ISSN: 2383-2568 Quarterly of International Archives of Health Sciences 2014;1(1):31-35

Application of Electrochemical Process in Removal of Heavy Metals from Landfill Leachate

ARTICLE INFO

Article Type
Original Research

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How to cite this article
Mostafaii Gh, Roozitalab N, Rabbani D, Moosavi Gh, Iranshahi L. Application of Electrochemical Process in Removal of Heavy Metals from Landfill Leachate. International Archives of Health Sciences. 2014;1(1):31-35.

ABSTRACT

Aims Municipal landfill leachate contains high concentrations of heavy metals, organics, ammonia. The efficeincy of electrochemically removal of heavy metals from landfill leachate was studied.

Materials & Methods The leachate was obtained from Kahrizak landfill in south of Tehran. The experiments were carried out by batch process. The 2liter batch reactor was made of glass. There were eight anodes and cathodes electrodes. The electrodes were placed vertically parallel to each other and they were connected to a digital DC power supply. The pH and conductivity were adjusted to a desirable value using NaOH or H2SO4, and NaCl. All the runs were performed at constant temperature of 25°C. In each run, 1.5liter of the leachate was placed into the electrolytic cell. Samples were extracted every 10min and then filtered through a mixed cellulose acetate membrane (0.42µm). The amount of Lead, Zinc and Nickel removal was measured at pH=7 and in current density of 0.5, 0.75, and 1A.

Findings When current density and time reaction increased, removal efficiency of heavy metals such as Lead, Zinc and Nickel increased. At initial pH=7, density 1A and reaction time= 60min, Lead, Nickel and Zinc were removed up to 86, 93 and 95%, respectively.

Conclusion Electrochemical process can be proposed as a suitable technique to remove heavy metal from landfill leachate.

Keywords Electrochemical Techniques; Metals, Heavy; Waste Disposal Facilities; Electrodes; Water Pollutants, Chemical

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Article History
Received: June 14, 2013
Accepted: December 20, 2013
ePublished: August 2, 2014

CITATION LINKS

[1] Coagulation-flocculation and air stripping as a pretreatment of young landfill ... [2] Landfill leachate treatment by means of anaerobic membrane ... [3] Comparison of diffrent coagulants efficiency for treatment of Hamedan landfills ... [4] Study on the performance of sequential two-stage up flow anaerobic sludge blanket reactor followed by aerated lagoon in municipal landfill ... [5] Survey of heavy metal concentration in municipal solid wastes leachate of Isfahan city and their reduction ... [6] Effect of compost leachate on yield and chemical composition of corn and the effects of leachate residual on soil ... [7] Toxic effect of heavy metals on the activated sludge protozoan ... [8] Application of electrochemical process for removal of Chromium and Copper from ... [9] Testing and electrochemical method for treatment of textile dye ... [10] Electrochemical treatment of landfill leachates using a boron-doped diamond ... [11] Electro coagulation (EC)-science and ... [12] Investigation of the electro-coagulation treatment process ... [13] Performance evaluation of electrocoagulation process using ... [14] Standard methods for the examination of ... [15] Influence of various parameters on the ... [16] The study on biodegradability enhancement of ... [17] Electrocoagulation of ... [18] Separation of pollutants from restaurant ... [19] Treatment of textile wastewaters by electrocoagulation ... [20] Removal of heavy metals from industrial water using ... [21] Removal of cadmium from industrial effluents ... [22] Application of electrocoagulation process in removal of cadmium from ... [23] Removal of arsenic ... [24] Decolorization of disperse and reactive dyes by continuous ... [25] Application of electrochemical process for landfill leachate treatment with emphasis on ... [26] Copper, chromium and nickel removal from metal ...

All keywords and available citations are linked in this page.

Introduction

Sanitary landfills are considered as the most cost-effective and environmentally method to disposal of municipal and industrial solid wastes [1]. Municipal landfill leachate is a high strength wastewater characterized by high concentrations of organics, ammonia, heavy metals and arsenic [1, 2]. Leachate composition is affected by several factors including seasonal precipitation, origin of waste and particularly the age of landfill [2, 3]. Landfill leachate has been identified as one of the major threats to groundwater resources [2-4], So leachate must be treated with proper technology to reduce pollutants before disposal or reuse.

