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# Optimization of Whey Treatment in Rotating Biological Contactor: Application of Taguchi Method

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Industrial waste management is the main concern of sustainable environment, and the proper control and operation of wastewater treatment plants for efficient removal of pollutants are certainly important. In this study, the L16 orthogonal array of the Taguchi method was applied to determine the optimum condition of some controlling parameters such as organic loading rate, hydraulic retention time, number of stages, rotational speed and recycling for treating whey effluent in a rotating biological contactor (RBC). In order to determine the impacts of levels and factors, the optimum condition of the experiment was predicted and determined. QUALITEK-4 has reported 76.25% COD removal based on a desired experimental condition (COD: 50000 mg L−1, HRT: 24 h, No. of stages: 3). To improve the performance of the RBC, second optimum condition (COD: 50000 mg L−1, HRT: 24 h, recycling: positive, rotational speed: 10 rpm, No. of stages: 3) was also investigated. According to the above-stated conditions, the highest COD removal was found to be 98%. Furthermore, two sets of test experiments were also conducted in lab scale under optimum conditions, and the prediction of other combinations of factors/levels was evaluated. Overall, the experimental results demonstrated that Taguchi method was able to predict COD removal with an average relative error of 6.5%.

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## INTRODUCTION

Environmental protection is one of the most important concerns of mankind. Discharge of industrial effluents may cause serious environmental pollution. Based on the nature of industrial effluents, suitable treatment methods should be employed. The disposal of whey produced in process of cheese production has always created a major problem in the dairy industry. Cheese effluents exhibited high COD values in the interval of 0.8–102 g $L^{-1}$ and BOD values in the range of 0.6–60 g $L^{-1}$ leading to a high consumption of dissolved oxygen in water bodies [1, 2]. In the last few decades, technological and economic advancement made it possible to recover soluble proteins from cheese whey [3]. However, whey reuse is not applicable with small dairies which produce cheese and their whey is discharged as waste with the rest of wastewater. As a result, their waste discharge loaded with organic material and other pollutants may cause environmental problems especially pollution in groundwater sources. Generally, biological treatment processes are mainly used to treat cheese whey wastewater [1, 4-9].

Based on microorganism growth, two distinct types of biological treatment processes exist known as, attached growth and suspended growth. Attached growth process is more stable than suspended growth; particularly when the wastewater includes high concentration of organic matter (up to 60 g COD $L^{-1}$), and high biodegradability. Very low bicarbonate alkalinity of cheese whey wastewater limits its direct treatment in high-rate anaerobic reactors that is probably due to problems encountered in maintaining stable operation [1, 8-10].

Aerobic rotating biological contactor (RBC) has several advantages such as short retention time, low power consumption, high biomass concentration, handling a wide range of flows and low sludge generation [8, 11]. Performance of RBC reactor was operated for high-strength wastewaters of poultry, palm oil mill effluent and landfill leachate [12-15].

The appropriate operation and maintenance of wastewater treatment plants became a major issue due to increasing concern for environmental pollution. In order to enhance the total efficacy of wastewater treatment plants, it is essential to use a robust model to predict

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certain key parameters of the influent based on previous observations. A Full factorial design (FFD) is a method of experiment design in which the effect(s) of two or more factors\variables, each with discrete values\levels and their possible interactions are determined. In this method, experimental units take on all possible combinations of these levels across all such factors. In most cases, use of FFD is extremely time-consuming, especially when the number of factors or levels increases. Taguchi as a family of FFE matrices was developed to minimize and control variation in a product or process and the number of tests required [16-19]. Using this method, the optimum experimental conditions can be easily determined. Up to now, Taguchi method has been extensively used to obtain the optimum process parameters in different areas such as developing space vehicles [20], agricultural products [21], physical activities[22], telecommunications [23], wastewater treatment [24, 25], structure [26], power [27, 28], metals manufacturing [29, 30], milling [31], engineering [27, 32, 33] and medical science [34].

