Vanadium and Nickel Removal Using Ion Exchange Resin and Activated Carbon

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Abstract

Vanadium (V) and nickel (Ni) are an industrial toxic waste in which it endangers the productivity and life of plants, crops, and the whole agricultural system. V and Ni were removed from the real industrial wastewater (V concentration=4.5 mg/L and Ni concentration=0.85 mg/L) which is obtained from an industrial wastewater treatment facility. The main goal of this study was to develop a method for efficient removal of V and Ni from industrial wastewater simultaneously. Batch (single- and two-stage) and column (two-stage) adsorption experiments were conducted to determine V and Ni uptake. Ion exchange resin (VD-25XT) and activated carbon (AC-NV-01) were used as adsorbents. In the batch system, the results showed that in the single-stage batch system, V and Ni removals are 93.6 and 30.3 percent, respectively. However, in the two-stage batch experiments, 99.5 and 96.3 percent of V and Ni were adsorbed, respectively. In the column experiments, the maximum removal percentages of V and Ni are 98.4 and 95.1, respectively. In addition, similar experiments were done after VD-25XT regeneration to study VD-25XT's stability and regeneration properties and results showed that the VD-25XT's performance did not decline. The proposed two-stage batch and continuous processes met the environmental limitations for the V and Ni concentrations in the effluents.

1. Introduction

Effluent limits are recently becoming more stricter due to rapid growth in the industry resulting in a huge amount of wastewater [1]. Therefore, industries should upgrade their wastewater treatment plans to meet the environmental regulations [1]. Vanadium (V) and nickel (Ni) are natural elements and their concentrations in the soil are 10 to 220 and 10 to 1000 mg/kg, respectively [2]. The V and Ni in the effluents should be less than 0.0662 and 0.4 mg/L, respectively. V and Ni are common elements of wastewaters from the metallurgical industry, battery manufacturing, and etc. [3]. V and Ni can be removed from wastewater by adsorption and

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ion exchange which is widely used in the industry [4,5]. The heavy metal removal from wastewater using ion exchange and adsorption was studied by several researchers [6–9]. They found out that the cationic exchange resin has a great potential for heavy metal removal from wastewaters. Furthermore, adsorption on the activated carbon showed a great performance for Ni removal from wastewater [3].

The main goal of this study is to develop a process to remove V and Ni to meet the environmental limitations which are 0.0662 and 0.4 mg/L for V and Ni, respectively. To achieve this goal, the V and Ni removal rate and capacity from industrial wastewater using ion exchange resin (VD-25XT, Dynalene Inc. Product) and activated carbon (AC-NV-01, Dynalene Inc. Product) are determined. The experiments were conducted by treating wastewater samples in single- and two-stage process (batch operation) and a two-stage column adsorption process (continuous operation).

2. Experiments

Wastewater samples were obtained from an Industrial wastewater treatment facility. VD-25XT and AC-NV-01 were obtained from Dynalene Inc. The wastewater was filtered before starting the experiments to remove the particles and debris. Two sets of experiments were conducted. The first set was batch experiments in which the experiments were carried out in single- and two-stage processes. For the batch experiments, two regeneration methods were utilized. In the first method, hydrochloric acid was used to regenerate VD-25XT and in the second method, the VD-25XT was regenerated by sodium hydroxide. Table 1 shows the experimental conditions for the single-stage batch experiments.

Table 1. Experimental conditions for the batch operations

Run	Treatment Type	Regenerant
1	Single-stage	Hydrochloric acid
2	Single-stage	Hydrochloric acid
3	Single-stage	Hydrochloric acid
4	Single-stage	Hydrochloric acid
5	Single-stage	Sodium hydroxide
6	Single-stage	Sodium hydroxide
7	Single-stage	Sodium hydroxide
8	Single-stage	Sodium hydroxide
9	Two-stages	Hydrochloric acid
10	Two-stages	Hydrochloric acid

VD-25XT was regenerated using hydrochloric acid and sodium hydroxide solutions. Then, the VD-25XT was filtered, washed, and stored in the ultra-pure water for the experiments. The VD-25XT and sample solutions were prepared. The prepared mixtures were stirred and then, filtered using a vacuum pump. The samples were analyzed to determine V and Ni concentrations.