Heavy metal pollution has become one of the most serious leachate problems [5]. Due to recalcitrance and persistence of heavy metals in the environment, treatment of them is concerned specially. Heavy metals are not biodegradable. They tend to accumulate in living organisms; many heavy metal ions are known to be toxic or carcinogenic [6, 7]. Zinc, copper, nickel, mercury, cadmium, lead and chromium are toxic heavy metals which are particularly concerned in treatment of industrial wastewaters [8].

Lead is one of the main heavy metals that causes nasal, laryngeal, and lung cancers. It contributes to osteoporosis and affects nervous, respiratory and cardiac systems as well. Lead functions like calcium in precipitation and is also prone to be synthesized with blood red cells. Children and teenagers are most likely to be affected by lead contamination. Excess amount of zinc limits protein synthesis and remains damaging effects on the central nervous system [7].

In recent years, various methods to remove heavy metal from wastewater have been extensively studied. These include chemical precipitation, ion-exchange, adsorption, membrane, filtration, coagulation flocculation, flotation and electrochemical methods [9].

Electrochemical methods have been applied most successfully to treat leachate and industrial waste water. Recently, many investigations have been especially focused on the use of electrochemically treatment of wastewater and also to treat heavy metal solutions [10]. Removal mechanisms reported in the electrolysis process generally include oxidation, reduction, decomposition, whereas the mechanisms in the electrochemical process include coagulation, adsorption, precipitation and flotation [1, 11].

The iron hydroxide flocks act as absorbents for heavy metal ions. Furthermore, heavy metal ions combine with the electro generated OH^- ions at the cathode and precipitate in form of their insoluble hydroxides. Both phenomena act synergistically leading to a rapid removal of heavy metal pollutants from leachate [12, 13].

The main goal of this research was to analyze the electrochemical method of removal of the heavy metals (Lead, Nickel and Zinc) from Kahrizak landfill leachate.

Materials & Methods

The experiments were done in evironmental health laboratory of Health Faculty of Kashan University of Medical Sciences. Leachate was obtained from kahrizak landfill in south of Tehran in summer 2013.

The Total Dissolved Solids (TDS) 9540mgL^{-1}, Chemical Oxygen Demand (COD) 66680mgL^{-1}, Conductivity 16.89mScm^{-1}, BOD5 2450mgL^{-1}, pH=7.82 and temprature of 21.4°C for leachate sample were determined considering standard methods [14]. The leachate was first filtered using screen filter to remove large suspended solids before using for the subsequent studies.

The experiments were carried out by batch process. The batch reactor was made of glass with 2 liter volume at constant stirring speed (300 rpm). There are eight electrodes, four anodes and four cathodes of the same dimensions. Iron cathodes and anodes were made from plates with dimensions of 2cm×15cm×0.5cm (width×length×depth). The active area of each electrode was 2×10cm and the spacing between electrodes was 15mm. The electrodes were placed vertically parallel to each other and they were connected to a digital DC power supply. The pH and conductivity were adjusted to a desirable value using NaOH or H_2SO_4, and NaCl (Merck; Germany), respectively [15-17]. The chloride salt added to the solution can also prevent the formation of the oxide layer on the anode and therefore reduce the inactiveness problem of the electrodes. All the runs were performed at constant temperature of 25°C.

In each run, 1.5 liter of the leachate was placed into the electrolytic cell. The current density was adjusted to a desired value and the coagulation was started. Samples were extracted every 10min and then filtered through a mixed cellulose acetate membrane (0.42μm).

The residual concentration of lead, Zinc and Nickel were determined using Inductivity Coupled Plasma (ICP) according to the standard method [14]. The amount of Lead, Zinc and Nickel removal was measured at pH equal to 7 and in current density of 0.5, 0.75, and 1A.

Findings

The initial concentration of Nickel, Zinc and Lead was 2.21, 2.51 and 0.798mg/l, respectively. The highest current density was 1A, which led to removal of nearly 86% Lead, some 90% of Zinc and some 90% of Nickel within 60min.

