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Original Article

Methods of Nickel Removal from Valerian Irrigating Waste Water

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Abstract

Industrial development and extensive use of heavy metals have led to the problem of environmental pollution. Nickel compounds are toxic to plants and have detrimental effects on their growth. Valerian is a plant used in herbal medicine. Considering the hazards of nickel, various methods have been developed to remove this contaminant from herbs irrigation wastewater, including the common chemical precipitation and the novel electrocoagulation methods. An advantage of electrocoagulation is its high efficiency in removal of contaminants. In this study, nickel at a concentration of 500 mg/L in a synthetic wastewater was removed by chemical precipitation with Sodium hydroxide, lime, and sodium sulfide, as well as by electrocoagulation; the removal efficacy was 80.66%, 78.92%, 86.02 and 99.96, respectively. The pilot used for electrocoagulation was made of plexiglass with 10 metallic electrodes of 11×7×0.2 cm. Comparison of the results showed high efficiency of electrocoagulation. In these experiments, pH was considered about 6.

Key words: Chemical precipitation, Electrocoagulation, Heavy metals, Nickel, Valerian

Introduction

Heavy metals are a group of environmental contaminants that are increasing day by day by growing of the industry. Entry of these contaminants into the ecosystem is a serious threat to its life. Accumulation of these long-living elements in environment endangers human health [1].

Research has shown that plants resist against them via various mechanisms. High levels of nickel in plants result in yellowing and decreasing of leaves [2]. It also reduces water content of plants which may affect the photosynthetic system; resulting in plants wilting. In some cases, low concentrations of the element can lead to a significant reduction in plants growth and its minimum tolerable concentrations vary among plants [1-6].

Valerian is a bushy plant with a height of 50 to150 cm and a short root. It grows wildly in most parts of Asia and Iran. The plant’s root has medicinal value in Iranian traditional medicine and is used as nerve sedative, hypnotic, anticonvulsant, anti-depressive, and food digester [5,7-9].

Considering the hazards of nickel, various methods have been developed to remove this contaminant from valerian irrigation wastewater. Precipitation is a conventional chemical method for removal of heavy metals and the point in this method is adjustment of the environment pH which is performed by NaOH or $Ca(OH)_2$ [10,11] .

However, chemical precipitation has some disadvantages such as consumption of high volume of chemicals, their costs, and great sludge production which is not suitable for agriculture [12]. Electrocoagulation is a novel approach for removal of heavy metal [13-18]. In this method, passing of an electric current through electrodes oxidizes metals into cations which are hydrolyzed in water, turn into hydroxide derivatives, and bond to contaminant; leading to their precipitation. Moving of ions in the solution toward the oppositely charged electrodes neutralizes their charges which results in clot formation [19-21]. The efficacy of electrocoagulation has been

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confirmed in studies on the removal of turbidity [22,23], heavy metals [24,25], sulfide [26], organic materials [26], color [23,26], COD [22,26,27], BOD [27], and coliform [23]. This study examined the performance of electrocoagulation in removal of Ni (II) using iron electrodes and compared it with conventional chemical precipitation method.

Material and Methods

A wastewater was produced containing 500 mg/L nickel ions and in order to remove the contaminant, it was poured in the plexiglass tank. Ten iron plates of 11×7×0.2 cm were placed in the tank with a constant distance of 2 cm. The electrodes had bipolar and monopolar configurations. Then separate experiments were carried out with sodium hydroxide, lime, and sodium sulfide. To investigate the precipitation method with sodium hydroxide, the pH of the solution was adjusted at 6 with sodium hydroxide 1N. The time required for reaction to take place and the time for the resulting clots to precipitate were considered 45 min and 30 min, respectively.

The solutions were then sampled and the remaining nickel in the solution was quantified using the standard methods of water and wastewater tests [28]. The same experiment was performed with lime and sodium sulfide. All experiments were carried out at 25 °C and with a magnetic stirrer velocity of 100 rpm.

In this study, Nickel nitrate, sodium hydroxide, lime, and sodium sulfide made by Merck, Germany, were used. Nickel was measured by atomic absorption spectrophotometer. The magnetic stirrer was IKA RCT basic, Germany, the power converter was DAZHENG DC POWER SUPPLY PS-305D, and the pH meter was 691 Metr Metrohm, Switzerland.

Results and Discussion

In this study, the feasibility of using the effluent of electrocoagulation and precipitation treatments for irrigation of valerian was studied. At first, the optimum time of the test was investigated for electrocoagulation at a nickel concentration of 500 mg/L. To this end, the experiments were performed at 15, 20, 25, 30, and 45 min, at a pH of about 6, and magnetic stirrer velocity of 100 rpm. The results are shown in Fig. 1 and Table 1.

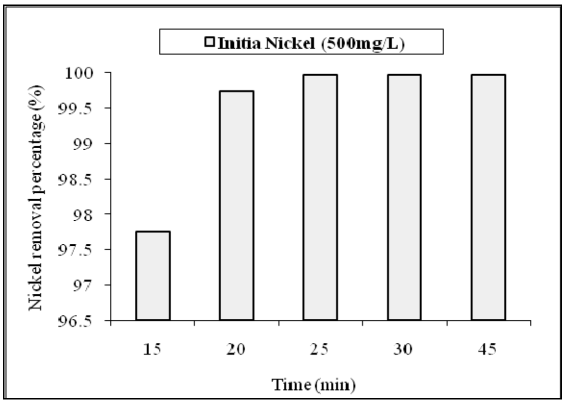

Fig. 1 Comparison of nickel removal percentages using electrocoagulation at different times of the test

Table 1 Comparison of initial and final nickel levels after electrocoagulation in different times

Test time (min)	Initial Nickel (mg/L)	Final Nickel (mg/L)
15	500	11.2
20	500	1.3
25	500	0.19
30	500	0.18
45	500	0.16

Considering the diagram, the optimum time was considered 25 min. Raising the test time increased the removal rate due to high production of metal hydroxide. However, excessive time increase led to a voltage drop due to deposit formation on the cathode. Bazrafshan [19] and Gao *et al.* [29] showed that raising the time can increase the removal of contaminant by electrocoagulation. Farhadi stated that the removal efficiency increases with increasing the time. On the other hand, by over increasing the time, for example, more than 90 minutes, the environment pH rises and negative ferric hydroxide ions are formed which reduce the efficiency [30].

