



# Evaluation of Electrochemical Process on Polyphosphate Removal from the Aqueous Solution

## ARTICLE INFO

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### Authors

Miranzadeh M.B.<sup>1</sup> PhD,  
Dehghan S.<sup>1</sup> MSc,  
Ghadami F.<sup>1</sup> MSc,  
Rabbani D.\* PhD

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## ABSTRACT

**Aims** The effect of electrochemical process on polyphosphate alone has not been yet investigated. The aim of this study was to study polyphosphate removal from synthetic wastewater by electrochemical process.

**Materials & Methods** This research was carried out experimentally on 50 samples of synthetic wastewater. In each run 2000ml of SW took place in a batch. A constant 600mA direct current was applied on the batch content through steel electrodes. First synthetic wastewater samples with initial concentrations in the range of 2-16mgL<sup>-1</sup>-P were examined and one sample was taken every 2min during 12min. Then samples in the range of 2 to 32mgL<sup>-1</sup>-P were tested and one sample was taken every 10min during 1 hour. Residual phosphorous in taken samples was measured according to Standard Methods book.

**Findings** The removal efficiency was 85-99.85%. Residual phosphorous concentration was reduced below 1mgL<sup>-1</sup>-P (Iranian standard) in 1.15mA/cm<sup>2</sup> DC. The needed reaction time was 10min. for 2-16mgL<sup>-1</sup>-P initial concentration whereas at higher concentrations it was 30min. Also, the reaction was first order with respect to the residual phosphorous concentration.

**Conclusion** This process is efficient for removal of the over 99% of poly phosphate from the wastewater and able to reduce the residual phosphorous in effluent to less than Iranian standard limits for reuse ( $\leq 1\text{mgL}^{-1}$ ).

**Keywords** Electrochemical Techniques; Polyphosphates; Waste Water

\*"Social Determinants of Health Research Center" and "Environmental Health Engineering Department, Health School", Kashan University of Medical Sciences, Kashan, Iran  
"Social Determinants of Health Research Center" and "Environmental Health Engineering Department, Health School", Kashan University of Medical Sciences, Kashan, Iran

### Correspondence

Address: Health School, Kashan University of Medical Sciences, Pezeshk Boulevard, 5th Kilometer of Kashan-Ravand-Road, Kashan, Iran. Postal Code: 8715973449  
Phone: +983155540111  
Fax: +983155540111  
rabbani-d@kaums.ac.ir

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[1] Wastewater engineering: Treatment & reuse [2] Study of the efficiency of electrolysis process in phosphorus removal from the wastewater effluent of treatment plants [3] Effect of coagulants on electrochemical process for phosphorus removal from activated sludge effluent [4] Removal of phosphate from aqueous solutions by electro-coagulation [5] Removal of phosphate from aqueous solutions using calcined metal hydroxides sludge waste generated from electrocoagulation [6] The effects of current density and phosphate concentration on phosphate removal from wastewater by electrocoagulation using aluminum and iron plate electrodes [7] Optimization of phosphate removal from wastewater by electrocoagulation with aluminum plate electrodes [8] A comparison between aluminum and iron electrodes on removal of phosphate from aqueous solutions by electrocoagulation process [9] Treatment of the textile wastewater by electrocoagulation: Economical evaluation [10] Enhancing phosphate removal from wastewater by using polyelectrolytes and clay injection [11] Phosphorus removal from wastewater: A literature review [12] Phosphorous and nitrogen removal from municipal wastewater: Principles and practice [13] Effect of electrochemical process on phosphorus removal from activated sludge effluent [14] Ozone-enhanced electroflocculation in municipal wastewater treatment [15] The effect of pH on phosphate removal from wastewater by electro coagulation with iron plate electrodes [16] Remediation of phosphate-contaminated water by electrocoagulation with aluminium, aluminium alloy and mild steel anodes [17] Electrochemical process efficiency for the removal of organic phosphorus from synthetic wastewater [18] Standard methods for the examination of water and wastewater

## 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 0.5-1mgL<sup>-1</sup>-P) for elimination of eutrophication. One mgL<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 it is well-matched to technology [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 600mA direct current reduced the initial 5.37mgL<sup>-1</sup>-P total phosphorus to 0.65 (87.9% removal) and 0.37 (93.1% removal) after 30 and 60min, respectively [13]. Also, adding some coagulants to electrochemical process could not improve the phosphorous removal from

activated sludge effluent [3]. Another study shows 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 16mgL<sup>-1</sup>-P initial concentration) in electro-coagulation process has been reported 95% [17].

