

## Polyphosphate Removal from Synthetic Wastewater by Electrochemical Process

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**Abstract.** The effect of Electrochemical Process (EC) on polyphosphate alone has not been yet investigated. Hence, this research was carried out experimentally on 50 samples of Synthetic Wastewater (SW). In each run 2000 ml of SW took place in a batch. A constant 600 mA Direct Current (DC) was applied on the batch content through steel electrodes. First synthetic wastewater samples with initial concentrations in the range of 2-16 mg L<sup>-1</sup>-P were examined and one sample was taken every 2 minutes during 12 minutes. Then samples in the range of 2 to 32 mg L<sup>-1</sup>-P were tested and one sample was taken every 10 minutes during 1 hour. Residual Phosphorous in taken samples was measured according to Standard Methods book. The removal efficiency was 85-99.85 percent. Residual Phosphorous concentration was reduced below 1mg L<sup>-1</sup>-P (Iranian standard) in 1.15 mA cm<sup>-2</sup> DC. The needed reaction time was 10 min. for 2-16 mg L<sup>-1</sup>-P initial concentration whereas at higher concentrations it was 30 min. Also, the reaction was first order with respect to the residual Phosphorous concentration.

**Keywords:** Wastewater, Phosphorous, Electrochemical process, Polyphosphate

### 1. Introduction

Phosphorous compounds including orthophosphate, polyphosphate and organically bounded phosphorous can get into the water bodies by many ways such as, domestic and industrial wastewater also precipitation, natural storm water and application of manufactured fertilizers. High levels of polyphosphate can be found in some industrial wastewater especially in fertilizer mills [1-3]. Phosphorous compounds along with nitrogen can be led to alga bloom in water bodies which it will result in eutrophication [4-7].

Phosphorous must be reduced below standard levels (usually 0.5-1 mg L<sup>-1</sup>-P) for elimination of eutrophication. One mg L<sup>-1</sup>-P has been set by Environmental Protection Organization of Iran as phosphorous standard level in effluents [2-7]. Phosphorous removal from municipal and industrial wastewater has received more attentions since 1960. Various processes such as Physical, biological and chemical have been practiced for this purpose while every method has its advantages and disadvantages [5, 8-10]. Physical methods consist of filtration, ultra filtration, reverse osmoses, ion-exchange and electro dialysis. Some of these methods are expensive and/or inefficient [10-12]. The maximum phosphorous removal in biological wastewater treatment processes is about 30%. Thus, additional treatment may be required. Chemical processes have some disadvantages for example too much usage of chemicals, more complex feeding equipment, and more operation and maintenance difficulties and/or costs [3].

Electrochemical is a progressive process that has recently received much attention because of its simplicity, selectivity, less reaction time and sludge production as well as lack of feeding equipment. Also, it is a simple multipurpose process that needs less space, and technology is well-matched to it [13]. Some studies have been carried out on phosphorous removal from wastewater by EC. For example application of this process on activated sludge effluent by steel electrodes showed that 600 mA direct current reduced the

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initial 5.37 mg L<sup>-1</sup>-P total phosphorus to 0.65 (87.90% removal) and 0.37(93.11% removal) after 30 and 60 minutes as respectively [13]. Also, adding some coagulants to electrochemical process could not improve the phosphorous removal from activated sludge effluent [3].

Another study showed that EC in combination with ozone could remove more than 91% of total phosphorous from municipal wastewater [14]. The optimum conditions of pH, Electric-Current Density and type of electrodes as well as initial concentration of Phosphorous was investigated in 2006 [7, 15].

Furthermore, remediation of phosphate-contaminated water by electro coagulation with aluminum, aluminum alloy and mild steel anodes has been investigated [16]. The efficiency of phosphate removal from aqueous samples (with 16 mg L<sup>-1</sup>-P initial concentration) in electro-coagulation process has been reported 95 percent [17]. However, the effect of EC on Polyphosphate alone has not been yet investigated. Thus, this research was aimed to study polyphosphate removal from SW by electrochemical process.

## 2. Materials and Methods

This is a bench scale experimental research which was carried out in a batch system on synthetic wastewater samples of polyphosphate. The initial concentrations of polyphosphate were 2, 4, 8, 16, 24, and 32 mg L<sup>-1</sup>-P. For preparation of synthetic wastewater adequate sodium hexa-meta phosphate salt were added to raw ground water. The electro conductivity of the ground water was measured 2070 micro mhos/cm and its total dissolved solid was about 1242 mg L<sup>-1</sup>. The natural pH of the raw water and its temperature were 7.2 and 21 °C respectively. Total and Calcium Hardness were measured 516 and 318 mg L<sup>-1</sup> as CaCO<sub>3</sub> respectively. Total phosphorous in the raw water was measured 0.049 mg L<sup>-1</sup>-P.