In this study, the influence of some operating conditions such as organic loading rate, hydraulic retention time, number of stages, rotational speed and recycling in the treatment of whey effluent by RBC was investigated. Moreover, in order to optimize the design of an existing process, it is necessary to identify which factor has the greatest influence; thus some experiments were conducted using Taguchi experimental design.

## MATERIAL AND METHODS

### RBC experiment

A 3-stage RBC similar to our previous study was built [2, 4, 8]. The RBC consisted of three equal-size compartments (75×35×30 $cm^3$/each), separated by fixed baffle plates with 16 lightweight PVC discs in each compartment. The total volume of RBC was 78.75 L. Discs mounted on a galvanized metal shaft had diameter of 32 cm, 3 mm thickness and interspacing of 8 mm. The total surface area available for microorganism growth on discs was 7.1 $m^2$. A changeable speed motor (NORD motor, model SK 63/4, Germany) was used to rotate the shaft with mounted discs. Based on steady-state assumption, the samples were taken for each volumetric flow rate after two times of corresponding retention time. The fresh raw wastewater was collected in a 20 liters container, then transported to the laboratory on a daily basis and finally refrigerated and stored at 4$^o$C to prevent from acidification and undesirable changes in their chemical composition. Diluted whey was fed into the reactor at pH 6.5 during the adaptation phase. Several dilutions of cheese whey were prepared using distilled water based on requirements of the tests. For the adjustment of feed pH to 6.5, a 6 M sodium hydroxide solution was used. The cheese whey used in this study was obtained from “Gela Factory” (Amol, Iran), which was collected from ultra-filtration process for the production of cheese.

The RBC reactor was inoculated with 10 L of the sludge with MLSS value of 3000 mg $L^{-1}$ which was obtained from the mentioned wastewater treatment plant. In order to form an initial accumulation of biofilm, the reactor was fed with raw whey containing 0.4 g COD $L^{-1}$ $d^{-1}$ at rotating speed of 4 rpm and HRT of 36 h. The amount of biofilm formed on the rotating discs was observed on the seventh day and then a fast biofilm accumulation was observed. The COD removal rate achieved 81% on the 12th days; that suggested the start-up of the RBC was completed. During the operation, the heavy biomass/ biofilm deposited on net-like discs at the three stages were 383.4, 311.1 and 175.2 g $m^{-2}$, respectively. The fabricated pilot unit with and without biofilm on the surface of discs are shown in Figure 1. The reactor design and operation parameters are summarized in Table 1.

**Figure 1**. The pilot RBC before and after developing biofilm

**TABLE 1**. The reactor design and operation parameters

| Reactor specifications | Value (type) |
|---|---|
| Geometrical shape | Rectangular |
| Number of stages | 3 |
| Number of discs in each stage | 16 |
| Disc diameter (mm) | 320 |
| Interspacing (mm) | 8 |
| Specific area ($m^2$) | 7.93 |
| Specific area after modification ($m^2$) | 8.72 |
| Working volume (L) | 65.6 |
| Submerge percentage (%) | 40 |
| Speed of rotation (rpm) | 4 |

**Analytical methods**
The collected samples were settled for 30 minutes to analyze COD and biomass concentration. Standard methods for the examination of water and wastewater were used to measure TSS and DO indicators [35]. In order to measure COD, a colorimetric method with closed reflux method was developed. Spectrophotometer (UNICO 2100, USA) at 600 nm was used to measure the absorbance of samples. Biofilm weight was subsequently quantified by a specified methodology: first, the biomass flashed off from a piece of meshed material by water, and then this effluent filtered with 0.45 µm membrane and dried for at least 24 h at 105 ºC. DO and pH meter (Hanna HI9024) were used to measure pH and dissolved oxygen. The reactor temperature was maintained basically at the room temperature (22 ºC).

**DOE (Design of Experiment)**
**Experiment No.1** The most important stage in the design of an experiment is the selection of the control factors from the major influential items involved; in this study, from both theoretical and empirical points of view and set their respective levels accordingly and appropriately. Table 2 indicates all factors and levels that might affect our experiment.