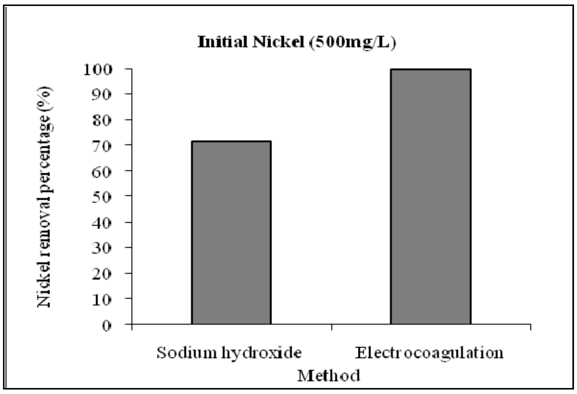

Fig. 2 Comparison between the rate of nickel removal percentages through precipitation with sodium hydroxide and electrocoagulation

Table 2 Comparison of nickel removal by electrocoagulation and precipitation with sodium hydroxide

Method	Test time (min)	Initial Nickel (mg/L)	Final Nickel (mg/L)
Precipitation with sodium hydroxide	25	500	142.13
Electrocoagulation	25	500	0.22

Golder's experiments showed that the time required for the contaminant to be removed was 50 min for bipolar and 60 min for monopolar configurations [31].

Thereafter, some experiments were performed to compare the new electrocoagulation method with conventional precipitation methods. Given the optimal time of 25 min obtained in electrocoagulation experiments, sodium hydroxide was tested at this time; the results are given in Fig. 2 and Table 2.

The results in Table 2 show that nickel was removed better by electrocoagulation than caustic soda precipitation. The removal efficacy of nickel was 71.6% with caustic soda precipitation in 25 min. Similar experiment was performed in 45 min to compare nickel removal by caustic soda precipitation and electrocoagulation, after which the yielded solution was sampled and the level of nickel was measured. Nickel was then precipitated with lime. Research conducted by Tadess *et al.* showed that metal removal by precipitation with lime at pH 11-12 and an experiment time of one day was 46-72%; then also he showed that the best pH for removal was approximately 8. It should be noted that to achieve this pH, the amount of lime should be increased; this increases sludge formation [32].

Nickel precipitation experiment was also performed with sodium sulfide. All experiments were carried out at 25 °C, test velocity of 100 rpm, test time of 45 min and precipitation time of 30 min. Given the metal precipitation conditions and use of produced effluent for irrigation of valerian herb, the initial pH was considered about 6 in these experiments [24,33]. For comparison, the results are presented in Fig. 3 and Table 3.

The results show that electrocoagulation was better than any of the precipitation methods in terms of test time and the rate of nickel removal.

The levels of nickel in the treated wastewater for irrigation of the plant, based the standards of Iran Department of Environment, are given in Table 4 [34]. Comparison of Tables 2, 3 and 4 shows that electrocoagulation reduces nickel to the standard level for irrigation of plants.

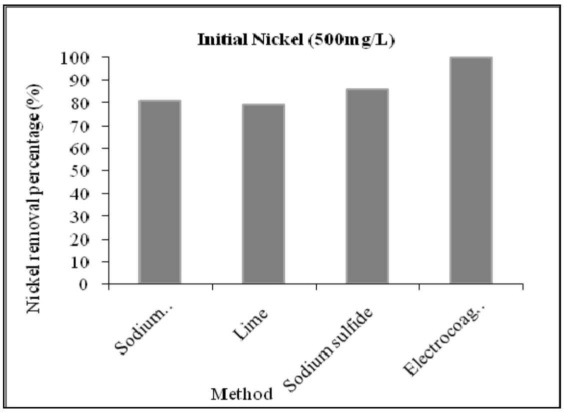

Fig. 3 Comparison between the rate of nickel removal percentages through precipitation with sodium hydroxide, lime, sodium sulfide and through electrocoagulation

Conclusion

High levels of nickel compounds are toxic to plants and have detrimental effects on plant growth and development. The mean poisoning concentration of nickel for plants is more than 5 mg/kg.

Table 3 Comparison of nickel removal by electrocoagulation and precipitation with sodium hydroxide, lime, and sodium sulfide

Method	Initial nickel (mg/L)	Final nickel (mg/L)
Precipitation with sodium hydroxide	500	96.7
Precipitation with lime	500	105.4
Precipitation with sodium sulfide	500	69.9
Electrocoagulation	500	0.2

Table 4 Standards of wastewater effluent for different acceptor sources [34]

Contaminant	Discharge in surface water (mg/L)	Discharge in absorber well (mg/L)	Agriculture and irrigation (mg/L)
Nickel	2	2	2

Thus, nickel containing wastewater is treated with chemical precipitation method and the novel method of electrocoagulation. In comparison to precipitation with lime, caustic soda, and sodium sulfide, electrocoagulation removes more nickel; the time of electrocoagulation to achieve the desired result of metal removal from wastewater is shorter than conventional precipitation methods. In addition, poor precipitation and prolonged precipitation time are problems with lime precipitation.

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