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MODELING AND OPTIMIZATION OF THENITROGEN AND PHOSPHORUS REMOVAL FROM WASTEWATER BY INTERMITTENTCYCLINGAEROBIC-ANAEROBICBIOREACTOR WITH GRANULARACTIVATED CARBON BED (ICAAGAC)

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Abstract

The wastewater nutrient including nitrogen and phosphorus has become an emerging worldwide concern due to the growth of plant and algae in water resources. Consequently, it is necessary high efficient new methods be introduced. Today, integrated processes have been revealed that they are more efficient rather than conventional methods. At present study, the efficiency of new integrated technique namely Intermittent Cycling Aerobic-Anaerobic Bioreactor with Granular Activated Carbon (ICAAGAC) were investigated for removal of the Nitrogen and Phosphorus. Experimental design was used to analyzing and nutrient modeling. However, the main important variables such as filling percentage of activated carbon (20-50), aeration time (2-6 h), mixing time without aeration (30-90 min) were considered. Results showed that increasing in nitrogen and phosphors removal efficiency with increasing in filling ratio of activated carbon is observed. Also, it was resulted the aeration time is the most effective parameter to removing the nitrogen. Accordingly, maximum removal efficiency for TKN, NH4, N-org and TN, was obtained about 96.8, 96.8, 96.9 and 95%,respectively. Under optimum condition, a removal efficiency about more than 60% was acquired for total phosphors in 4 hours of aeration. Based on results, it can be concluded that the ICAAGAC is able to remove the nitrogen and phosphorus from wastewater successfully.

Keyword: Municipal wastewater, Nitrogen and Phosphorus, Granular Activated Carbon, Modeling and Optimization

Introduction: Primarily, the main objective of establishment of wastewater treatment plants was the removal of organic contaminants, suspended solids, and bacterial contaminants. However, over time, comprehension of the impacts of the nitrogen and phosphorous-containing compoundsin aqueous media led to imposing some restrictions in the released wastewater to the environment andreceiving water(1).The new strict standards have emphasized on separation of nutrients, heavy metals and priority contaminants before than wastewater discharge(2).Nitrogen and phosphorous are important contaminants of wastewater which may not be removed using conventional treatment methods and as results advanced systems are required. Phosphorous is introduced into the wastewater from many sources such as consumed water, human feces and urine, industrial and commercial wastes, municipal solid waste leachate, synthetic detergents and household cleaning products.

Nitrogen is capable of taking different oxidation states and may be found in organic form, ammonia, nitrite, and nitrate. Variation of the oxidation states of nitrogen in the media is induced biologically by living organisms. In municipal waste water, nitrogen is existed often in the form of organic nitrogen (60%) and ammonia (40%), which mainly results from metabolism of proteins in human body (4).Discharge the waste waters-containing nitrogen and phosphorous is lead to; increasing in plant growth, eutrophication, toxicity to fish and other aquatic organisms (from free ammonia from), depletion of dissolved oxygen, enhancing the taste and odor in water. Introducing the nitrite to the blood can be makingmethemoglobinemia in children, and as resulting positional asphyxia and death(5-6).Furthermore, the nitrite can reacts with other stable compounds of nitrogen like amines and creates the nitrosamine which is a carcinogenic compound (7-11).

Various methods for removal of nutrients from waste water have been developed including physical, chemical, biological and combined methods. Choosing any of these methods depends on environmental factors such as; nitrogenous type, treatment quality, and in particular technical/economic aspects (12).Since the physical and chemical methods are costly the biological is more interesting in comparison to other methods due to higher efficiency and applicability, simplicity, low costs, and biocompatibility.

In recent years, application of biofilm systems in biological purification process as a global approach has increased. The suspended growth systems have been promoted using biofilm systems like submerged biological filters. Organic and nutrients are removed from the waste water flow by crossing through a bed containing attached growth. Many materials used in the attached growth process as carrier materialsencompassing rocks, sands, zeolite, pieces of wood, a wide range of plastics and synthetic materials. Activated carbon is one of the mostly used chemicals in adsorption processes

(13).This type of bed is used predominantly for removal of organic contaminants from contaminated waters and wastewaters because of its unique characteristics such as porosity, high surface area and great adsorption capacity. This applicable material is also convenient for removal of antibiotics and toxins from wastewater(14).However, nowadays, application of granular activated carbon as a suitable bed for growing microorganisms along with physical adsorption has attracted attention to improve the performance in biological systems. Application of biological activated carbon (BAC)demonstrates higher yields compared to the physical adsorption in removal of compounds such as; dissolved organic material, phenol, aniline, heavy metals (copper, lead, cadmium, and bivalent nickel), aromatic material, and in treatment of wastewater of explosives (military) (15-16).Considering unique properties of granular activated carbon, it was chosen as the media for improvement of biological system for removal of nutrients from urban wastewater.

Material and methods

Material: All chemical and regents were provided from analytical grade (Merck and Sigma).