According to the removal rate the investigated metals ranked in the order of Zinc>Nickel>Lead (Figure 1).

Figure 1) Mean concentration of Lead, Nickel and Zinc before and after electrochemical process using iron electrodes (Initial pH=7)

Current Density (Amp)	Reaction Time (min)						
	0	10	20	30	40	50	60
Lead (mg/lit)							
0.5	0.80	0.73	0.62	0.58	0.54	0.50	0.36
0.75	0.80	0.69	0.53	0.35	0.29	0.23	0.15
1	0.80	0.67	0.35	0.30	0.27	0.18	0.11
Nickel (mg/lit)							
0.5	2.28	1.70	1.01	0.58	0.52	0.42	0.28
0.75	2.28	1.68	0.94	0.35	0.38	0.23	0.17
1	2.28	1.30	0.30	0.22	0.19	0.17	0.13
Zinc (mg/lit)							
0.5	2.51	1.83	0.97	0.73	0.65	0.57	0.45
0.75	2.51	1.27	0.79	0.63	0.43	0.26	0.19
1	2.51	1.15	0.37	0.33	0.27	0.21	0.11

Discussion

This study aimed to investigate the removal of heavy metals (Lead, Nickel and Zinc) from Kahrizak landfill leachate. As electrochemical process is affected by several operating parameters, such as initial pH, pollutants concentrations, current density, COD and contact time so current density and contact time have been explored in order to evaluate a treatment technology for Lead, Nickel, Zinc removal from landfill leachate.

It is well-known that current density not only determines the coagulant dosage rate but also the bubble production rate and size and the flocs growth which can influence the treatment efficiency of the electrochemical. Therefore, the effect of current density on the pollutants removal was investigated [13, 18, 19].

The highest current density (1A) produced the quickest treatment with more than 85% Nickel and Zinc reduction and more than 60% Lead reduction occurring after 30min. The lowest heavy metals removal efficiency occurred in the lowest current density (0.5A). This might be attributed to the difference in removal mechanisms of each heavy metal in the treatment process.

As expected, it appears that for a given time, the removal efficiency increased significantly with increase of current density [20, 21]. This is ascribed to the fact that at high current, the amount of iron oxidized increased, resulting in a greater amount of precipitate for the removal of pollutants. In addition, it was demonstrated that bubbles density increases and their size decreases with increasing current density, resulting in a greater upwards flux and a faster removal of pollutants and sludge flotation [22, 23]. As the current decreased, the time needed to achieve similar efficiencies increased and the results of this research confirm this fact. This expected behavior is explained by the fact that the treatment efficiency was mainly affected by charge loading (Q=It) [19, 24].

The results of Thaereemaitree *et al.* in electrocoagulative removal of heavy metals and landfill leachate pollutants confirmed more than 90% efficiency of lead removal and 70% decreaseing of colour [25].

Akbal *et al.* have studied the efficiency of removal of Cu, Cr, and Ni by electrochemical process and the effect of current density, wastewater pH, conductivity, and electrode material on them. According to their result, current density of 10mA/cm^2 is able to achieve 100% Cu, 100% Cr, and 100% Ni removal at an electrocoagulation time of 20min. This efficiency is slightly different from that in our study. This difference is most probably due to varied reaction time, electrode material, initial pH, and current density [26].

The electrochemical process is currently the most effective process for treating leachate containing heavy metal ions, but its removal efficiency was significantly affected by various parameters including the current density, initial pH and electrolysis time. It is suggested that it will be better to study on leachate from another city during the year.

Conclusion

When current density and time reaction increases, removal efficiency of heavy metals such as Lead, Zinc, Nickel increases too. Initial pH equal to 7, density 1A and reaction time equal to 60 minutes removes the Lead, Nickel and Zinc of landfill leachate up to 86, 93 and 95%, respectively.

Acknowledgement: Authors are grateful to Deputy Research of Kashan University of Medical Sciences for financial support.

Ethical Permission: Not needed.

Conflict of Interests: None declared by authors.

Funding Sources: This paper is extracted from the results of a research project No. 8951 performed in Kashan University of Medical Sciences.

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