Statically Evaluation of Factors Affecting the Leaching Performance of Metal Coating Industry

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Abstract

Heavy metal pollution has become one of the most serious environmental problems today. In recent years various methods for heavy metal removal from wastewater have been extensively studied. Metal electroplating waste sludge is a heavy metals-bearing byproduct that comes from the electroplating industry's activities. Some of it consists of multiple metals such as copper, nickel, zinc, chromium, and iron, etc. all together in a complicated liquid solid mixture. It is a discharged residue after chemical precipitation of heavy metals from acidic or alkaline solutions as well as rinse waters generated by the electroplating processes. The sludge is categorized as hazardous waste heavy metals accumulated in sewage sludge during wastewater treatment can be leached out by (i) acid addition (ii, iron oxidation using thiobacillus ferrooxidans or (iii) sulphur oxidation using Thiobacillus thioparus,and Thiobacillus thiooxidans. In this study, a factorial experimental design tecgnique was used to investigate the leaaching of sulfuric acid from electroplating processes sludge. Factorial design of experiments is employed to study the effect of three factors pH (2 and 7), solid loading rate (1, 5 and 8 g in 50 mL water) and time (2 and 24 hours) at the levels low and high. Main effects of three factors were analyzed using statically techniques. A regression model suggested and it was found to fit the experimental data very well. The results were analyzed statically using Minitab 16 software and lack of fit to define most important process variables affecting the percentage.

Key words: Leaching, heavy metal, factorial design

1. Introduction

Environmental remediation technologies include in situ or ex situ techniques for decontaminating the polluted soils, such as soil-washing, physical separation, biological treatment, phytoremediation, and leaching [1].

Metal electroplating waste sludge are defined as hazardous waste. If not handled properly, it will cause very serious harmful effect to the environment, animals and human health. On the other hand, there are so much valued metals in the Cu, Ni, Pb and Zn.. . etc. Therefore, recycling of these spent batteries is necessary and important from both economical aspect as well as environmental protection [2]. Recycling processes make economic sense where the recovered materials are chemically important, quite valuable, and to avoid disposal costs. Furthermore, the metal value in waste sludge when recovered, represents an important secondary source for these metals with a higher grade than those found in natural minerals and ores. Different pyrometallurgical and hydrometallurgical processes were investigated to leach and recover such valuable metal components from metal electroplating waste sludge [3].

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There is a need to better understand copper leaching for the successful implementation of industrial hydrometallurgical leaching [4]. To determine the leaching parameters, the dissolution of sludge in sulphuric acid solutions has been recently studied by full factorial design method.

2. Materials and Methods

2.1. Leaching Experiments

In the scope with this study, waste sludge emerged metal plating ındustry processes was leached with H_2SO_4. Magnetic stirrer was used for experiments. In this experiments was it was examined affects of parameters including of pH, time and solid rate. In this study, affects of maximum and minimum parameters values was investigated to yield of leaching. Trials for pH 2 and 7, for time 2 and 24 hours; for solid rate 2 and 8 mg waste sludge/ 50 mL solution of leaching was done and was recorded yield of leaching. As a result of, with this leaching data was made factorial experimental design.

2.2. Factorial experimental design

Factorial design is employed to reduce the total number of experiments in order to achieve the best overall optimization of the system. It was used to reduce the number of experiments, time, overall process cost and to obtain better response [5]. The design determines that factors have important effects on a response as well as how the effect of one factor varies with the level of the other factors. The number of experimental runs at b levels is b^k, where k is the number of factors [6]. Today, the most widely used kind of experimental design, to estimate main effects as well as interaction effects, is the 2^p factorial design in which each variable is investigated at two levels [7].

The high and low levels defined for the 2^3 factorial designs were listed in Table1. The low and high levels for the factors were selected according to some preliminary experiments. The leaching efficiency was determined as average of two parallel experiments. The order in which the experiments were made was randomized to avoid systematic errors. The results were analyzed with the Minitab 16 software, and the main effects and interactions between factors were determined.

Table 1. Factors and levels used in the factorial design.

Factor	Coded Symbol	Low Level (-1)	High Level (+1)
pH	*A*	2	7
Solid rate (g/50 mL)	*B*	1	8
Time (hour)	*C*	2	24

3. Result and Discussion

Results are shown in the Table 2. The efficiency was defined as

$$R = \frac{(C_o - C_e)}{C_o} 100 \qquad (1)$$

where C_0 is initial concentration and C_e is final concentration of copper in the solution. The results were analyzed using MINITAB 16 for windows. The main effects were determined. The effect of a factor is the change in response, here, percentage copper recycling produced by a change in the level of a factor, pH, solid rate and time form lower to higher level.

Table 2. Experimental datas.

pH	Solid rate (g/mL)	Time (hour)	% Efficiency (R)
-1	-1	-1	61,13
1	-1	-1	1,81
-1	1	-1	28,23
1	1	-1	4,27
-1	-1	1	94,04
1	-1	1	0,23
-1	1	1	8,91
1	1	1	3,44
-1	-1	-1	61,14
1	-1	-1	1,83
-1	1	-1	28,22
1	1	-1	4,26
-1	-1	1	94,05
1	-1	1	0,24
-1	1	1	8,91
1	1	1	3,45

The main effects plots were generated to represent the results of regression analysis. It shows only the factors that were significant at the 95% confidence interval. The main effects represent deviations of the average between the high and low levels for each factor. When the effect of a factor is positive, efficiency increases as the factor changes from low to high levels. In contrast, if effects are negative, a reduction in efficiency occurs for high level of the same factor [8].