Setup

An Intermittent Cycle Extended Activated System (ICEAS) with an effective volume about 4 L was used as previous work [20].The schematic plan of considered reactor is represented in Fig.1. The bioreactor column was a plexiglass cylinder with an inner diameter of 8 inches, overall height of 110 cm, effective volume of 4 liters, and total volume of 5.5 liters. An automatic discharge system was installed on the body of the reactor at a height of 60 cm from the bottom of the reactor (75% of total volume) for cutoff unloading. Therefore, the hydraulic retention time was calculated based on 1 L as the interchangeable volume. In each operating cycle, about 1 L of the supernatant clear liquid was removed and the same amount of fresh wastewater was added to the reactor. This influenced the dilution rate of the material inside the reactor. After stabilization of the system, the reactor with retention time of 3-8 h, which was the total time for phase mixing (anaerobic), aerobic phase, and settling phase was started to exploit. A peristaltic pump was used to supply a constant wastewater feed and a circulator was used to mix the contents of the reactor. The required air for the reactor was supplied by a blower and four air diffusers of fine bubble which had been placed in columns. The ICEAS reactor was equipping with activated carbon (AC) in three filling ratio (20 %, 35 %, and 50 % in regard to reactor volume). As can be seen from table 1, the profile of the used granular activated carbon is shown. To being the startup phase, the reactor was seed using municipal wastewater treatment plant sludge (from return activated sludge with a MLSS about 10000 mg/L). In order to feeding, the raw wastewater was considered and its characteristics are shown in Table 2. Several months (more than two) took that the ICAAGACR system was steady state (data not shown) and biofilm formation be appeared. The system was controlled by an automatic timer and was started by anaerobic section and then continued by aeration cycles, sedimentation and discharge steps. In all operational cycles, the sedimentation and discharge steps were considered 30 minutes and 4 minutes, respectively. The amount of dissolved oxygen was set in the range of 3.5-5 g/L. The pH value was adjusted within the range of 6.8-7.2. Mixed liquor suspended solids (MLSS) of the system was kept constant around 4000 mg/L without considering the microbial film attached to the activated carbon.

Table 1: Profile of the activated carbon media.

Media properties	amounts	properties	amounts
Total specific area (m^2/g)	900	Media volume at 20% filling	800 mL
Approximate length (mm)	3	Media volume at 35% filling	1400 mL
Approximate diameter (mm)	1	Media volume at 50% filling	2000 mL
Density	1.3		

Table 2: Raw wastewater characteristics

Parameters	Concentration (mg/L)
COD	365.8±23.07
BOD	162.42±21.91
TKN	51.67±3.99
NH_4^-H	31.54±2.8
N-Org	20.12±1.77
TN	51.70±3.99
TP	9.42±0.81
Alkalinity	309.11±30

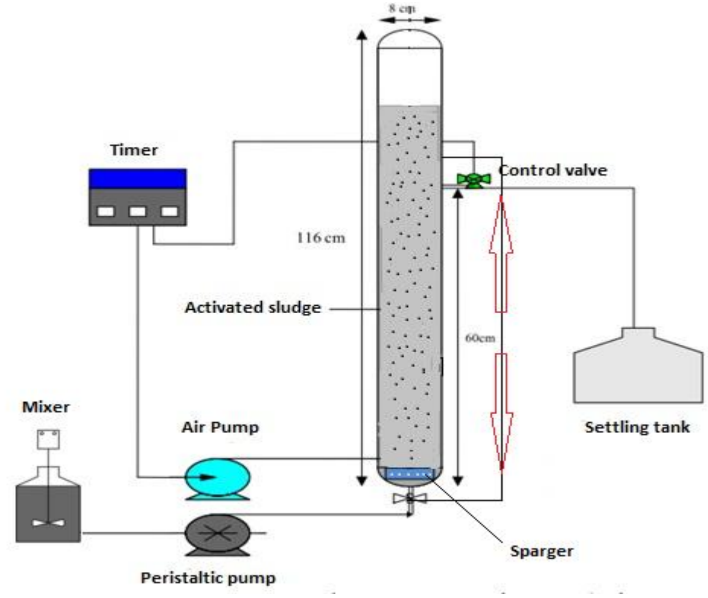

Figure 1: Scheme plan of the ICAAGACR system.

2. Design of Experiments

Response Surface Methodology (RSM) is a useful set of statistic and computational methods for analysis of multiple independent variables on the function of the system which has important application in designing and optimization of a process. In the present work, the statistic design of the experiment was performed using "Design expert" software version 7.Thereupon, 20runs (one central point, 7 axial points, 7 variable points, 5 repeated points in the center) were designed. Three independent variables including aeration time, mixing time (without aeration) and granular activated carbon filling ration (in term of percentage) were considered. The experimental levels of independent variables are presented in Table 3.

Table 3: Experimented levels of independent variables.

Variable	Code	Duration and levels
		-10+1
Mixing time (min.)	A	306090
Aeration time (h)	B	246
Media filling percentage (%)	C	50%35%50%

Analysis

To determine the system responses, sampling took place from three points of the system including the input, output, and contents inside the reactor (40 cm from bottom of the reactor). It should be noted that, to achieve the stable condition in each step, the sampling took place at fourth repetition after three time of repeating the step. To determine the amounts of NO_3^-, NO_2^-,TKN, NH_4^-N, and TP contaminants, Reduction Cadmium 4500-NO_3^- E, Colorimetric Method 4500- NO_2^- B, Macro-Kjeldahl Method 4500-N_{org}-B, NesslerizationMethod4500- NH_3H, Stannous chloride Method 4500-P D were used, respectively.

Results and discussion

According to the experiment design, analysis and optimizing the parameters under consideration were defined 20 runs. Table 4 displays the number of experiments and results of the system for removal of nutrients include nitrogen and phosphorus compounds.