**Signal-to-noise ratio**
In Taguchi designs, the signal to noise ratio (S/N ratio), was used to identify control factors that reduce variability in the process by minimizing the effects of uncontrollable factors (noise factors). The term “signal” represents the desirable control factors during the process and “noise” represents the undesirable effect. The S/N ratio can be calculated by the following equation [36]:

$$\frac{S}{N}\ \text{ratio} = -10\log(\text{MSD}) \qquad (1)$$

Where “MSD” is the Mean Square Deviation, which was obtained using equation (2) [36].

$$\text{MSD} = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{Y_i^2} \qquad (2)$$

Where ‘n’ is the number of repetitions and ‘$Y_i$’ is the observed data obtained from the present experimental work. Note that there are three main categories of the quality characteristics, they are: i. smaller is better, ii. nominal is better and iii. bigger is better. To obtain high percentage of COD removal, the ‘bigger is better’ quality characteristic was chosen.

**TABLE 2.** Factors and their levels considered in the Taguchi DOE

| Factors | Level1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|---|
| COD(g $L^{-1}$) | 40 | 50 | 60 | 70 |
| HRT(h) | 12 | 16 | 24 | 36 |
| STAGE | 1 | 2 | 3 | - |

**RESULTS AND DISCUSSION**

**Experiment No. 1**
In our experiment, Taguchi method proposes 16 conditions of the experiment to conduct for 2-4 level-factors and 1-3 level- factor. The experimental conditions were obtained by combining Table 3 and the M16 orthogonal array. The result of each experiment is entered by its trial number in Table 4, respectively. Numbers in front of trials represents levels of factors chosen for each trial. This method demands the result of each condition for calculating variations and efficacy of each level of each factor in the outcome of our experiment.

Results of experiments are based on the percentage of COD removal. QUALITEK-4 calculates ideal condition and evaluates the obtained results and projected data of 16 designed experiments. Based on the different given data, Taguchi method demonstrated how each factor quantitatively or even each level of them can influence the results of our experiments. The mean values of S/N ratios for COD removal are shown in Figure 2.

**TABLE 3.** Result of experiment, M16 orthogonal array

| Trial No. | COD | HRT | STAGE No. | ılts of Exp. (COD removal %) |
|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 41 |
| 2 | 1 | 2 | 2 | 60 |
| 3 | 1 | 3 | 3 | 66 |
| 4 | 1 | 4 | 1 | 55 |
| 5 | 2 | 1 | 3 | 72 |
| 6 | 2 | 2 | 1 | 46 |
| 7 | 2 | 3 | 1 | 58 |
| 8 | 2 | 4 | 2 | 64 |
| 9 | 3 | 1 | 1 | 28 |
| 10 | 3 | 2 | 3 | 53 |
| 11 | 3 | 3 | 2 | 62 |
| 12 | 3 | 4 | 1 | 54 |
| 13 | 4 | 1 | 2 | 23 |
| 14 | 4 | 2 | 1 | 21 |
| 15 | 4 | 3 | 1 | 34 |
| 16 | 4 | 4 | 3 | 35 |

**TABLE 4.** Results of designed experiments

| Trial No. | Results of .exp (COD removal % ) | No. of trials | STAGE No. | Results of exp. (COD removal % ) |
|---|---|---|---|---|
| 1 | 41 | 9 | 28 | 41 |
| 2 | 60 | 10 | 53 | 60 |
| 3 | 66 | 11 | 62 | 66 |
| 4 | 55 | 12 | 54 | 55 |
| 5 | 72 | 13 | 23 | 72 |
| 6 | 46 | 14 | 21 | 46 |
| 7 | 58 | 15 | 34 | 58 |
| 8 | 64 | 16 | 45 | 64 |