However, the effect of EC on Polyphosphate alone has not been yet investigated. The aim of this study was to study polyphosphate removal from synthetic wastewater by electrochemical process.

## Materials & Methods

This is a bench scale experimental research that carried out in a batch system on 50 synthetic wastewater samples of polyphosphate. The initial concentrations of polyphosphate were 2, 4, 8, 16, 24, and 32mgL<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 2070micromhos/cm and its total dissolved solid was about 1242mgL<sup>-1</sup>. The natural pH of the raw water and its temperature were 7.2 and 21°C, respectively. In each run 2000ml of SW sample with expected concentration took place in an electrolytic cell and 600mA direct current applied on it. Cathodes and anodes were made of eight steel plates with 2mm thickness, 2.5cm width and 15cm length which 13cm of them was merged in under research SW samples. The Distances between electrodes were 1.5cm. A digital ammeter/voltmeter was applied for input power control. The wastewater in the electrolytic cell was mixed by a 300rpm 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 2-16mgL<sup>-1</sup>-P for maximum 12min reaction

time and one sample was taken every 2min for residual phosphorus measurement. Based on results from the first stage in the next, synthetic wastewater samples in the range of 2-32mgL<sup>-1</sup>-P were studied. The maximum reaction time was increased to 60min and one sample was taken every 10min 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.

In the laboratory analysis for residual Phosphorous measurement, first, every sample was digested according to 4500-PB instruction in the Standard Methods for Examination of Water and Wastewater book [18]. Then, residual phosphorus was measured by 4500-PD instruction in the same book. Whenever, residual phosphorous was reduced below 1mgL<sup>-1</sup>-P, it was interpreted as phosphorous removal. Last, data was statistically analyzed by Repeated Measurement and Anova tests.

### Findings

Total and Calcium Hardness were measured 516 and 318mgL<sup>-1</sup> as CaCO<sub>3</sub>, respectively. Total phosphorous in the raw water was measured 0.049mgL<sup>-1</sup>-P.

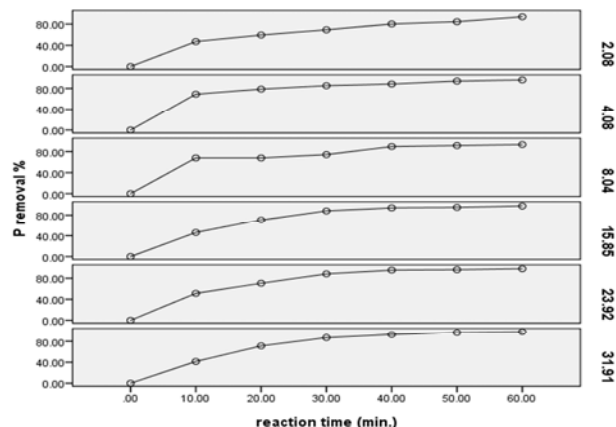
All of the means of sodium hexa-meta phosphate concentrations were reduced below 1mgL<sup>-1</sup>-P in 10min reaction time and longer. After 10min reaction time, the minimum efficiency was 85.86% which is related to 2mgL<sup>-1</sup>-P initial cocentration (Figure 1).

