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Efficiency of Removing Chromium from Plating Industry Wastewater using the Electrocoagulation Method

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Authors
Borghe-ei S.M.[1] *PhD,*
Goodarzi J.[2] *MSc,*
Mohseni M.[3] *PhD,*
Amouei A.* *PhD*

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*Environmental Health Research Center, Babol University of Medical Sciences, Babol, Iran
[1]Environmental Engineering Department, Environment Faculty, Sharif University of Technology, Tehran, Iran
[2]Environmental Health Department, Para-Medicine School, Mazandaran University of Medical Sciences, Sari, Iran
[3]Chemical Engineering Department, Engineering & Technology Faculty, British Columbia University, Vancouver, Canada

Correspondence
Address: Ganj Afrooz Street, Babol University of Medical Sciences, Babol, Iran. Postal Code: 4774547176
Phone: +981112234366
Fax: +981112234367
Iamouei1966@gmail.com

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ABSTRACT

Aims Chromium is one of the most important metallic pollutants in plating industry wastewater. This toxic metal is a serious threat to human health and to the environment due to its cumulative effects and non-degradability. This research intended to study the effects of pH, contact time, and voltage on the degree of chromium removal from wastewater of plating industry by using the electrocoagulation method.

Materials & Methods This laboratory research conducted from late May to late November 2012. A 1000cc reactor at laboratory scale was used that included 4 aluminum electrodes of 90% purity, dimensions of 5 by 10cm, and thickness of 1mm, with parallel arrangement. Synthetic chromium-bearing wastewater was prepared at the initial concentration of 50mg/l. The process is done at pH values of 3, 7, and 9, electric potentials of 20, 30, and 40 volts contact durations of 20, 40, 60, and 80 minutes.

Findings The degree of chromium reduction did not change linearly with time in the solution and strongly depended on the pH. The efficiency of chromium removal in the samples had an ascending trend with increases in voltage from 20 to 30 and 40 volts. The degree of chromium removal increased at longer contact times.

Conclusion Lower pH, more contact time and higher voltages are effective factors in the chromium removal from wastewater by coagulation method.

Keywords Industry; Waste Water; Chromium; Electrocoagulation

CITATION LINKS

[1] Review of pollutants removed by electrocoagulation and electrocoagulation/flotation processes [2] Electrocoagulation (EC)- Science and applications [3] Arsenic removal via electrocoagulation from heavy metal contaminated groundwater in La Comarca Lagunera México [4] Complexing agent and heavy metal removals from metal plating effluent by electrocoagulation with stainless steel electrodes [5] Performance evaluation of electrocoagulation process for removal of Chromium (VI) from synthetic chromium solutions using iron and aluminum electrodes [6] Removal of chromium, nickel, zinc and turbidity from industrial wastewater by electrocoagulation technology (case study: Electroplating and galvanized wastewater of industrial zone in boomhen) [7] Removal of Cadmium from industrial effluents by electrocoagulation process using Iron electrodes [8] Industrial wastewater treatment (plating-Dairy-Textile) [9] Removal of cr (VI) from simulated electroplating wastewater by maghemite nanoparticles [10] Treatment of dairy wastewaters by electrocoagulation using mild steel electrodes [11] Removal of nickel, copper, zinc and chromium from synthetic and industrial wastewater by electrocoagulation [12] Cadmium removal from aqueous solutions by aluminium electrodes in electrocoagulation process [13] Removal of COD and turbidity to improve wastewater quality using electrocoagulation technique [14] Electrolytic removal of hexavalent chromium from aqueous solutions [15] Treatment of textile wastewaters by electrocoagulation using iron and aluminum electrodes [16] Electrochemical technologies in waste water treatment [17] Removal of trivalent chromium by electrocoagulation [18] Removal turbidity and separation of heavy metals using electrocoagulation-electroflotation technique: A case study [19] Removal of chromium(VI) from wastewater by combined electrocoagulation–electroflotation without a filter [20] Treatment of electroplating wastewater containing Cu2+, Zn2+ and Cr(VI) by electrocoagulation [21] Removal of Zn(II), Cu(II), Ni(II), Ag(I) and Cr(VI) present in aqueous solutions by aluminium electrocoagulation [22] Removal of Cr(VI) from polluted solutions by electrocoagulation: Modeling of experimental results using artificial neural network [23] Removal of nickel, copper, zinc and chromium from synthetic and industrial wastewater by electrocoagulation