Table 4: Experiments and results of the ICAAGACR system for removal of nutrients.

components	Filling percentage of media (%)	Mixing period (min)	Aeration period (h)	TKN Removal efficiency (%)	NH_3^-N Removal efficiency (%)	N-Org Removal efficiency (%)	TN Removal efficiency (%)	TP Removal efficiency (%)	NO_3 Removal efficiency (%)	NO_2 Removal efficiency (%)
1	20	30	2	59.6	58.3	61.5	45.8	25.4	21.87	0.27
2	50	30	2	88.2	87.5	89.2	83.5	36.9	13	0
3	20	30	6	91.9	92.5	91	81.9	33.7	10.26	0.09
4	50	30	6	97	96.7	97.5	89.8	47.6	13.3	0
5	20	90	2	58.1	55.7	61.8	46.5	29.8	19.46	0.19
6	50	90	2	90.8	90.4	91.5	84.5	41.6	13.2	0
7	20	90	6	93.1	93.9	91.9	84.8	36.9	8.9	0.05
8	50	90	6	96.8	96.8	96.9	95	50.6	14.73	0
9	20	60	4	79.2	78.5	80.4	71.2	27.1	11.65	0.11
10	50	60	4	94.4	93.5	95.7	87	60.7	13	0
11	35	60	2	68.2	66.9	70.3	54.8	33.2	14.73	0.42
12	35	60	6	96.4	96.2	96.7	87.6	42.3	10.57	0.06
13	35	30	4	79.9	80.1	79.6	66.7	29.5	19.58	0.17
14	35	90	4	85.9	85.3	86.7	72.4	33.9	17.51	0.23
15	35	60	4	82.5	82.1	82.9	69.3	30.4	17.03	0.18

16	35	60	4	80.8	80.3	81.7	66.9	29.7	17.52	0.52
17	35	60	4	79.4	80.5	77.6	68.4	32.9	14.73	0.13
18	35	60	4	82	84.8	77.5	68.8	27.4	14.73	0.22
19	35	60	4	78.3	76.1	81.8	67.2	26.8	14.73	0.33
20	35	60	4	78.9	75.5	84.7	69.1	29.8	14.73	0.14

Removal of nitrogenous compound

Considering the significant amounts of organic nitrogen in municipal wastewater, investigation of the effective parameters on biological performance is considerable. The maximum removal efficiency of organic nitrogen was obtained at maximum mixing time about 90 min, 6 h of aeration and 50% filing ratio for AC media. As seen in Fig. 2, it clear that the increasing in AC media ratio and aeration time is lead to better removal rate of organic nitrogen.

Based on the obtained results, when mixing time is rising, the organic nitrogen is digested to inorganic nitrogen compounds and consequently ammonification process occurs. This considerable nitrogen depletion at maximum filling ratio of the media (50%) is correlated to high porosity and available high surface area of the activated carbon for growth and activity of nitrogen-removing microorganism. In addition, great adsorption ability of activated carbon can be contributed in enhancing nitrogen removal (22-27).According to Fig. 2 b, can be found that the aeration time and media filling have the most impact on organic nitrogen removal in comparison with the mixing time. This fact reveals the mass-transfer isn't restricting agent for nitrogen removal and exposer between substrate and biomass is enough.

Considering to ammonia removal it is clear that the better biological performance is seen with upper aeration time and media filling percentage. Fig. 3.illustrates the ammonia depletion rateat maximum anaerobic duration and deviation of variables from central point. Accordingly, removal efficiency is slightly from 2 to 4 h and filling percentage around 20 % to 35 %.Outside from this range, ammonia removal was improved so that desirable depletion (more than 96%) was provided at 6 h aeration and filling percentage 50%.Lack of ammonia depletion at narrow time 2-4 h can be related togeneration of ammonia nitrogen from organic nitrogen conversion (ammonification).At a higher mixing condition and media filling, the efficiency of ammonia removal increased with a sharp slope during aeration time. Whereas, this was obtained only 5 percent for narrow time around 30-90 min. Slight decrease of ammonia at an aerobic condition was found and it can be occurred by anaerobic bacteria consumption. According to the slope of Fig. 3 b, and regard to removal efficiency of ammonia, it was recognized the aeration time was more effective parameter in comparison to the mixing time. At this time, overcoming the nitrification process was caused the ammonia be converting to nitrite and nitrate. Overlay in presence of AC with upper filling percentage, the population of the attached growth microorganisms was promoted. On the other hands, high capability adsorption of AC was making desirable ammonia depletion(4).Furthermore, application of granular activated carbon in biological systems improves the ammonia removal by adsorption of toxic material which inhibits nitrifying microorganism's growth(24-28).

According to Fig. 4 and 5, there are the nitrite and nitrate removal percentage trends at the maximum mixing time (90 min). With regard to Fig. 4, it is evidence that the increases in media filling from 20to 35% has caused on nitrite rising. But out of this range the nitrite was remarkable decreasing trend. This failure (nitrite accumulation) can be occurred following by presence of inadequate nitrite oxidizing bacteria. By increasing the percentage of the media filling up to 50%, the nitrogenous microorganisms relatively increased in the system as well as nitrite consumption. Decrease of the output nitrite at maximum aeration and mixing times was due to the increase of hydraulic retention time and hence complete nitrification in the system. In this time the nitrifying bacteria predominates in bioreactor in comparison with heterotrophic bacteria and consequently better nitrite removal was observed. On the other hand, this situation may be creates a decreasing in BOD (29).