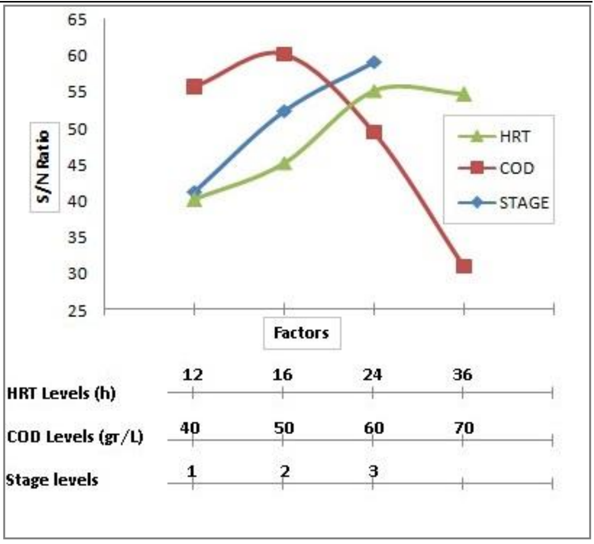


**Figure 2.** Effect of different factors on S/N ratio in experiment No. 1

Among the levels of each factor, there is only one level which is the most effective level than others. It demonstrates the importance of noted levels with higher effectiveness rates in our study; these are essential to pursuing "bigger is better" characteristic.

The knowledge of the contribution of individual parameters is critically important for the control of the final response. In order to study the significance of the parameters in affecting the quality characteristic of COD removal, ANOVA was performed. Table 5 shows the results of analysis of variance (ANOVA) for the COD removal.

Where DOF stands for the degree of freedom, SS is the sum of squares and the variance is mean square factor. Also, F-ratio for each process parameter is simply a ratio of the mean of the squared deviations to the mean of squared errors. Percent is contribution percentage of each factor on the response which indicates the influences of factors and interactions assigned to the column to the variations of the results.

The row labeled other/error, contains information about the sources of variability of the results which indicates information about the influence from three sources.

1. Experimental error
2. Factors which are not included in the experiment
3. Uncontrollable noise factors [37].

Thus, based on the S/N ratio and ANOVA analyses, the optimum condition of the conducted experiment can be predicted and reported. At the optimum condition (COD= 50000 mg $L^{-1}$, HRT=24, Stage No. = 3) QUALITEK-4 has predicted COD removal of 76.25%. Implementation of the above optimal condition has resulted in 71% COD removal. The small deviation (error of 6.8%) was generally caused by the factor which was devoted by noise factor. Such error caused insufficient COD removal which was due to the limitation in oxygen mass transfer and disc surface area for the attached growth system. The fact is, COD removal efficiency increased with an increase in HRT and the system achieved the highest COD removal efficiency at the HRT of 24 h. Normally, high HRT provides enough contact time for the biodegradation of organic matter in the reactor and hence, a long contact time between support media and wastewater; that may enhance the pollutant removal efficiency. The justification might be the result of enough time for attachment of microorganisms on disk's surface and hence, developing a very active biomass layer on disk's surface. Furthermore, a slight decline in the trend of COD removal from HRT of 24 to 36 h could be attributed to the increasing of biofilm layer thickness presented on the disk's surface at highest HRT, which resulted in reducing oxygen mass transfer. For having sufficient COD removal, the experiment was improved and the other parameters for a desired contact time of microorganisms were considered in experiment No. 2.

**Experiment No. 2**

Two effective items were suggested to be added to Table 2. These items include rotational speed and recirculation rate. Since it was observed in previous studies, these items have an effect on reactor performance in COD removal [38, 39]. Therefore, the alternative optimum result for our new DOE conditions was investigated and the results are shown in Table 6. L16 arrays were selected to design and calculate based on the average value of the results. The result of each experiment is shown in Table 7.

**TABLE 5.** Analysis of variance in ANOVA table

| FACTOR | DOF | SS | Variance | F-Ratio | Pure sum | Percent |
|---|---|---|---|---|---|---|
| COD | 3 | 1985.25 | 661.75 | 14.676 | 1849.982 | 49.921 |
| HRT | 3 | 584.75 | 194.916 | 4.322 | 449.482 | 12.129 |
| STAGE | 2 | 820.125 | 410.062 | 9.094 | 729.946 | 19.697 |
| Other/error | 7 | 315.625 | 45.089 | | | 18.253 |
| Total | 15 | | | | | 100 |

