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Determining the Reaction Rate of Electrochemical Process for Purification of Polluted Water

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ABSTRACT

Aims Turbidity in higher than standard levels, indicates failure in the water treatment plant. An electrochemical disinfection process takes place through electricity transition between two or more electrodes. This research aimed to determine the reaction rate of electrochemical process for purification of polluted water.
Materials & Methods This is a bench scale, experimental study performed in a batch system on synthetic wastewater. 1700ml of prepared synthetic wastewater was put in an electrolytic cell and constant 600mA current was flowed into the cell content through merged aluminum electrodes for 1 hour. Samples were taken from the batch in the beginning and every 10 minutes and were analyzed for, turbidity, Coliform bacteria (probably, confirmed and E. coli) and Heterotrophic Plat Count. Fisher exact test was used to analyze data.
Findings All the parameters of turbidity, HPC, total coliform, confirmed coliform and E. coli were decreased during the time. The electrochemical process reduced the average of turbidity below 3NTU after 50 minutes (91.05% removal). The HPC number reduced from 130n/ml to 2.4n/ml (98.15% removal) after 50 minutes. No coliforms were seen after 40 minutes of the electrochemical process.
Conclusion 40 minutes of electrochemical process in 600mA by aluminum electrodes is the optimum condition for removing the turbidity, Coliform bacteria (total, confirmed and E. coli) and HPC from polluted water.

Keywords Water; Electrochemical Techniques; Enterobacteriaceae

CITATION LINKS

[1] Environmental engineering laboratory manual for first year engineering students [2] Electrochemical processes for the remediation of wastewater and contaminated soil: Emerging technology [3] Electrochemical treatment of pentachlorophenol in water and pulp bleaching effluent [4] Electrochemical technologies in wastewater treatment separation [5] Electrochemical removal (ECAR) for rural Bangladesh–merging technology with sustainable implementation [6] Removal of cod and turbidity to improve wastewater quality using electrocoagulantion technique [7] A novel electro-chemical process for water treatment [8] Effect of coagulants on electrochemical process for phosphorus removal from activated sludge effluent [9] Electrochemical impedance spectroscopy: An effective tool for a fast microbiological diagnosis [10] Electrochemical coagulation of clay suspensions [11] Removal turbidity and separation of heavy metals using electrocoagulation-electroflotation technique: A case study [12] Electrochemical treatment of industrial wastewater [13] Ground water coagulation using soluble stainless steel electrodes [14] Treatment of chemical mechanical polishing wastewater by electro coagulation: System performances and sludge settling characteristics [15] Efficacy of electrolyzed oxidizing water for inactivating Escherichia coli O157:H7, Salmonella enteritidis, and Listeria monocytogenes [16] Application of direct current to protect bioreactor against contamination [17] Disinfection of water by electrochemical treatment [18] Electrochemical treatment applied to food-processing industrial wastewater [19] Standard methods for the examination of water and Wastewater

Introduction

The size of colloidal particles in aqueous environments is 0.001-1μm and the general settling velocity of a particle with diameter of 0.1μm is 3m in one million years. So, these particles cannot be removed by gravitational force and have to be removed by other processes [1].

In general, water turbidity is due to clay, silt, viruses, bacteria, fulvic and/or humic acids, also from inorganic maters, e.g. asbestos, silicate and radioactive particles. Turbidity renders the water appearance objectionable; in addition, it may shelter microorganisms against disinfection. Also, turbidity in higher than standard levels, indicates failure in the water treatment plant [2, 3].

Application of electricity for water treatment was first considered in Europe in 1889 and electro dialyze was applied first by Elmer for water demineralization in 1904 [4]. An electrochemical disinfection process takes place through electricity transition between two or more electrodes. The main advantage of the process is in site production of a chemical disinfectant [4, 5]. Also, this process has been used for water purification and deionization. Some anions and cations such as sulfate, phosphate, chloride, copper, mercury, lead, nickel and iron, as well as organic compounds, have been removed by this process. In addition, the process improves turbidity, taste and odor [6]. Direct current (DC) electricity and also high and low frequency alternative current (AC) electricity have been used for electrochemical treatment. Different types of electrodes have been used in this process such as graphite, composite, carbon fibers, titanium, stainless still, silver, and aluminum. Sometimes sodium chloride/sodium bromide has been added in order to improve the efficacy. Electrochemical treatment of water destroys a wide range of microorganisms. This process destroys about 40 species of microorganisms in different sizes, e.g. viruses, bacteria and alga [6, 7].

Electrochemical method has some advantages over other methods, e.g. reverse osmoses and ion exchange. Of course, this method has some limitations; for example the necessity of an electrical power supplies [6, 8-10]. Recently, some electrochemical processes have been represented that could remove color, BOD, COD, suspended solids and heavy metals from wastewater simultaneously [11, 12]. Khanniche *et al.* have claimed that their method can remove 99% of heterotrophic plate counts, coliforms, Streptococcus and Pseudomonas from river water samples and eliminate 90% of turbidity from drinking water [7].