Considering to the output nitrate, it is clear that the similar pattern nitrite change exists for nitrate, and minimum output nitrate occurred at maximum aeration and mixing time and media filling (Fig. 5 a and b). Increase of the output nitrate in the mixing time of 60 minutes without aeration compared to the first 30 minutes showed the domination of phosphate bacteria and shortage of organic material for denitrifying bacteria. Of the other effective factors on the nitrate removal was found the percentage of media filling for biofilm of denitrifying microorganisms. At higher amount of carrier media percentage, the population of nitrogenous microorganisms increased due to high porosity and increase of cellular retention time, and thus more nitrate was reduced. According to results, it can be concluded that the activated carbon as a suitable carrier improves growth of nitrogenous microorganisms that it is demonstrated by literatures (30-32).At 50% of media filling, the minimum nitrate output took place at maximum aeration and mixing times. By increasing from the mixing and lack dissolved oxygen in the system, the condition for denitrifying bacteria was provided and complete denitrification took place. In addition, the decrease of the output nitrate at maximum aeration time is due to depletion of ammonia nitrogen source in the bioreactor and utilization of nitrate as a nitrogen source for cell synthesis.

Kjeldahl nitrogen is considered astotal organic and ammonia nitrogen, and it was determined to investigate the overall nitrogen changes in bioreactor. Results showed higher removal efficiency at maximum mixing time is occurred (Fig. 6).It is demonstrated that the same pattern removal at maximum mixing time is existed for all nitrogen compounds. The highest Kjeldahl nitrogen removal rate occurred in the maximum amount of the considered factors. Because, with the increase of aeration and mixing time, the hydraulic retention time increased and then ammonia and organic nitrogen was removed completely from the system by denitrification process. According to the deviation from central pointin Fig 6b, removal efficiency of Kjedahl nitrogen (depending on intensity) is affected by the aeration time, media percentage, and mixing time (without aeration), respectively. Application of granular activated carbon prevents the microorganisms from the poisoning and it provides a convenient situation for nitrifying low growth rate by adsorption of heavy metals (zinc, copper, cadmium, etc.) (33).

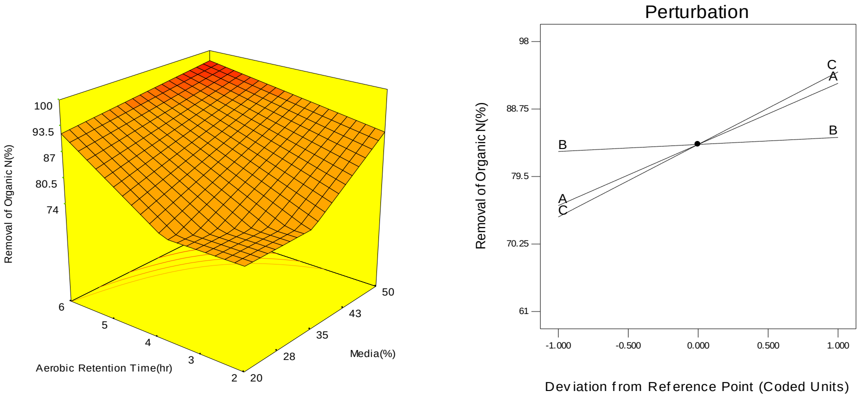

Fig. 2. 3D plot of organic nitrogen removal at maximum mixing time (a), deviation from central point in organic nitrogen removal efficiency (b).

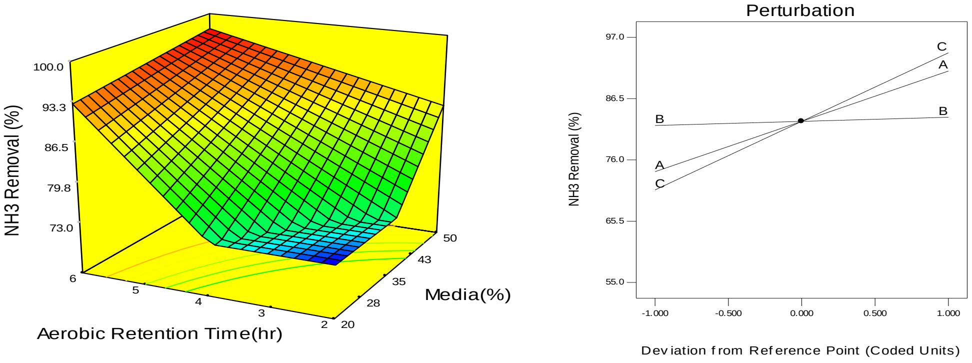

Fig. 3.3 D graph of ammonia nitrogen removal at maximum anaerobic section (a), deviation from central point in ammonia nitrogen removal efficiency (b).