Introduction

Water and energy are two main challenges of today world. Nowadays, good sufficient quality water is provided through necessary engineering sciences, but not in the third-world countries that lack suitable infrastructure and required capital investments [1-3]. Rivers, canals, and other water resources are always under the threat of pollution that is caused by dumping industrial and other activities wastewater and natural processes [4, 5]. Heavy metals, e.g. chromium, cadmium, copper, zinc, and nickel that are usually found in industrial wastewater are among the most common pollutants which damage the aquatic environment and endanger human health [6-8].

A broad spectrum of water and wastewater treatment processes (physical operations and biological, physiochemical and chemical processes) have been introduced for removing pollutants that require the use of various compounds [2] and many different strategies are employed to treat industrial wastewater and removing heavy metals [4]. Ion exchange processes, electrical reduction, sedimentation, reverse osmosis, chemical precipitation with lime together with absorption, and adsorption are among these strategies, each having its own advantages and disadvantages [9, 10]. Although using chemical compounds to treat wastewater and remove heavy metals from industrial wastewater has an old history, they are not very desirable nowadays probably because of their expense, producing great volumes of sludge and secondary chemical compounds, and increasing the Total Dissolved Solids (TDS) concentration of wastewater [11, 12]. However, some promising techniques have been developed based on electrochemical technologies that are not beset by the mentioned problems. One of such techniques is the electrocoagulation (EC) process that employs the following mechanism:

$Al \rightarrow Al^{+3} + 3e^-$ Anode reaction (oxidation)

$Cr^{6+} + 3e^- \rightarrow Cr^{3+}$ Chromium-bearing wastewater

$2H_2O + 2e^- \rightarrow 2OH^- + H_2\uparrow$ Cathode reaction (reduction)

$Al^{3+} + 3OH^- \leftrightarrow Al(OH)_3\downarrow$

$Cr^{3+} + 3OH^- \leftrightarrow Cr(OH)_3\downarrow$

In recent decades, this technology has been increasingly used in South America and Europe to treat wastewater containing heavy metals [12] and it has been employed for treating wastewater of textiles and food industries and carwash facilities, and for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS) removal [13]. Moreover, it has had applications in treating wastewater containing chemicals, organic matter in the form of landfill leachate, and multiple detergents and gangue, because it uses less electricity and has higher efficiency in removing these pollutants [14]. In North America also, this technology is employed for pretreatment of wastewater in pulp and paper, mining, and metal industries [15]. Electrocoagulation is an effective and quick method for treating water or wastewater containing dissolved salts or toxic metal compounds. The ion exchange mechanism by anode plates is used in electrocoagulation, no chemical is added to the water to cause coagulation, and the volume of produced sludge is less compared to most other common treatment methods [16].

This research intended to study the effects of pH, contact time, and voltage on the degree of chromium removal from wastewater of plating industry by using the electrocoagulation method.

Materials & Methods

This laboratory research conducted as a pilot project in the water and wastewater chemical laboratory of Environmental Health Engineering Department at Babol University of Medical Sciences from late May to late November 2012.

Specifications of the reactor: The main tank of the electrocoagulation process was a 1000cc Pyrex glass beaker. To reinforce the aluminum plates, pieces of rubber and a 10cm long iron axle were placed on them (which were an innovative technique). An insulator coating was used to insulate this metal axle and to guide the electric current to pass only through the plates to the fluid. The selected plates were of 90% pure aluminum, with dimensions of 5 by 10cm and thickness of 1mm, and were sanded to remove the metal burrs. 6 holes each 0.7cm diameter were made in each plate by using a number 6 drill

bit size so that the synthetic wastewater could move better in the reactor.

