficiency can be seen in figure 4 for above reaction times.

Table 3: concentrations of T.P after Electrochemical Process on different PAC doses

| Phosphorus Concentration | Total Phosphorus remained (mg/l-P) | |
|--------------------------|------------------------------------|-----------------------|
| | 6min.reaction time* | 12min.reaction time** |
| PAC doses (mg/l) | | |
| 0.00 | 1.49 | 0.56 |
| 3.33 | 0.88 | 0.53 |
| 6.67 | 0.75 | 0.53 |
| 13.33 | 0.64 | 0.56 |
| 26.67 | 0.57 | 0.49 |

*Initial T.P con. of effluent=1.89mg/l-P

**Initial T. P con. of effluent=2.30mg/l-P.

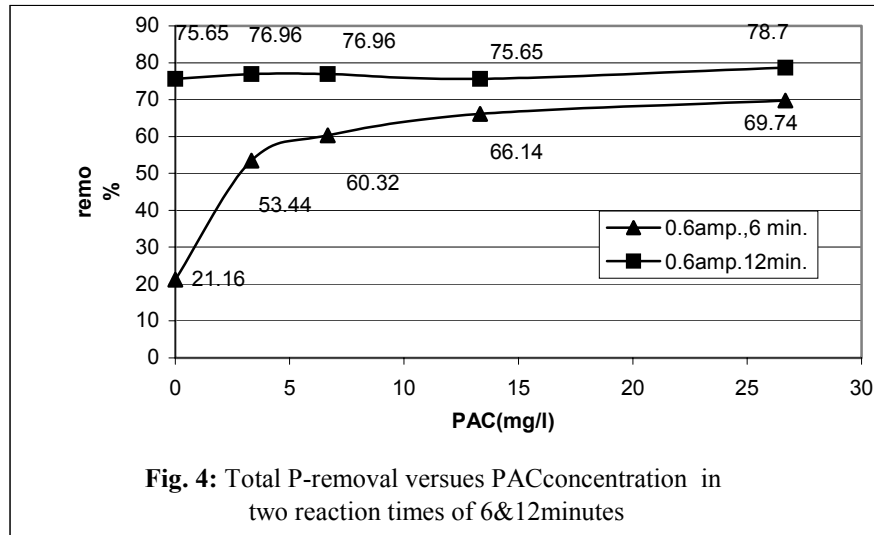


Fig. 4: Total P-removal versus PAC concentration in two reaction times of 6&12minutes

In reaction time of 6 min, 27 mgL⁻¹ PAC additions, can improve the efficiency of P-removal up to 50%, but similar improvement cannot be gained in 12min. Tables 4 – 5 show the concentrations of T.P after electrochemical process on different alum and ferrous sulfate

doses respectively. Finally, figures 5 and 6 shows the effects of alum and ferrous sulfate feeding on P- removal efficiency. Again, both of these coagulants have a relatively similar behavior to PAC electrochemical process.

Table 4: concentrations of T.P after Electrochemical Process on different Alum doses

| Phosphorus Concentration | Total Phosphorus remained (mg/l-P) | |
|--------------------------|------------------------------------|-----------------------|
| | 6min.reaction time * | 12min.reaction time** |
| Alum doses (mg/l) | | |
| 0.00 | 1.49 | 0.5 |
| 21.78 | 0.98 | 0.53 |
| 43.56 | 0.67 | 0.54 |
| 87.11 | 0.65 | 0.48 |
| 174.22 | 0.64 | 0.49 |