**TABLE 6.** Factors and levels in experiment no. 2

| Factors | Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|---|
| COD | 40000 | 50000 | 60000 | 70000 |
| HRT | 12 | 16 | 24 | 36 |
| Recycling | Positive | Negative | - | - |
| Rotational speed | 4 | 10 | - | - |
| STAGE | 1 | 2 | 3 | _ |

Similarly, the quality characteristic was set on optimized parameter “bigger-is-better” and experiments and calculations to read final and optimized outcome proceeded similarly to experiment No. 1. The control factors indicate the trend of influence and variations of factors with their levels. Figure 3 displays plots which show the influence of each factor in the studied levels. COD, HRT, and stage No. had the same behavior as experiment No. 1.

As it was discussed earlier, recycling plot remains no discussion on its positive effect in experiment No. 2. Also, rotational speed comes with 2 levels, 4 rpm and 10 rpm. The plot shows that high speed (10 rpm) improved the results. Table 8 summarized optimum conditions in new design experiment No. 2.

In the second optimum condition COD: 50000, HRT: 24, recycling: positive, rotational speed: 10 rpm, stage No.: 3 expected COD removal was 98 %. The findings confirmed that the result of the second experiment by means of determining the robust design condition was mostly similar with experiment No. 1. However, the outcome of the second condition is the much elegant condition.

The result indicates that the COD removal improves when rotational speed increases from 4 to 10 rpm. The main reason was due to an increase in dissolved oxygen (DO) level when the rotational speed increased to 10 rpm. In fact, in low rotational speed, the rate of aeration was not as necessarily enough to treat the wastewater. Therefore, after few days of operation, the bad odor was spread out due to the oxygen depletion. In addition, COD removal efficiency was firmly affected by recirculation. It was concluded that the recirculation may be beneficial when the inlet organic loading rate of chemical shock was extremely high.

Similar to the previous result, using these conditions for COD removal from experiment resulted in 92% COD removal, only 6.1% less than obtained result by Taguchi model, and very close to experiment No. 1. The obtained results prove that the proposed method with fair accuracy can be employed for the different experimental conditions.

## CONCLUSION

Using Taguchi method, the optimum conditions of whey treatment using RBC reactor were investigated. This study examined the power of Taguchi’s optimization method to predict the COD removal in response to different combinations of factors/levels through conducting a very limited number of experiments with an acceptable level of accuracy. The results showed that Taguchi method was successfully able to model the COD removal in RBC reactor. Moreover, the percentage contribution of each studied factor to whey treatment was also determined using the procedure explained by the method. The information generated in this study might help environmental engineers and managers to come up with suitable decisions in dealing with waste treatment. It is highly recommended to conduct further studies with other determinant factors for COD removal; that might allow drawing the comprehensive conclusion.

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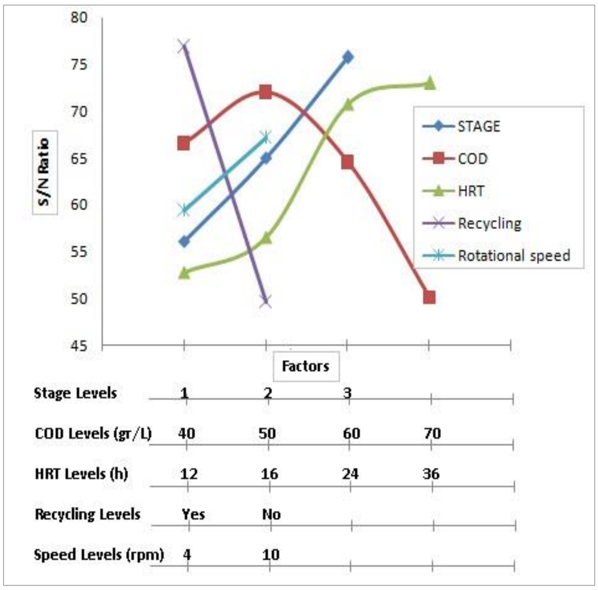