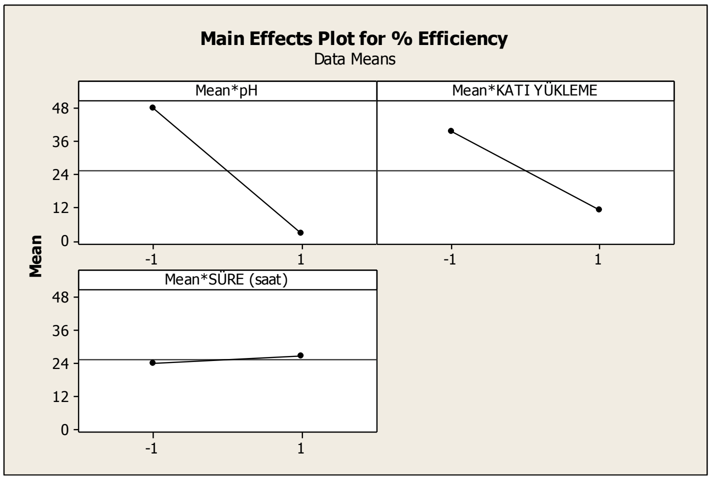

Figure 1. Main effects for percentage leaching efficiency

Fig. 1. shows the main effects of the three factors on percentage copper recycling. The main effects plots were generated to represent the results of regression analysis. In figure, the parameter pH and solid rate that has a negative influence upon leaching process efficiency can be seen. The time has a very weak positive effect upon responses.

In Table 3, the sum of squares used to estimate the factors effects and *F-ratios* are shown. The effects are statistically significant when *P-value*, defined as the smallest level of significance leading to rejection of null hypothesis, is less than 0.05.

Table 3. Analysis of Variance

Analysis of Variance for % efficiency (coded units)						
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	3	11520,1	11520,1	3840,04	78411410,64	0,00
pH	1	8330,9	8330,9	8330,88	1,70112E+08	0,00
SOLİD RATE	1	3157,9	3157,9	3157,95	64483473,98	0,00
TİME (HOUR)	1	31,3	31,3	31,29	638917,46	0,00
2-Way Interactions	3	4551,5	4551,5	1517,18	30979946,82	0,00
pH* SOLİD RATE	1	3825,5	3825,5	3825,46	78113653,70	0,00
pH* TİME (HOUR)	1	64,0	64,0	64,04	1307699,79	0,00
SOLİD RATE * TİME (HOUR)	1	662,0	662,0	662,04	13518486,97	0,00
3-Way Interactions	1	702,0	702,0	702,00	14334482,22	0,00
pH*SOLİD RATE* TİME (HOUR)	1	702,0	702,0	702,00	14334482,22	0,00
Residual Error	8	0,0	0,0	0,00		
Pure Error	8	0,0	0,0	0,00		
Total	15	16773,7				

3.1. Analysis of variance (ANOVA)

Based on the student's *t-test* and *F-test*, few interaction effects which seem insignificant compared to other effects, were neglected and the effect, regression coefficient, standard error, *t* and *p-value* were recalculated with remaining variables. Resultant values are shown in Table 4. Reduced Model Equation with resultant coefficients were

% R= 25.26 -22.82 pH – 14.05 solid rate + 1.40 time + 15.46 ph solid rate – 2.00 ph* time – 6.43 solid rate * time + 6.62 solid rate * time* (2)

Table 4. Estimated effects and coefficient

Estimated Effects and Coefficients for % efficiency (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		25,26	0,001750	14439,71	0,000
pH	-45,64	-22,82	0,001750	-13042,69	0,000
SOLİD RATE	-28,10	-14,05	0,001750	-8030,16	0,000
TİME (HOUR)	2,80	1,40	0,001750	799,32	0,000
pH* SOLİD RATE	30,93	15,46	0,001750	8838,19	0,000
pH* TİME (HOUR)	-4,00	-2,00	0,001750	-1143,55	0,000
SOLİD RATE * TİME (HOUR)	-12,87	-6,43	0,001750	-3676,75	0,000
pH*SOLİD RATE* TİME (HOUR)	13,25	6,62	0,001750	3786,09	0,000

S = 0,00699807 PRESS = 0,00156713
R-Sq = 100,00% R-Sq(pred) = 100,00% R-Sq(adj) = 100,00%

Conclusions

As a result of experiments, it was examined effects of parameters including of pH, time and solid rate to leaching process. It was determined leaching yields at maximum and minimum parameter values with experiments. Using this yield values, it was designed experiments with MINITAB 16 for windows. The main effects were determined. The effect of a factor is the change in response, here, percentage copper recycling produced by a change in the level of a factor, pH, solid rate and time form lower to higher level. The main effects plots were generated to represent the results of regression analysis. Using Analysis of variance (*ANOVA*) it was determined Reduced Model Equation for reach to results. It can be estimated effects and coefficients for leaching processes with this Reduced Model Equation.

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