Apparatuses and equipment: Three holes were made on each side in the body of the supports to adjust the depth of the electrodes in the fluid by using a metal axle. After the reactor was constructed and assembled, it was put on a Co-W24 magnetic stirrer (Pars Azma; Iran) with the constant speed of 450rpm. A laboratory power converter (MEGA TEAK; Taiwan) was used to provide the required electricity that could be set at various voltages (from 0 to 60 volts) and amperes (from 0 to 3 amperes) and could covert AC to DC. Voltage was changed from 20 to 40 volts together with changes in pH values (3, 7, and 9). The clamps on the converter were connected to the anode and the cathode of the device on the one side and to the electrodes on the other (in the bipolar parallel arrangement). The electrodes were 0.5cm apart, and the fluid volume in all the experiments was 1000cc. A digital pH meter (Aqualytic Company; Germany) was employed to measure the pH of solution.

Used chemicals and synthetic wastewater preparation: Based on studies conducted in Iran and other countries on the quality of plating industry wastewater [17-19], mean chromium concentration in plating industry wastewater was less than 50mg/l (14.5±10mg/l). Therefore, we selected the concentration of 50mg/l to study the effects of the electrocoagulation process. Potassium dichromate (Merck; Germany) was used to prepare the synthetic wastewater, and the effects of pH on the efficiency of chromium removal were determined using the electrocoagulation method (all experiments were carried out at pH values 3, 7, and 9). To achieve these pH values, 0.02N sulfuric acid (for creating acidic conditions) and 0.02N sodium hydroxide (for creating basic conditions) were used.

Methodology

After constructing the reactor and preparing the synthetic wastewater, the electrodes were first weighed, and the speed of the stirrer was set at 450rpm and the voltage at 20 to 40 volts. The power converter and the stirrer were then turned on. The required laboratory containers and supplies (Erlenmeyer flasks, funnel with Whatman filter paper 42, and special beakers) were prepared and, after 20, 40, 60, and 80min, a syringe pipet was used to draw the liquid from inside the reactor. This liquid was poured into 1000cc beakers and after the selected contact times passed and the sediments precipitated on the bottom of the beakers, 10cc samples were taken from the supernatant and passed through Whatman filter papers. 40cc of each sample liquid that passed through the filter paper were poured in a 50cc Poly Lab plastic container equipped with a lid. Totally, 108 synthetic wastewater samples were taken at voltages of 20, 30, and 40 volts, contact times of 20, 40, 60, and 80 minutes, and pH values of 3, 7, and 9. Each treatment had three replicates. Absorbance was read at 357.9nm by a PG-990 atomic absorption spectrophotometer (PG-Instrument 990; England) using the standard EPA method at the Biochemistry Department Laboratory of the Babol University of Medical Sciences. At the end of the reactions, the electrodes were place in distilled water for 5 minutes and were then dried and weighed.

Findings

The degree of chromium reduction did not change linearly with time in the solution and strongly depended on the pH. It was 99.2% at pH=3, 96.5% at pH=7 and 90% at pH=9.

The efficiency of chromium removal in the samples had an ascending trend with increases in voltage from 20 to 30 and 40 volts. The degree of chromium removal increased at longer contact times (Figure 1).

Figure 1) Removal percentage of chromium from wastewater at various contact times and pH values (initial chromium concentration 50mg/l at 20, 30 and 40 volts)

Parameters		pH=3	pH=7	pH=9
20 volts				
	20min	87	84	68
	40min	92	90	80
	60min	96	93	84
	80min	98	96	88
30 volts				
	20min	90	87	70
	40min	94	92	82
	60min	97	95	86
	80min	98	97	90
40 volts				
	20min	92	89	72
	40min	95	93	84
	60min	98	96	88
	80min	99	98	91

Discussion

The highest efficiency of chromium removal was achieved at pH values of 3 and 7. These results are similar to those found by Gao *et al.* [19] and Adhoum *et al.* [20]. The maximum chromium removal (87%) was observed in the pH range 3-7.