**Figure 1)** The mean of residual P in the 2-16mgL<sup>-1</sup>-P initial concentration samples during 0-12min reaction time (n=5)

Reaction time	2mgL <sup>-1</sup>	4mgL <sup>-1</sup>	8mgL <sup>-1</sup>	16mgL <sup>-1</sup>
0min	2.05±0.07	4.04±0.10	8.02±0.07	15.86±0.52
2min	1.84±0.05	1.83±0.08	7.69±0.13	12.06±0.68
4min	1.03±0.16	1.18±0.11	3.66±0.05	8.43±0.13
6min	0.57±0.05	0.73±0.04	0.94±0.10	3.46±0.05
8min	0.38±0.20	0.38±0.02	0.69±0.01	2.82±0.11
10min	0.29±0.04	0.33±0.02	0.63±0.01	0.86±0.02
12min	0.24±0.06	0.27±0.02	0.57±0.02	0.74±0.02

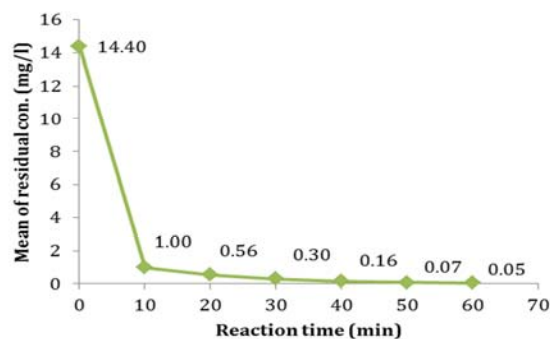
In removal of polyphosphohate from the SW samples the initial P cocentrations were in the range of 2-32mgL<sup>-1</sup>-P. After 30min reaction time the mean of all initial concentrations

were reduced below 1mgL<sup>-1</sup>-P. The maximum efficiency (99.85% removal) was obtained after 60min reaction time when the residual phosphorous was reduced from 2 to 0.003mgL<sup>-1</sup>-P. The minimum efficiency was 97.66% which was obtained for more than 16mgL<sup>-1</sup> initial cocentrations after 30min reaction time (Figure 2).



**Figure 2)** the simple error bars for polyphosphate removal efficiencies for 2-32mgL<sup>-1</sup>-P initial concentrations

Also the initial concentrations in measuring the residual polyphosphorus concentrations as a function of reaction time was 2-32mgL<sup>-1</sup>-P. The mean of initial concentrations was reduced from 14.40mgL<sup>-1</sup>-P bellow 1mgL<sup>-1</sup>-P after 10min (Figure 3).



**Figure 3)** The mean of residual polyphosphorus as a function of reaction time

The semi-log plot of means of residual phosphorous versus reaction time for SW samples with initial concentrations in the range of 2-16mgL<sup>-1</sup>-P has been shown in Figure 3 (R<sup>2</sup>=0.975). The R square for the samples with initial concentrations in the range of 2-32mgL<sup>-1</sup>-P and 1 hour reaction time was 0.898.

## 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 2-16mgL<sup>-1</sup> changes of logC 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 2-32mgL<sup>-1</sup> changes of logC versus reaction time was formulated as  $\log C = 0.686 - (0.37T)$ ; ( $R^2 = 0.898$ ). In 1.15mA/cm<sup>2</sup> current density this process could decrease the polyphosphate concentrations below 1mgL<sup>-1</sup>-P as Iranian standard. For reduce the remainders below 1mgL<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 2-16mgL<sup>-1</sup>-P initial concentrations were 10min and for more than 16mgL<sup>-1</sup>-P (up to 32) it was 30min. Our method is better than those stated by Mahvi *et al* because energy consumption is less. They achieved 90.1% phosphorous removal efficiency after 10min reaction time by 50 volts and 160A [2].

Also, 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 60min respectively. The first is compatible with findings of Rabbani *et al* [13]. Because of less consumption of energy, our findings are better than those were reported by Samarghandi *et al* [17]. They have stated that by 20 Volts and 2 hours reaction time, could remove 95% of phosphate from aqueous solution The maximum Phosphorous removal was 99.85% in this research which, is more than stated by Nelson & Smith [14], they had shown that electrochemical process in combination with ozone could remove 91% of total phosphorous from municipal wastewater.

## Conclusion

The removal of polyphosphates by electrochemical process follows the first order reaction. Also, this process is efficient for

removal of over 99% of polyphosphates from the wastewater and able to reduce the residual phosphorous in effluent to less than Iranian standard limits for reuse ( $\leq 1\text{mgL}^{-1}$ ).

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**Conflict of Interests:** None declared by Authors.

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