In each run 2000 ml of SW sample with expected concentration took place in an electrolytic cell and 600 mA direct current applied on it. Cathodes and anodes were made of eight steel plates with 2 mm thickness; 2.5 cm width and 15 cm length which 13 cm of them was merged in under research SW samples. The Distances between electrodes were 1.5 cm. A digital ammeter/voltmeter was applied for input power control. The wastewater in the electrolytic cell was mixed by a 300 rpm magnetic stirrer during the electrochemical process. All runs were performed at laboratory temperature (about 20 °C).

In the first step, the process was practiced on synthetic wastewater samples in the range of 2-16 mg L<sup>-1</sup>-P for maximum 12minutes reaction time and one sample was taken every 2 minutes for residual phosphorus measurement. Based on results from the first stage in the next, synthetic wastewater samples in the range of 2-32 mg L<sup>-1</sup>-P were studied. The maximum reaction time was increased to 60 minutes and one sample was taken every 10 minutes and its residual phosphorous was measured. In the both stages, for each expected concentration five different synthetic wastewater samples were prepared and the process was applied on them.

Table 1: mean of residual P in the 2-16 mg L<sup>-1</sup>-P initial concentration samples during 0-12 min. reaction time

Reaction Time (min.)	Initial Concentration (mg/L-P)			
	2 (n=5)	4 (n=5)	8 (n=5)	16 (n=5)
0	<b>2.05±0.07</b>	<b>4.04±0.10</b>	<b>8.02±0.07</b>	<b>15.86±0.52</b>
2	<b>1.84±0.05</b>	<b>1.83±0.08</b>	<b>7.69±0.13</b>	<b>12.06±0.68</b>
4	<b>1.03±0.16</b>	<b>1.18±0.11</b>	<b>3.66±0.05</b>	<b>8.43±0.13</b>
6	<b>0.57±0.05</b>	<b>0.73±0.04</b>	<b>0.94±0.10</b>	<b>3.46±0.05</b>
8	<b>0.38±0.20</b>	<b>0.38±0.02</b>	<b>0.69±0.01</b>	<b>2.82±0.11</b>
10	<b>0.29±0.04</b>	<b>0.33±0.02</b>	<b>0.63±0.01</b>	<b>0.86±0.02</b>
12	<b>0.24±0.06</b>	<b>0.27±0.02</b>	<b>0.57±0.02</b>	<b>0.74±0.02</b>

In the laboratory analysis for residual Phosphorous measurement, first, every sample was digested according to 4500-P.B. instruction in the Standard Methods for Examination of Water and Wastewater book.

Then, residual phosphorus was measured by 4500-P.D. instruction in the same book [18]. Whenever, residual phosphorous was reduced below  $1\text{ mg L}^{-1}\text{-P}$ , it was interpreted as phosphorous removal. Last, data was statistically analyzed by Repeated Measurement and Anova tests.

### 3. Findings

Table 1 shows the effect of constant 600 mA direct current on SW samples in the range of 2 to  $16\text{ mg L}^{-1}\text{-P}$  during the process. It is obvious that. All of the means of sodium hexa-meta phosphate concentrations were reduced below  $1\text{ mg L}^{-1}\text{-P}$  in 10 minutes reaction time and longer. After 10 minutes reaction time, the minimum efficiency was 85.86% which is related to  $2\text{ mg L}^{-1}\text{-P}$  initial cocentration.

Fig 1 shows the effect of constant 600 mA electrical direct current on removal of polyphosphohate from the SW samples. In this case the initial P cocentrations were in the range of 2-32  $\text{mg L}^{-1}\text{-P}$ . After 30 minutes reaction time the mean of all initial concentrations were reduced below  $1\text{ mg L}^{-1}\text{-P}$ . The maximum efficiency (99.85% removal) was obtained after 60 minutes reaction time when the residual phosphorous was reduced from 2 to  $0.003\text{ mg L}^{-1}\text{-P}$ . The minimum efficiency was 97.66% which was obtained for more than  $16\text{mg/L}$  initial cocentrations after 30 mionutes reaction time.