Our findings showed that hexavalent chromium ions were first converted into Cr^{+3} in "$Cr_2O_7^{2-} + 6e^- + 7H_2O \rightarrow 2Cr^{3+} + 14OH^-$" reaction that took place around the cathode electrode. The Cr^{3+} ions then reacted with the OH^- produced from water hydrolysis and $Cr(OH)_3$ precipitated [18]. However, when the pH was in the 3-7 range, the Al^{3+} cations that were formed around the anode caused more efficient removal of Cr^{+3} ions through the sweep coagulation process (besides forming polymeric species including $Al_{13}O_4(OH)_{24}^{7+}$). This conclusion was proved by others in removing hexavalent chromium removal from aqueous solutions [17, 21, 22] and by Dermentzis *et al.* [23] in removing heavy metals from plating industry wastewater using electrocoagulation, but disagree with Bazrafshan *et al.* [12]. Moreover, it is only the amphoteric behavior of $Al(OH)_3$ under acidic and alkaline conditions (pH values lower than 4 and higher than 8) that caused the formation of Al^{+3} cations and, finally, the production of $Al(OH)_4^-$ anions and the reduction in removal efficiency [15].

In our study, chromium removal efficiency improved with increases in contact time because more coagulant material was formed with the passage of time (which could increase the removal percentage and reduce the concentration of chromium in the solution). This result completely agrees with Bazrafshan *et al.* [12] found in their research on removal of chromium from aqueous solutions and Dermentzis *et al.* [23] in the study on removing heavy metals from industrial wastewater.

In our research, chromium removal efficiency improved with increased differences in electrical potential and maximum chromium removal took place at 40 volts. The improved chromium removal efficiency with increased differences in electrical potential results from two basic factors. First, increased electrical current improved anode dissolution which (according to Faraday's law) leads to production of greater quantities of Al^{+3} ions. Consequently, the destabilization process of the particles present in the solution was enhanced and $Al(OH)_3$ production increased, which helped in increasing chromium removal through the sweep coagulation phenomenon. Golder *et al.* [17], Merzouk *et al.* [18], and Goa *et al.* [19] reached the same conclusions in their studies.

Replacement requiring of electrodes during the reaction, expense of the electricity and the use of synthetic solutions instead of actual wastewater and batch scale against continuous system are the limitations of this study. Assessing the main factors affecting the process (e.g. voltage, pH, time, type and amount of salts) and using electro-coagulation technology for industrial wastewater treatment and removal of heavy metals are suggested.

Conclusion

Lower pH, more contact time and higher voltages are effective factors in the chromium removal from wastewater by coagulation method.

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References

1- Emamjomeh MM, Sivakumar M. Review of pollutants removed by electrocoagulation and electrocoagulation/ flotation processes. J Environ Manage. 2009;90(5):1663-79.

2- Mollah MYA, Schennnach R, Parga JR, Cocke DL. Electrocoagulation (EC)- Science and applications. J Hazard Mater. 2001;84(1):29-41.

3- Parga JR, Cocke DL, Valenzuela JL, Gomes JA, Kesmez M, Irwin G, et al. Arsenic removal via electrocoagulation from heavy metal contaminated groundwater in La Comarca Lagunera México. J Hazard Mater. 2005;124(1-3):247-54.

4- Kabdaşli I, Arslan T, Olmez-Hanci T, Arslan-Alaton I, Tünay O. Complexing agent and heavy metal removals from metal plating effluent by electrocoagulation with stainless steel electrodes. J Hazard Mater. 2009;165(1-3):838-45.