**Figure 3.** Effect of different factors on S/N ratio in experiment No. 2

**TABLE 7.** L-16 New DOE, results input

| Trial No. | COD | HRT | Recycling | Rotation | Stage No. | (COD removal %) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 58 |
| 2 | 1 | 2 | 1 | 1 | 2 | 73 |
| 3 | 1 | 3 | 2 | 2 | 3 | 74 |
| 4 | 1 | 4 | 2 | 2 | 1 | 61 |
| 5 | 2 | 1 | 1 | 2 | 3 | 94 |
| 6 | 2 | 2 | 1 | 2 | 1 | 72 |
| 7 | 2 | 3 | 2 | 1 | 1 | 58 |
| 8 | 2 | 4 | 2 | 1 | 2 | 64 |
| 9 | 3 | 1 | 2 | 1 | 1 | 28 |
| 10 | 3 | 2 | 2 | 1 | 3 | 53 |
| 11 | 3 | 3 | 1 | 2 | 2 | 92 |
| 12 | 3 | 4 | 1 | 2 | 1 | 85 |
| 13 | 4 | 1 | 2 | 2 | 2 | 31 |
| 14 | 4 | 2 | 2 | 2 | 1 | 28 |
| 15 | 4 | 3 | 1 | 1 | 1 | 59 |
| 16 | 4 | 4 | 1 | 1 | 3 | 82 |

**Table 8.** Optimum condition in experiment No. 2

| Factor | Level | No. of Level | Contribution |
|---|---|---|---|
| COD (g $L^{-1}$) | 50000 | 2 | 8.75 |
| HRT(h) | 36 | 4 | 9.75 |
| Recycling | Positive | 1 | 13.625 |
| Rotational speed (rpm) | 10 | 2 | 3.875 |
| STAGE | 3 | 3 | 12.5 |

## REFERENCES


1. Janczukowicz, W., M. Zieliński and M. Dębowski, 2008. Biodegradability evaluation of dairy effluents originated in selected sections of dairy production. Bioresource Technology, 99(10): 4199-4205.
2. Ebrahimi, A., M. Asadi and G. Najafpour, 2009. Dairy wastewater treatment using three-stage rotating biological contactor (NRBC). International Journal of Engineering, 22(2): 107-114.
3. Bylund, G. and T. Pak, Dairy processing handbook2003: Tetra Pak Processing Systems AB Lund.
4. Ebrahimi, A., G.D. Najafpour, M. Mohammadi and B. Hashemiyeh, 2010. Biological treatment of whey in an UASFF bioreactor followed a three-stage RBC. Chemical Industry and Chemical Engineering Quarterly, 16(2): 175-182.
5. Yorgun, M., I.A. Balcioglu and O. Saygin, 2008. Performance comparison of ultrafiltration, nanofiltration and reverse osmosis on whey treatment. Desalination, 229(1): 204-216.
6. Farizoglu, B., B. Keskinler, E. Yildiz and A. Nuhoglu, 2007. Simultaneous removal of C, N, P from cheese whey by jet loop membrane bioreactor (JLMBR). Journal of hazardous materials, 146(1): 399-407.
7. Fang, H.H., 1991. Treatment of wastewater from a whey processing plant using activated sludge and anaerobic processes. Journal of dairy science, 74(6): 2015-2019.
8. Najafpour, G., A. Zinatizadeh and L. Lee, 2006. Performance of a three-stage aerobic RBC reactor in food canning wastewater treatment. Biochemical engineering journal, 30(3): 297-302.
9. Çinar, Ö., H. Hasar and C. Kinaci, 2006. Modeling of submerged membrane bioreactor treating cheese whey wastewater by artificial neural network. Journal of biotechnology, 123(2): 204-209.
10. Mba, D. and R. Bannister, 2007. Ensuring effluent standards by improving the design of Rotating Biological Contactors. Desalination, 208(1): 204-215.
11. Kubsad, V., S. Chaudhari and S. Gupta, 2004. Model for oxygen transfer in rotating biological contactor. Water research, 38(20): 4297-4304.
12. Najafpour, D.G., P.N. Naidu and A.H. Kamaruddin, 2008. Rotating biological contactor for biological treatment of poultry processing plant wastewater using Saccharomyces cerevisiae. ASEAN Journal of Chemical Engineering, 2(1): 1-6.
13. Najafpour, G., H.A. Yieng, H. Younesi and A. Zinatizadeh, 2005. Effect of organic loading on performance of rotating biological contactors using palm oil mill effluents. Process biochemistry, 40(8): 2879-2884.
14. Castillo, E., M. Vergara and Y. Moreno, 2007. Landfill leachate treatment using a rotating biological contactor and an upward-flow anaerobic sludge bed reactor. Waste Management, 27(5): 720-726.
15. Sirianuntapiboon, S. and C. Chuamkaew, 2007. Packed cage rotating biological contactor system for treatment of cyanide wastewater. Bioresource technology, 98(2): 266-272.
16. Erzurumlu, T. and B. Ozcelik, 2006. Minimization of warpage and sink index in injection-molded thermoplastic