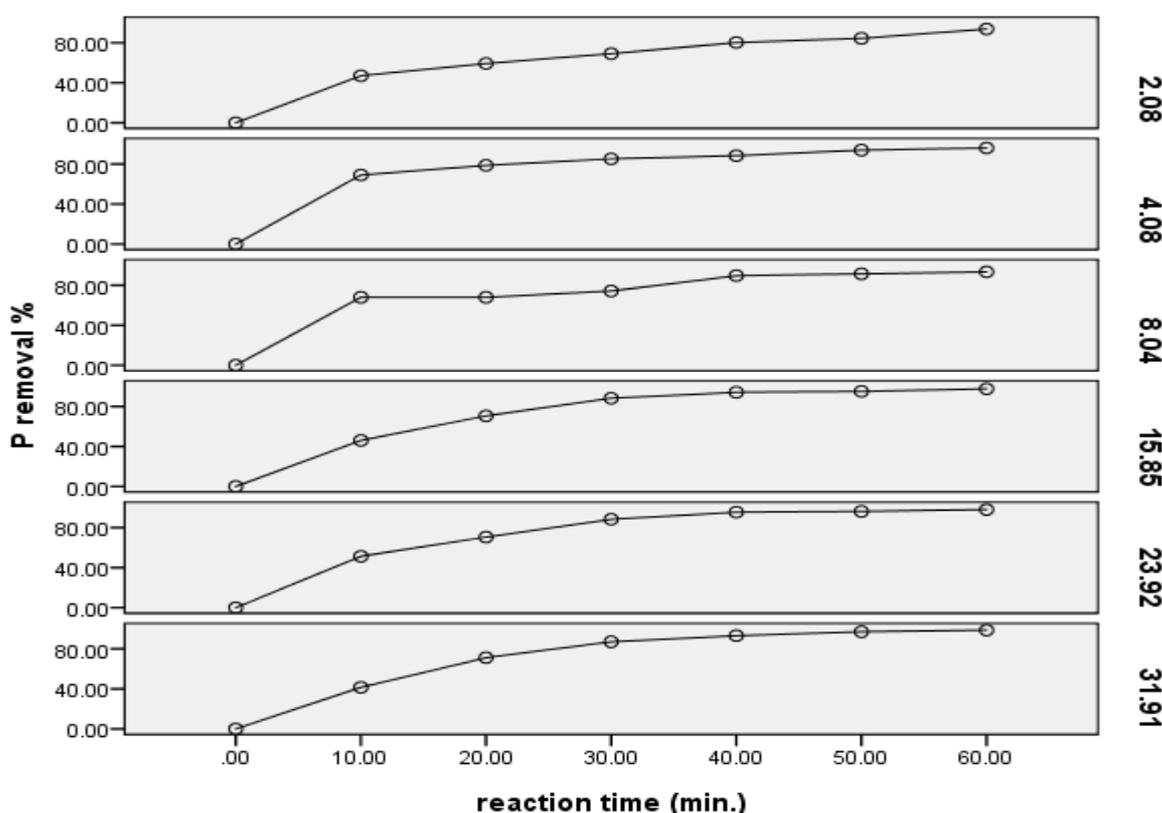


Fig. 1: the simple error bars for polyphosphate removal efficiencies for 2-32  $\text{mg L}^{-1}\text{-P}$  initial concentrations

Fig 2 shows the means of residual polyphosphorus concentrations as a function of reaction time. Also the initial concentrations in this case was 2-32  $\text{mg L}^{-1}\text{-P}$ . It can be seen that the mean of initial concentrations was reduced from  $14.40\text{ mg L}^{-1}\text{-P}$  bellow  $1\text{ mg L}^{-1}\text{-P}$  after 10 minutes.

The semi-log plot of means of residual phosphorous versus reaction time for SW samples with initial concentrations in the range of 2-16  $\text{mg L}^{-1}\text{-P}$  has been shown in fig ( $R^2=0.975$ ). The R square for the samples with initial concentrations in the range of 2-32  $\text{mg L}^{-1}\text{-P}$  and 1 hour reaction time was 0.898 .

### 4. Discussion

Findings showed that the poly phosphate removal by electrochemical process is a first order reaction because the semi-log plot of means of residual phosphorous versus reaction time is a straight line. For initial concentrations between 2-16  $\text{mg/L}$  changes of  $\log C$  versus reaction time was formulated as

Log C=0.921-(0.112T) which T is reaction time in minute ( $R^2=0.975$ ). Also, for initial concentrations between 2-32 mg L<sup>-1</sup> changes of log C versus reaction time was formulated as Log C=0.686-(0.37T), ( $R^2=0.898$ ).