After analyzing the results from the single-stage processes, a two-stage process was proposed to continue the investigation. The hydrochloric acid was chosen as regenerant based on the results determined (see next section). First, the VD-25XT was regenerated using a similar procedure as described before. Then, the regenerated VD-25XT was used to treat a wastewater sample. The treated sample was filtered to separate wastewater sample from the VD-25XT. The second stage of this treatment was conducted by treating the sample with AC-NV-01. A similar procedure was used to process the sample using AC-NV-01. This experiment repeated by processing the wastewater sample with AC-NV-01 at first and then with regenerated VD-25XT.

The second set of experiments were performed by conducting experiments in a two-stage column adsorption procedure by VD-25XT and AC-NV-01. The processed wastewater recycled to the columns three times to determine the lowest possible concentrations for V and Ni.

Samples were taken at different times to determine V and Ni concentration as well as VD-25XT's saturation point. For the continuous processes, the experiments were repeated after regeneration of the used VD-25XT in the column to determine VD-25XT's stability and performance.

3. Results

Table 2 shows the V and Ni concentrations for the single-and two-stage batch processes. The results show that V is better removed from the wastewater samples when hydrochloric acid was used as a regenerant for VD-25XT. Initially, the concentration of V and Ni in the wastewater samples were 4.5 and 0.89 mg/L, respectively. In this method, 93.6 percent of the V is removed from samples (see Table 2). In contrast, using sodium hydroxide as a VD-25XT regenerant does not have a large impact on the V removal (see Table 2).

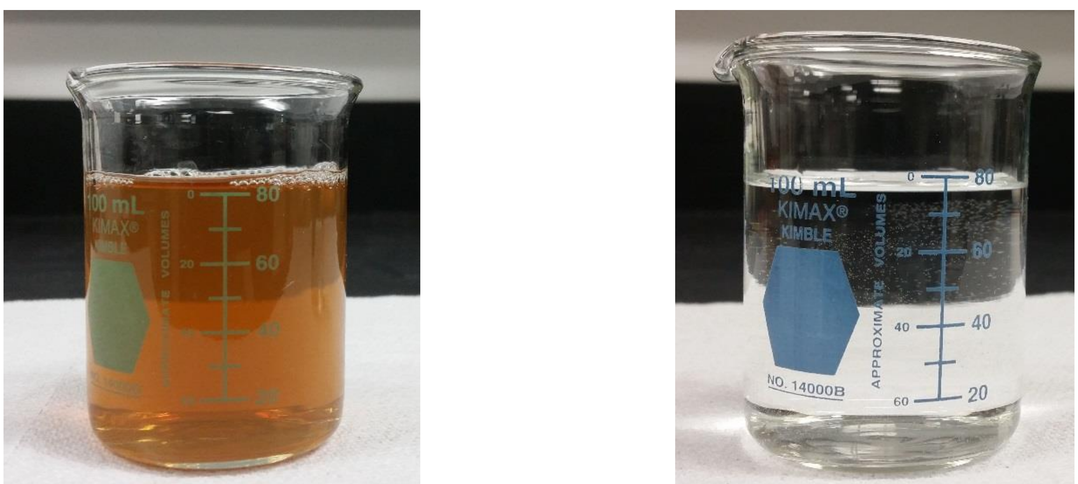
Table 2. Experimental results for the batch operations

Run	Treatment Type	V Concentration (mg/L)	V Removal Percent	Ni Concentration (mg/L)	Ni Removal Percent
1	Single-stage	1.3	71.1	0.69	22.5
2	Single-stage	1.4	68.9	0.69	22.5
3	Single-stage	0.79	82.4	0.70	21.3

4	Single-stage	0.29	93.6	0.64	28.1
5	Single-stage	3.5	22.2	0.67	24.7
6	Single-stage	3.5	22.2	0.66	25.8
7	Single-stage	3.4	24.4	0.64	28.1
8	Single-stage	3.2	28.9	0.62	30.3
9	Two-stages	0.11	97.6	0.0074	99.2
10	Two-stages	0.024	99.5	0.033	96.3

Ni is better adsorbed by the sodium hydroxide regenerated VD-25XT. 30.3 percent of Ni is adsorbed when sodium hydroxide used as a VD-25XT regenerant. However, the hydrochloric acid regenerated VD-25XT also showed almost similar results.