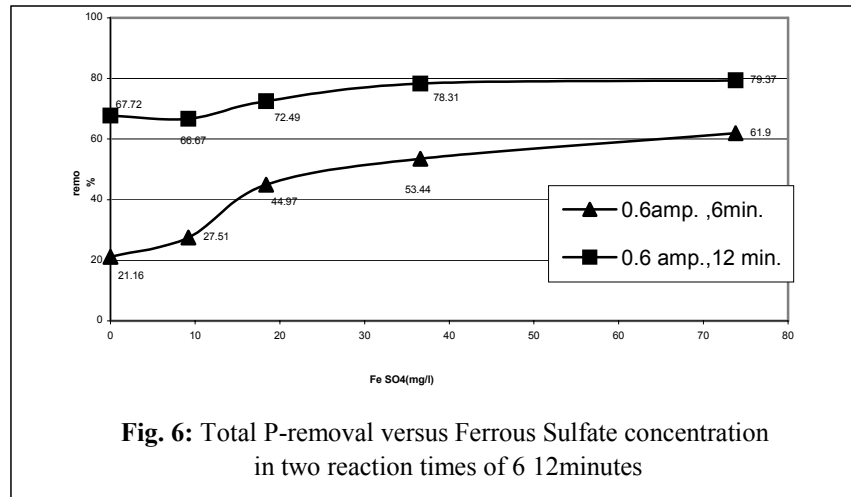
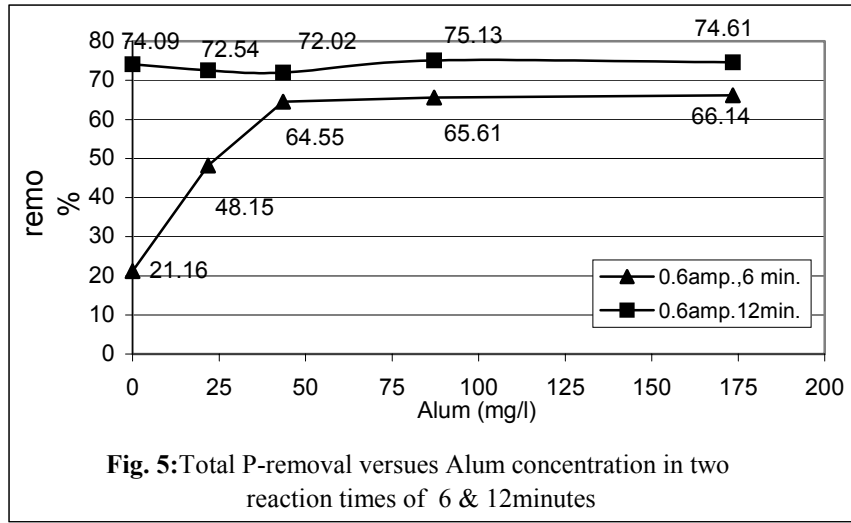
*Initial T.P con. of effluent=1.89mg/l-P

**Initial T.P con. of effluent=1.93mg/l-P

Table 5: concentrations of T.P. after Electrochemical Process on different Ferrous Sulfate doses

| Phosphorus Concentration | Total Phosphorus remained (mg /l-P) * | |
|------------------------------|---------------------------------------|---------------------|
| | 6min.reaction time | 12min.reaction time |
| Ferrous sulfate doses (mg/l) | | |
| 0.00 | 1.49 | 0.61 |
| 9.2 | 1.37 | 0.63 |
| 18.4 | 1.04 | 0.52 |
| 36.8 | 0.88 | 0.41 |
| 73.8 | 0.72 | 0.39 |

*Initial T. P con. of effluent=1.89mg/l-P



Discussion

Results of this study have indicated that the use of coagulant has no special advantage for electrochemical process of P-removal. Equal amounts of coagulants cannot improve P-removal efficiency in a same rate. Besides, and as it is seen in figure2, electrochemical treatment by itself can remove about 93% of P-content of effluent without need to change the initial characteristics of effluent samples. This consequence is similar to the result of the study conducted by J Naumczyk (14). The minimum ratio of electrical current to 1% P-removal could be achieved at 0.6amp and the corresponding current density in this case is 1.78 m amp/ cm².

According to figure 3 for this current density, the minimum reaction time for 1% P-removal is achieved when the reaction time is about 15minutes. The P-removal efficiency in this case is about 65%. So these conditions are not favorable to reduce P in excess of 5.6 mgL⁻¹ (3) in the effluent to the discharge standard. According to Peng and SH Lin (13), the efficiency of electrochemical process in COD removal can be increased from 21% to 56% by 40 mgL⁻¹ PAC addition. Figure 4 shows that by addition of 27 mgL⁻¹ PAC. P-removal efficiency has improved about 50% at the current density of 1.78 m amp/cm² (corresponding to 0.6 amp) and

in 6 minute reaction time, but this dose not suffice to meet the discharge standard, and has not a considerable effect on P-removal at 12 min reaction time (The increase in efficiency is only about 3%). In addition, results of treatment by the 2 other coagulants were relatively similar to PAC. As the gradient of P- removal is not constant versus coagulant concentration, the mentioned difference is not unsound. With the regard to the mentioned benefits for PAC (16) comparing results of PAC treatment with other coagulants indicates that PAC as it is expected is superior.

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