parts using Taguchi optimization method. Materials & design, 27(10): 853-861.
17. Wang, T.-Y. and C.-Y. Huang, 2007. Improving forecasting performance by employing the Taguchi method. European journal of operational research, 176(2): 1052-1065.
18. Ho, W.-H., J.-T. Tsai, B.-T. Lin and J.-H. Chou, 2009. Adaptive network-based fuzzy inference system for prediction of surface roughness in end milling process using hybrid Taguchi-genetic learning algorithm. Expert Systems with Applications, 36(2): 3216-3222.
19. Taguchi, G. and D. Clausing, 1990. Robust quality. Harvard Business Review, 68(1): 65-75.
20. Singaravelu, J., D. Jeyakumar and B. Nageswara Rao, 2009. Taguchi's approach for reliability and safety assessments in the stage separation process of a multistage launch vehicle. Reliability Engineering & System Safety, 94(10): 1526-1541.
21. Oztop, M.H., S. Sahin and G. Sumnu, 2007. Optimization of microwave frying of potato slices by using Taguchi technique. Journal of Food Engineering, 79(1): 83-91.
22. Burton, M., A. Subic, M. Mazur and M. Leary, 2010. Systematic design customization of sport wheelchairs using the Taguchi method. Procedia Engineering, 2(2): 2659-2665.
23. Al-Darrab, I.A., Z.A. Khan, M.A. Zytoon and S.I. Ishrat, 2009. Application of the Taguchi method for optimization of parameters to maximize text message entering performance of mobile phone users. International Journal of Quality & Reliability Management, 26(5): 469-479.
24. Aber, S., D. Salari and M. Parsa, 2010. Employing the Taguchi method to obtain the optimum conditions of coagulation–flocculation process in tannery wastewater treatment. Chemical Engineering Journal, 162(1): 127-134.
25. Zolfaghari, G., A. Esmaili-Sari, M. Anbia, H. Younesi, S. Amirmahmoodi and A. Ghafari-Nazari, 2011. Taguchi optimization approach for Pb (II) and Hg (II) removal from aqueous solutions using modified mesoporous carbon. Journal of hazardous materials, 192(3): 1046-1055.
26. Türkmen, İ., R. Gül and C. Çelik, 2008. A Taguchi approach for investigation of some physical properties of concrete produced from mineral admixtures. Building and environment, 43(6): 1127-1137.
27. Rosa, J.L., A. Robin, M. Silva, C.A. Baldan and M.P. Peres, 2009. Electrodeposition of copper on titanium wires: Taguchi experimental design approach. Journal of Materials Processing Technology, 209(3): 1181-1188.
28. Zeng, M., L. Tang, M. Lin and Q. Wang, 2010. Optimization of heat exchangers with vortex-generator fin by Taguchi method. Applied Thermal Engineering, 30(13): 1775-1783.
29. Dingal, S., T. Pradhan, J.S. Sundar, A.R. Choudhury and S. Roy, 2008. The application of Taguchi's method in the experimental investigation of the laser sintering process. The International Journal of Advanced Manufacturing Technology, 38(9-10): 904-914.
30. Lakshminarayanan, A. and V. Balasubramanian, 2008. Process parameters optimization for friction stir welding of RDE-40 aluminium alloy using Taguchi technique. Transactions of Nonferrous Metals Society of China, 18(3): 548-554.
31. Zhang, J.Z., J.C. Chen and E.D. Kirby, 2007. Surface roughness optimization in an end-milling operation using the Taguchi design method. Journal of materials processing technology, 184(1): 233-239.
32. Palanikumar, K., 2008. Application of Taguchi and response surface methodologies for surface roughness in machining glass fiber reinforced plastics by PCD tooling. The International Journal of Advanced Manufacturing Technology, 36(1-2): 19-27.
33. Hasçalık, A. and U. Çaydaş, 2008. Optimization of turning parameters for surface roughness and tool life based on the Taguchi method. The International Journal of Advanced Manufacturing Technology, 38(9-10): 896-903.
34. Lin, C.L., S.H. Chang, W.J. Chang and Y.C. Kuo, 2007. Factorial analysis of variables influencing mechanical characteristics of a single tooth implant placed in the maxilla using finite element analysis and the statistics- based Taguchi method. European journal of oral sciences, 115(5): 408-416.
35. Apha, A., 1999. WEF, 2005. Standard methods for the examination of water and wastewater, 21: 258-259.
36. Naik, S.S. and Y.P. Setty, 2011. OPTIMIZATION OF PARAMETERS FOR DENITRIFICATION OF WASTEWATER USING FLUIDIZED BED BIOREACTOR BY TAGUCHI METHOD. International Journal of Biotechnology Applications, 3(3).
37. Madaeni, S. and S. Koocheki, 2006. Application of taguchi method in the optimization of wastewater treatment using spiral-wound reverse osmosis element. Chemical Engineering Journal, 119(1): 37-44.
38. Ayoub, G. and P. Saikaly, 2004. The combined effect of step-feed and recycling on RBC performance. Water research, 38(13): 3009-3016.
39. Costley, S. and F. Wallis, 1999. Effect of disk rotational speed on heavy metal accumulation by rotating biological contactor (RBC) biofilms. Letters in applied microbiology, 29(6): 401-405.