The treatment of wastewater samples using single-stage batch processes did not meet the environmental limitation for V and Ni. Therefore, the wastewater samples are treated using a two-stage batch process as described before. Since sodium hydroxide regeneration method does not have a large impact on the V and Ni adsorption, the VD-25XT only regenerated by hydrochloric acid for the rest of the experiments. The results are summarized in Table 2. The first sample was first treated using VD-25XT and then, it was treated by AC-NV-01. The results showed that 97.6 percent of V is adsorbed. Also, 99.2 percent of Ni is removed. Furthermore, the treatment process removes the color and odor of the wastewater sample. Figure 1 shows the wastewater sample before and after the treatment process.



(a) (b)

Figure 1. Wastewater sample: a) before process b) after process

The second sample was treated with AC-NV-01 first, and then it was treated by VD-25XT. The results indicate that 99.5 percent of V removed during the treatment process. Furthermore, 96.3 percent of Ni was adsorbed. The studied two-stage batch processes meet environmental limitations. Therefore, column adsorption processes were conducted based on the results of the two-stage batch processes to remove V and Ni simultaneously in a continuous process.

Table 3 and 4 show the V and Ni removal percentages for the column experiments. The results showed that the maximum removal percentage of V is 98.4. The recycling wastewater did not have a large effect on V removal. However, it helps to decrease the V concentration to below the allowable concentration (0.0662 mg/L). Furthermore, %95.1 Ni was removed using adsorption columns. The results after VD-25XT regeneration shows that the removal rate for V and Ni is similar to the fresh VD-25XT. Therefore, VD-25XT is stable and regeneratable (see Table 4). The tested continuous process for simultaneous removal of V and Ni meets the environmental limitations for wastewater effluents.

Table 3. Experimental results for the continuous operations

Run	Recycle Count	V Concentration (mg/L)	V Removal Percent	Ni Concentration (mg/L)	Ni Removal Percent
1	0	0.12	97.3	0.044	95.1
2	1	0.55	87.8	0.30	66.3
3	2	0.30	98.3	0.17	80.1

Table 4. Experimental results for the continuous operations after VD-25XT regeneration

Run	Recycle Count	V Concentration (mg/L)	V Removal Percent	Ni Concentration (mg/L)	Ni Removal Percent
1	0	0.073	98.4	0.044	95.1
2	1	0.13	97.1	0.044	95.1
3	2	0.072	98.4	0.044	95.1

4. Conclusion

The experiments to study the vanadium (V) and nickel (Ni) removal using ion exchange resin (VD-25XT) and activated carbon (AC-NV-01) are conducted. The results indicated that VD-25XT can remove 93.6 and 30.3 percent of the V and Ni from the wastewater samples by treating the samples in a single-stage batch process, respectively. Furthermore, the two-stage batch process showed a good performance for V and Ni removal from wastewater in which at least 96 percent of each metal was removed. Furthermore, V and Ni removal was studied in a two-stage continuous process (adsorption columns) and the results indicated that 98.4% of V and 95.1% of Ni can be removed from the wastewater. The results showed that the two-stage batch and continuous processes meet the environmental limitation for V and Ni disposal.

Ion exchange using VD-25XT and adsorption on the AC-NV-01 showed a great performance for simultaneous removal of V and Ni. The lowest achievable V and Ni concentrations using two-stage batch process 0.024 and 0.033 mg/L, respectively. Also, 0.072 and 0.044 are the lowest attainable concentrations for the V and Ni, respectively. Both V and Ni were well removed from wastewater samples using a two-stage batch or continuous process. Therefore, a two-stage process, batch or continuous, is recommended for simultaneous removal of V and Ni from industrial wastewaters.

5. References

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