5- Bazrafshan E, Mahvi AH, Nasseri S, Mesdaghinia AR. Performance evaluation of electrocoagulation process for removal of Chromium (VI) from synthetic chromium solutions using iron and aluminum electrodes. Turkish J Eng Env Sci. 2008;32(2):59-66.
6- Amouei A, Borqhei M, Mohseni M, Goodarzi J, Faraji H. Removal of chromium, nickel, zinc and turbidity from industrial wastewater by electrocoagulation technology (case study: Electroplating and galvanized wastewater of industrial zone in boomhen). J Mazandaran Univ Med Sci. 2015;24(120):209-19. [Persian]
7- Bazrafshan E, Mahvi AH, Nasseri S, Mesdaghinia AR, Vaezi F, Nazmara Sh. Removal of Cadmium from industrial effluents by electrocoagulation process using Iron electrodes. Iran J Environ Health Sci Eng. 2006;3(4):261-6.
8- Hoseinian M. Industrial wastewater treatment (plating-Dairy-Textile). Tehran: Shahrab Publications; 2009. pp 67-8. [Persian]
9- Khodabakhshi A, Amin MM, Mozaffari M, Bina B. Removal of cr (VI) from simulated electroplating wastewater by maghemite nanoparticles. 2010;6:935-44. [Persian]
10- Sengil IA, Ozacar M. Treatment of dairy wastewaters by electrocoagulation using mild steel electrodes. J Hazard Mater. 2006;137(2):1197-205.
11- Dermentzis K, Christoforidis A, Valsamidou E. Removal of nickel, copper, zinc and chromium from synthetic and industrial wastewater by electrocoagulation. Int J Environ Sci. 2011;1(5):976-84.
12- Bazrafshan E, Mahvi AH. Cadmium removal from aqueous solutions by aluminium electrodes in electrocoagulation process. Tabib-e-Shargh. 2007;1(9):61-70. [Persian]
13- Niam MF, Othman F, Sohaili J, Fauzia Z. Removal of COD and turbidity to improve wastewater quality using electrocoagulation technique. Malaysian J Anal Sci. 2004;1:198-205.
14- Chaudhary A, Goswami NC, Grimes SM. Electrolytic removal of hexavalent chromium from aqueous solutions. J Chem Technol Biotechnol. 2003;78(8):877-83.
15- Kobya M, Can OT, Bayramoglu M. Treatment of textile wastewaters by electrocoagulation using iron and aluminum electrodes. J Hazard Mater. 2003;100(1-3):163-78.
16- Chen G. Electrochemical technologies in waste water treatment. J Separation Purif Technol. 2004;38(1):11-4.
17- Golder AK, Samant AN, Rey S. Removal of trivalent chromium by electrocoagulation. J Separation Purif Technol. 2007;53(1):33-41.
18- Merzouk B, Gourich B, Sekki A, Madani K, Chibane M. Removal turbidity and separation of heavy metals using electrocoagulation-electroflotation technique: A case study. J Hazard Mater. 2009;164(1):215-22.
19- Gao P, Chen X, Shen F, Chen G. Removal of chromium(VI) from wastewater by combined electrocoagulation–electroflotation without a filter. Separation Purif Technol. 2005;43(2):117-23.
20- Adhoum N, Monser L, Bellakhal N, Belgaied JE. Treatment of electroplating wastewater containing Cu2+, Zn2+ and Cr(VI) by electrocoagulation. J Hazard Mater. 2004;112(3):207-13.
21- Heidmann I, Calmano W. Removal of Zn(II), Cu(II), Ni(II), Ag(I) and Cr(VI) present in aqueous solutions by aluminium electrocoagulation. J Hazard Mater. 2008;152(3):934-41.
22- Aber S, Amani-Ghadim AR, Mirzajani V. Removal of Cr(VI) from polluted solutions by electrocoagulation: Modeling of experimental results using artificial neural network. J Hazard Mater. 2009;171(1-3):484-90.
23- Dermentzis K, Christoforidis A, Valsamidou E. Removal of nickel, copper, zinc and chromium from synthetic and industrial wastewater by electrocoagulation. J Environ Sci. 2010;5:976-82.