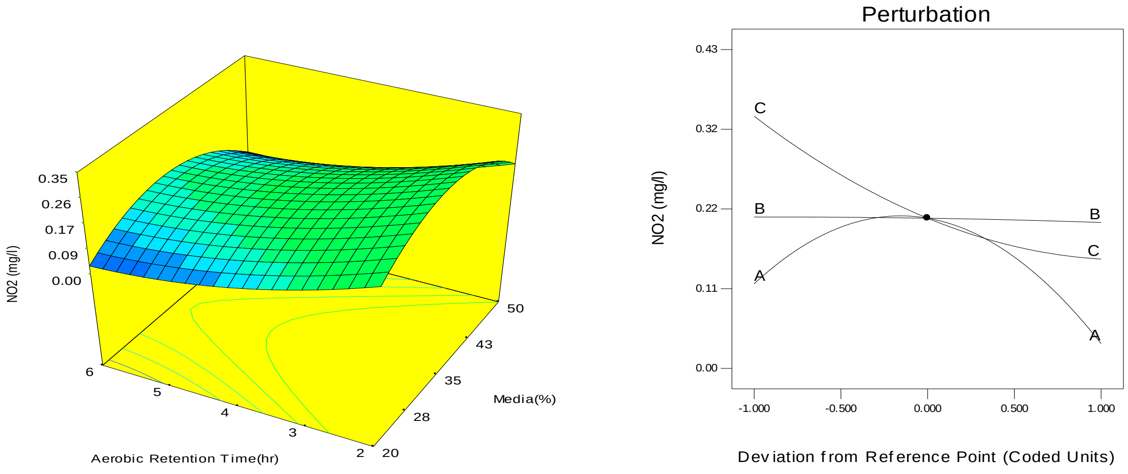

Fig. 4.3-D plot of output nitrite at maximum aeration time (a), deviation from central point at output nitrite (b).

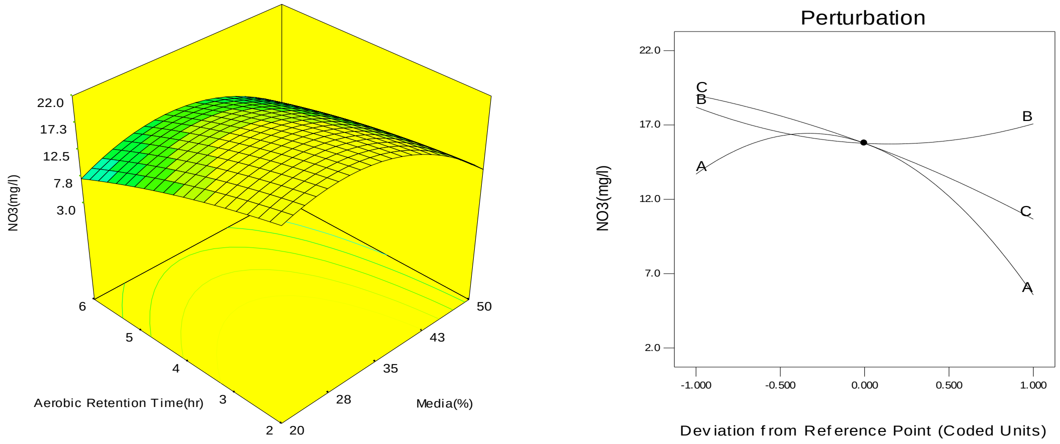

Fig. 5.3-D plot of output nitrate at maximum aeration time (a), deviation from central point at output nitrate(b).

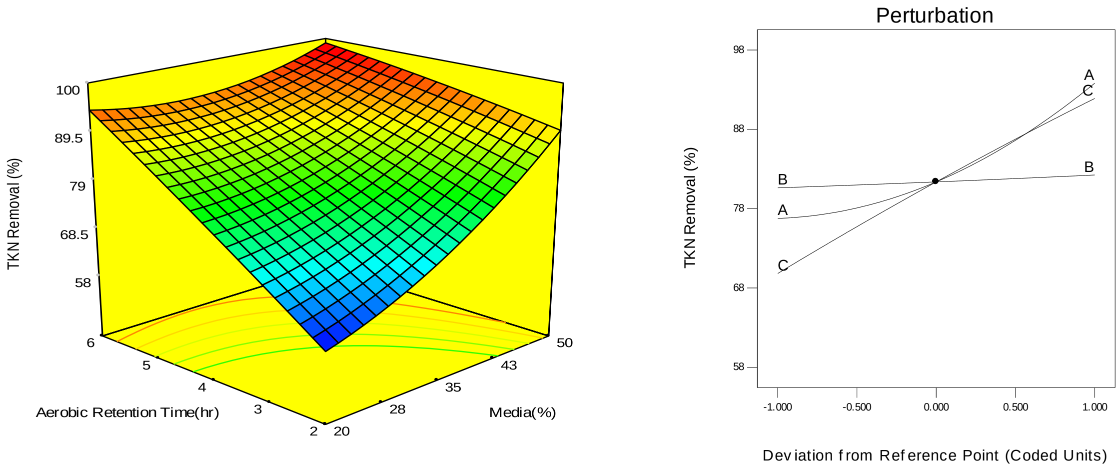

Fig. 6.3-D plot of output Kjeldahl nitrogen at maximum aeration time (a), deviation from central point at outputKjeldahl nitrogen (b).

Phosphorous removal

Phosphorous is another important nutrient in wastewater from its environmental effects likeeffect oneutrophication phenomenon. In comparison with nitrogen compounds, the maximum removal efficiency of the total phosphorous was obtained at an aeration time about4 h and 60 min of mixing time. The functionality of the system was seen similarat range of 20 to 35% of media filling. Also, at maximum aeration time, the maximum phosphorous losses were obtained at 60 min of mixing (without aeration) (Fig. 7). Desirable phosphorous removal happened at 50% of media filling remarkably. The efficiency of phosphorous removal increased from 39.36% to 53% following the increase of mixing time without aeration at 50% of media filling.