Abuzaid *et al.* succeeded to remove about 95% of turbidity by still electrodes and 1Amp electrical current [13]. Also, Lai & Lin electrochemical study for turbidity removal by coupled Fe^{2+}/Al^{3+} electrodes leads to 96.5% reduction before 30 minutes reaction time [14]. Venkitanarayanan *et al.* have reported that electrochemical process in 10v through generation oxidizing agents kills *E. coli* (type H: 0157), *Salmonella enteritis* and *Listeria monocytogenes* [15]. Tokudoa & Nakanishi have applied 60mA direct current to prevent growth of *E. coli*, *Bacillus subtilis*, *Pseudomona aeruginosa* and *Staphylococcus aureus* [16]. Patermarakis & Fountoukidis have utilized a 2.5mA/cm^2 direct current to remove numerous coliform bacteria and fecal Streptococci from natural surface water after a 30 minute reaction time [17]. Mosavian & Rezaie have reported 99.9% removing of fecal coliform by electrochemical process in 5A with steel electrodes [18].

Despite many studies have taken place on electrochemical reduction of turbidity and microbes from polluted water, there is no available report of their reaction rates. So this research aimed to determine the reaction rate of electrochemical process for purification of polluted water.

Materials & Methods

This is a bench scale experimental study, which was carried out on artificially polluted water in a batch reactor in Water and Wastewater Laboratory of Health School of Kashan University of Medical Sciences, Iran.

The synthetic wastewater from the standpoint of turbidity and bacterial contamination took after river raw water quality. Afterwards 1700ml of it was poured in an electrolytic cell and submerged aluminum electrodes passed 600mA direct current through it.

In each run, 40gr of clay (Mesh; 120μm) and 50ml of municipal wastewater treatment plant effluent was added to 10 liters of tap water. At the beginning, one sample was taken from the prepared synthetic wastewater as the control sample and one sample was taken from the cell content every 10 minutes up to 1 hour. This process was repeated on 5 different synthetic wastewater samples.

The samples were analyzed for, turbidity, most probable number of coliform bacteria (total, confirmed and *E. coli*) and Heterotrophic Plat Count (HPC) according to the Standard Methods for Examination of Water and Wastewater book (21^{st} edition) [19]. Fisher exact test was used in SPSS 19 software to compare the data in different times.

Findings

All the parameters of turbidity, HPC, total coliform, confirmed coliform and *E. coli* were decreased during the time. The electrochemical process reduced the average of turbidity below 3NTU after 50 minutes (91.05% removal). The HPC number reduced from 130n/ml to 2.4n/ml (98.15% removal) after 50 minutes. No coliforms were seen after 40 minutes of the electrochemical process (Figure 1).

Figure 1) Turbidity, HPC, total coliform, confirmed coliform and *E. coli* removing rate by electrochemical treatment of polluted water

Time (min)	**Turbidity** (NTU)	**HPC** (n/ml)	**Total coliform** (MPN/100ml)	**Confirmed** (MPN/100ml)	***E. coli*** (MPN/100ml)
0	29.64±2.61	130.20±18.74	77.66±23.87	16.66±7.27	7.97±1.00
10	7.16±1.54	15.00±2.54	31.83±30.72	8.94±5.55	4.73±2.66
20	5.71±0.84	11.80±1.30	10.29±5.46	5.35±4.45	1.32±1.82
30	4.88±0.33	9.40±1.14	4.56±8.08	1.90±4.24	0.60±1.34
40	3.79±0.96	7.20±0.83	0	0	0
50	2.65±0.82	4.80±0.44	0	0	0
60	1.30±0.34	2.40±0.89	0	0	0

There was a significant difference between <30 minute reaction time and more for 90% removal of all variables ($p=0.001$); But, there was no significant differences between 30 to 40 and 40 to 50 minute intervals ($p>0.05$).

Discussion

The findings showed that electrochemical process by 600mA and aluminum electrodes could remove coliform bacteria (total, confirmed and *E. coli*) up to 100% during a 40-minute reaction time and more. Also, the process eliminated up to 95.61% of turbidity and 98.15% of heterotrophic bacteria. These findings are more efficient than what was stated by Barrera-Díaz *et al*. They have reported the removing of 93% of total coliform bacteria under optimal conditions of pH=4 and 18.2A/m^2 current density by aluminum electrodes from food-industry wastewater [18].

Our research showed that the electrochemical process reduced the turbidity from 29.64+2.61 to 1.30+0.34NTU (95.61% removal). This result is compatible to the findings of Abuzaid *et al.* that stated the ability of removing 95% of turbidity by iron electrodes and 1A electrical current [13].

Another study by Lay et al showed that electrochemical process by iron and aluminum electrodes after 30 minutes of reaction time removes 96.5% of turbidity which in less than 30 minutes, is slightly better than our findings [14].

Generally, our findings are compatible with Tokudoa & Nakanishi [16] and also Patermarakis & Fountoukidis [17] but some differences may be related to unlike conditions like temperature, pH, electro conductivity and etc.

Conclusion

40 minutes of electrochemical process in 600mA by aluminum electrodes is the optimum condition for removing the turbidity, Coliform bacteria (total, confirmed and *E. coli*) and HPC from polluted water.

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