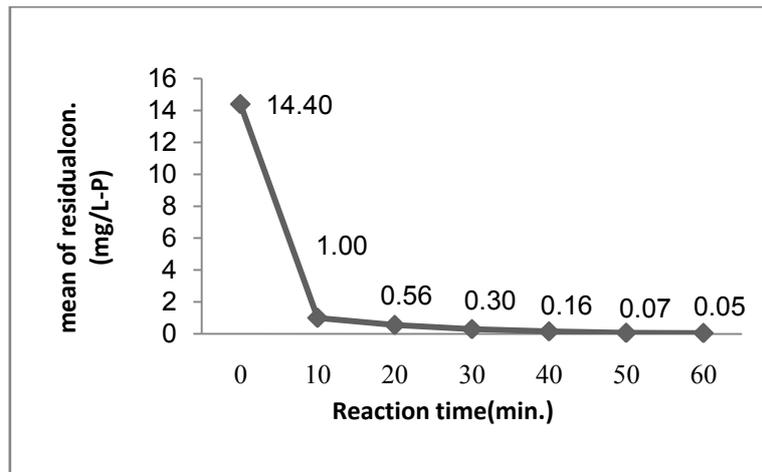


Fig. 3: the mean of residual polyphosphorus as a function of reaction time

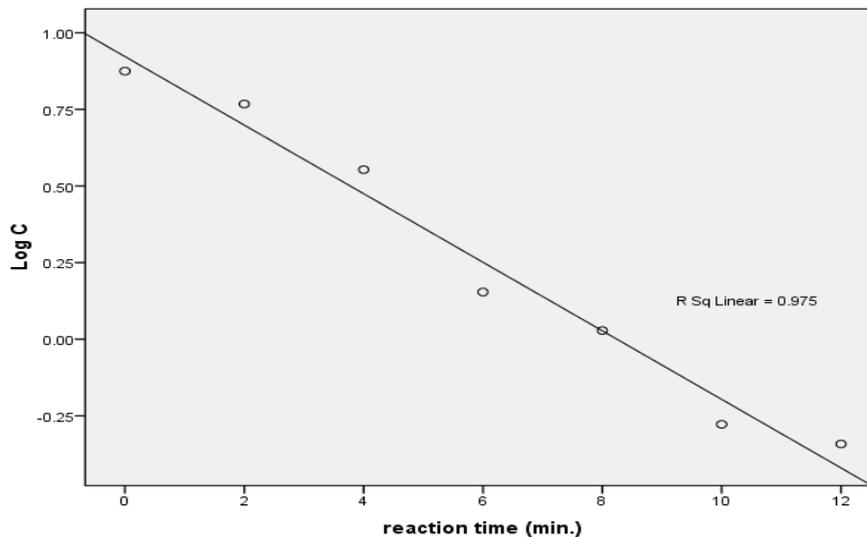


Fig. 2: the Semi-Log Plot of mean of residual P versus reaction time for samples with 2-16 mgL<sup>-1</sup>-P initial con.

In 1.15mA/cm<sup>2</sup> current density this process could decrease the polyphosphate concentrations below 1mg L<sup>-1</sup>-P as Iranian standard. For reduce the remainders below 1mg L<sup>-1</sup>-P there was a meaningful correlation between initial concentrations of polyphosphate and needed reaction time ( $P<0.001$ ). It means that, more initial concentration needs more reaction time. The minimum needed reaction time for 2-16 mg L<sup>-1</sup>-P initial concentrations were 10 min and for more than 16 mg L<sup>-1</sup>-P (up to 32) it was 30 min. Our finding is better than those stated by Mahvi et al because energy consumption is less. They achieved 90.1% phosphorous removal efficiency after 10 minutes reaction time by 50 Volts and 160 A[2].

Also, in this research there was a meaningful relation between reaction time and phosphorous removal efficiency ( $P<0.001$ ). Consequently the phosphorous removal efficiencies were 85% and 99.85% after 10 and 60 min. respectively. The first is compatible with findings of Rabbani et al in 2003[13]. Because, less energy consumption, our findings are better than those were reported by Samarghandi et al in 2009. They have stated that by 20 Volts and 2 hours reaction time, could remove 95% of phosphate from aqueous solution [17]. The maximum Phosphorous removal was 99.85% in this research which, is more than stated by Nelson and Smith. They had shown that electrochemical process in combination with ozone could remove 91% of total phosphorous from municipal wastewater [14].

## 5. Acknowledgements

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## 6. References

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