Considering the need of biological removal of phosphorous for consequent anaerobic and aerobic steps, the sufficient source of carbon is necessary for polyphosphate microorganisms. ICEAS reactor is considered among the novel biological processes for removal of nutrients from raw wastewater (34). In the present study, the efficiency of phosphorous removal was decreased in contrast with the efficiency of nitrogen containing compounds removal at 6 h aeration, as a result of the aggregation of by complete nitrification process and domination of denitrifier bacteria in competition with phosphate bacteria for adsorption of organic material. Hence, at 50% media, the maximum efficiency of phosphorous removal took place at 4 h of aeration (Table 4). Also, in the investigation of Pishrafti *et al* for removal of total phosphorous from municipal wastewater, the efficiency of phosphorous removal declined from 52.2% to 26% following enhancing the aeration time from 4 h to 6 h (35).

In addition, investigation of the impacts of the mixing time and media percentage at optimum condition (4h aeration) demonstrated the higher impact of the media percentage for maximum efficiency of phosphorous removal (Figure 7-C). Following increasing the amount of activated carbon filling and improving the anaerobic condition, the phosphate bacteria dominated and adsorbed more phosphorous at aerobic condition. Karakani *et al* also conducted a study for removal of phosphorous from municipal wastewater by ICEAS, in which the maximum efficiency of phosphorous removal was acquired as 55.9% upon 16 h of hydraulic retention time, in both studies, whereas in current study, the efficiency of phosphorous removal enhanced up to 60.7% at 5.5 h hydraulic retention time, following addition of granular activated carbon bed (36-37). Hoon Lee *et al* reported 36%-61.1% of phosphorous removal at hydraulic retention time of 4-10 h by using activated ceramic, while in the present study a removal efficiency of 36.9% was reached at 3 h hydraulic retention time which proves the superiority of the granular activated carbon over activated ceramic in growth and activity of polyphosphate microorganisms. Therefore, on the basis of the conducted studies and the obtained results, the granular activated carbon is not only a suitable bed for growth of polyphosphate microorganisms, but also is a powerful adsorbent for phosphorous removal (38).