**Persian Abstract**

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**چکیده**

مدیریت زباله های صنعتی نگرانی اصلی محیط زیست پایدار است و کنترل و کارآمد گیاهان تصفیه پساب برای حذف موثر آلاینده ها قطعا اهمیت دارد. در این تحقیق، آرایه افقی L_16 از روش Taguchi برای تعیین وضعیت بهینه برخی از پارامترهای کنترل مانند سرعت بارگذاری آلی، مدت زمان هیدرولیکی، تعداد مراحل، سرعت چرخش و بازیافت برای درمان پساب پنیر در یک کنتاکتور بیولوژیکی چرخان استفاده شد (RBC). به منظور تعیین تأثیر سطوح و عوامل، شرایط مطلوب آزمایش پیش بینی و تعیین شد. QUALITEK-4 گزارش تخلیه 76.25 COD٪ را بر اساس شرایط آزمایشی مورد نظر (COD: 50000 میلی گرم L-1، HRT: 24 ساعت، تعداد مراحل: ۳) گزارش کرده است. برای بهبود عملکرد RBC، شرایط بهینه دوم (COD: 50000 میلی گرم $L^{-1}$، HRT: 24 ساعت، بازیافت: مثبت، چرخش سرعت: ۱۰ دور در دقیقه، تعداد مراحل: ۳) نیز مورد بررسی قرار گرفت. با توجه به شرایط فوق، بیشترین حذف 98 COD٪ بود. علاوه بر این، دو مجموعه آزمایش آزمایش نیز در آزمایشگاه در شرایط مطلوب انجام شد و پیش بینی ترکیبات دیگر عوامل / سطوح مورد بررسی قرار گرفت. به طور کلی، نتایج تجربی نشان داد که روش Taguchi قادر به پیش بینی حذف COD با خطای متوسط نسبی ۶,۵٪ بود.