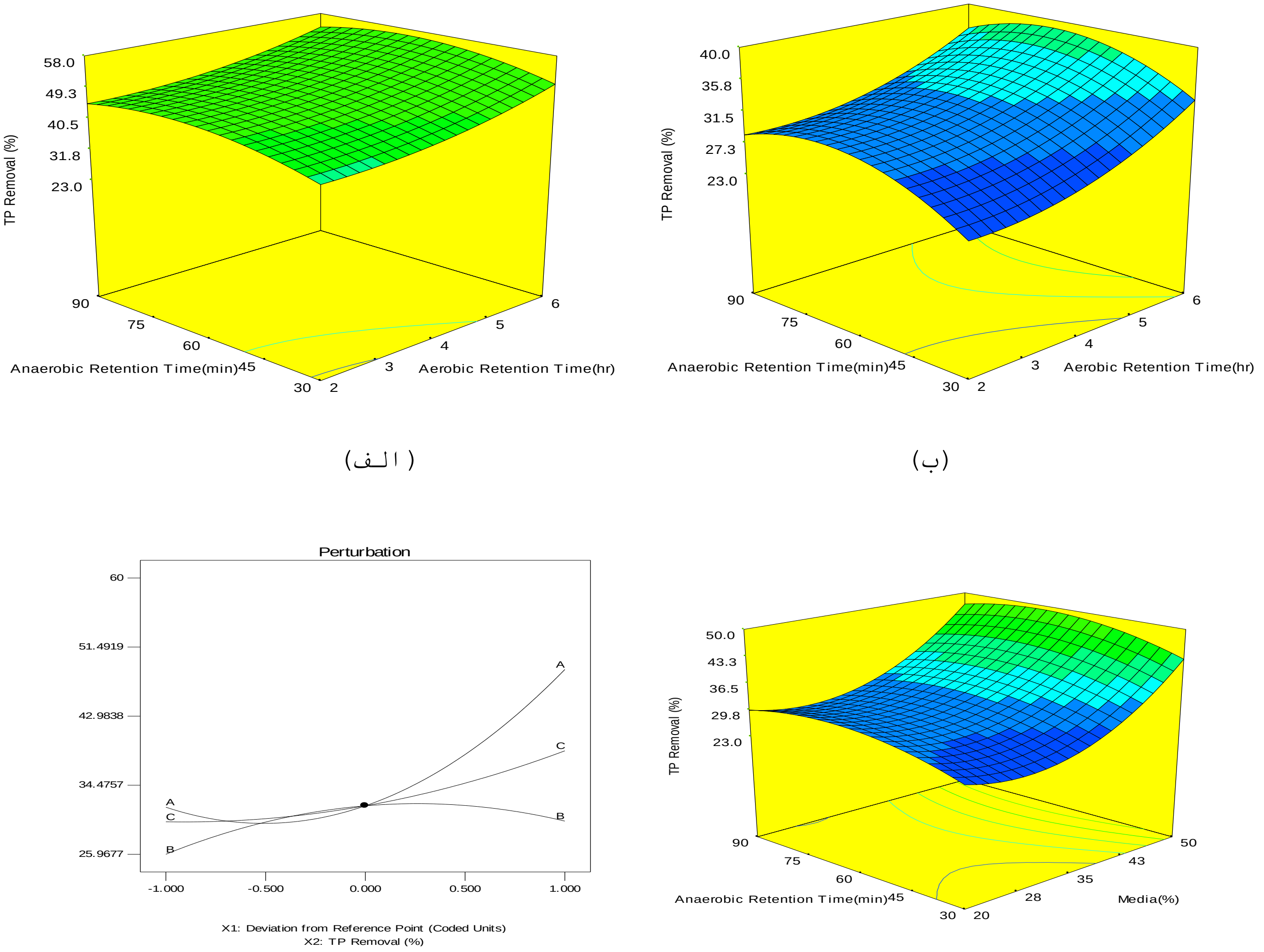

Figure 7-A) 3-D diagram of TP removal efficiency under conditions (a) 35%, (b) 50%, (c) maximum aerobic condition, B) diagram of deviation from central point in TP removal efficiency [A: media (%), B: mixing time (min), C: aeration (h)].

Statistical analysis of the process

Central compound design (CCD) was used to find the relation between variables and process response. Models with encoded factors as well as variance analysis of the results (ANOVA) for responses are provided at table 5. The degrees of significance (P-value) are shown in each response to determine the significance of each model. The obtained P-values for removal of total nitrogen and phosphorous compounds are ($P<0.0001$) and ($P<0.01$), respectively. Also, in this study, accuracy values of (7.49-23.60) were obtained. On the basis of the suggested models, the determination coefficient in removal efficiency of TKN, NH_4, N-Org, TN, and TP are 0.97, 0.93, 0.91, 0.97, and 0.80, respectively. In accordance with the results of statistical analysis ANOVA, the P-values for determining the significance of the model for removal of all forms of total nitrogenous and phosphorous compounds were obtained by Design Expert software as ($P<0.05$). This valueproves the significance of the suggested models in removal of nutrients. High determination coefficient (R^2) also confirms the correlation of the coefficients with the suggested model. The measurement of accuracy is to determine the amounts of experimental errors and a ratio higher than 4 is a favorable value. In this study, the value of accuracy obtained was 7.49-23.60, which are remarkably greater than 4. According to the results obtained from the equations of Design Expert software, the mixing time (without aeration) was determined as the factor with minimum impact on removal of the contaminants. As, the least model coefficient was devoted to this factor. Furthermore, the highest impact in removal of nitrogenous compounds is attributed to aeration time and media percentage, respectively. As for removal of total phosphorous compounds, the filling percentage of the reactor with media (total solid load) was more effective compared to the aeration time (Table 5).

Table 5: Results of variance analysis (ANOVA) for the responses under study in Design Expert software.

Removal efficiency	Significant equations for expected response* (A, B, and C, media percentage, anaerobic, and aerobic, respectively)	Model type	R^2	accuracy	P-value
TKN	$+81.37+8.53A+0.81B+11.05C+0.35AB-6.56AC-0.025BC+3.92A^2+0.060B^2-0.52C^2$	Quadratic	0.97	20.84	**0.0001<**
NH4	$+82.6+8.62A+0.71B+11.75C+0.52AB-7.11AC+0.13BC$	2FI	0.93	19.10	**0.0001<**
N-Org	$+83.89+8.38A+0.97B+9.94C+0.084AB-5.72AC-0.26BC$	2FI	0.91	17.43	**0.0001<**
TN	$+69.22+11.22A+1.14B+12.82C-0.17AB-6.70AC+0.31BC+8.49A^2-0.99B^2+0.62C^2$	Quadratic	0.97	23.60	**0.0001<**

TP	$+31.93+8.48A+2.04B+4.37C+0.094AB+0.49AC-0.31BD+8.31A^2-3.93B^2+2.40C^2$	Quadratic	0.80	7.49	**0.01<**

Table 6: Confirmation of the experiment in optimum condition.

		Responses						
Components	Operation condition	TN (%)	TKN (%)	NH3 (%)	N.Org (%)	NO3 (mg/L)	NO2 (mg/L)	TP (%)
Experiment results		87	94.4	93.5	95.7	13	0	60.7
Model response	Aeration time 4 (h)	89.5	94.15	91.5	92.55	5.6	0.03	49.06
Standard deviation	Aeration time 60 (min.) Media filling percentage	+2.5	-3.5	-2	-3.15	-7.4	+0.03	-11.64

Results of the experiment are presented in the table as well as the results of the suggested model at optimum condition for removal of nutrients and standard deviations. According to the results, the experimental values are in good agreement with those of the suggested model.

Conclusion

The RSM showed that aeration time is known as the most effective variable in removal of nitrogen containing material. The maximum removal is achieved at 6 h aeration, 90 minutes mixing time (without aeration), and 50% media filling. The removal efficiency for TKN, NH_4, N-org, and TN were obtained as 96.8, 96.8, 96.9, and 95 respectively. The maximum efficiency of TN removal was reached at 4 h aeration, 90 minutes mixing time (without aeration) and the 50% media filling of the reactor. The media filling percentage was the primary factor in removal of total phosphorous.

References

1. Richard s, phosphorou & nitrogen removal from wastewater. tehran: farabeh. 1996, P:15-16.
2. Metcalf & Eddy. Wastewater engineering, treatment and reuse. New York. 2003, 4: 1189.
3. Bruce E. Environmental biotchnology principles and appliccations. Sharif University of Technology. 2001, P:595.

4. Hussain S, Aziz H.A, Isa M.H, Adlan M.N & Asaari F.A. Physico-chemical method for ammonia removal fromsynthetic wastewater using limestone and GAC in batch and column studies. Bioresource technology. 2007, 98(4):, P: 874-880.
5. Golbabaei K.F, Amini R.H and Asadi M, Effect of Membrane Bio Reactor on Nutrient Removal from Hospital Wastewater. Heath. 2013, 3(4), P: 63-71.
6. Gautam A.K, Kumar S and Sabumon P. Preliminary study of physico-chemical treatment options for hospital wastewater. Journal of environmental management. 2007, 83(3), P: 298-306.
7. Howarth R.W, et al. Regionalnitrogen budgets and riverine N & P fluxes for the drainages to the North Atlantic Ocean, Natural and human influences. Nitrogen cycling in the North Atlantic Ocean and its watersheds. Springer. 1996, P: 75-139.
8. Halling-Sørensen B and Jorgensen S.E. The removal of nitrogen compounds from wastewater. 1993, P: 12.
9. Chowdhury N, Nakhla G and Zhu J. Load maximization of a liquid–solid circulating fluidized bed bioreactor for nitrogen removal from synthetic municipal wastewater. Chemosphere. 2008, (5)71, P: 807-815.
10. United Nations Environment Program, WHO. Water Quality Monitoring. New York, Chapman & Hal. 1996.
11. Waki M. Yokoyama H, Ogino A, Suzuki K & Tanaka Y. Nitrogen removal from purified swine wastewater using biogas by semi-partitioned reactor. Bioresourcetechnology. 2008, 99(13), P: 5335-5340.
12. Benefield L.D and Randall C.W. Biological process design for wastewater treatment. Prentice Hall Series in Environmental Sciences. 1981, P: 526.
13. Baghalha M and Badri N. Elucidate the mechanisms and the effective diffusioncoefficient in the Adsorption of Cu (II), Zn (II (and Cr (VI) On activated carbon fertilized with SDDC. College of Chemistry and Chemical Engineering, 2007, 26(3).
14. Alahabadi A, Moussavi G, Yaghmaeian K & Karemisany H. Adsorption potential of the granular activated carbon for the removal of amoxicillin from water. Quarterly Journal of Sabzevar University of Medical Sciences, 2013, 20(4).
15. Orshansky F and Narkis N. Characteristicsof organics removal by PACT simultaneous adsorption and biodegradation. Water Research, 1997. 31(3): P: 391-398.

16. Augulyte L, et al. Multivariate analysis of a biologically activated carbon (BAC) system and its efficiency for removing PAHs and aliphatic hydrocarbons from wastewater polluted with petroleum products. Journal of hazardous materials, 2009, 170(1) P: 103-110.
17. Frasnson M. PACT system for difficult wastewaters. Hydrocarbon processing. 1999, 78(12), P:8-16.
18. Maloney S.W, Adrian N.R, Hickey R.F & Heine R.L. Anaerobic treatment of pinkwater in a fluidized bed reactor containing GAC. Journal of Hazardous Materials, 2002, 92(1), P: 77-88.
19. Lee K and Lim P. Bioregeneration of powdered activated carbon in the treatment of alkyl-substituted phenolic compounds in simultaneous adsorption and biodegradation processes. Chemosphere, 2005, 58(4), P: 407-416.
20. Hawari A.H and Mulligan C.N. Biosorption of lead (II), cadmium (II), copper (II) and nickel (II) by anaerobic granular biomass. Bioresource technology, 2006, 97(4), P: 692-700.
21. Pirsaheb M, Mohamadi M, Mansouri A. M, Zinatizadeh A. L, Sumathi S & SharafiK. Process modeling and optimization of biological removal of carbon, nitrogen and phosphorus from hospital wastewater in a continuous feeding & intermittent discharge (CFID) bioreactor. Korean Journal of Chemical Engineering, 2015, P: 1-14.
22. Glesceria L and Eton A. Standard Methods for the Examination of water and wastewater. 21th ed,washington DC: APHA. 2005, P: 189-98.
23. Ayati B, Ganjidoust H and Delnavaz M. Application of moving bed biofilm reactor(MBBR) in sanitary & industerial weastewater treatment. Tarbiat modares university press. 2011, P: 3.
24. Naseri S, MesdaghiNia A and Jafarzadeh N. Evaluating the sudden arrival of phenol and furfural in the conventional activated sludge (AS) and the PACT system. Ecologe. 1997, 28(1), P:41-50.
25. Marquez M and Costa C. Biomass concentration in PACT process. Water Research. 1996, 30(9), P:2079-2085.
26. Flynn B, Robertaccio F and Barry L. Truth or consequences: biological fouling and other considerations in the powdered activated carbon-activated sludge system. Proceedings-Industrial Wastes Conference. Purdue University (USA). 1977, P: 855-862.
27. Gholami M, et al. Evaluation of Powdered-Activated Carbon Treatment (PACT) Process in Textile Dye Removal. ZUMS Journal. 2007, 15(61), P: 59-70.

28. Baglin Y and et al. treatmed phenolic wastewater by combined AS-PAC method. water treatment. 1991, 6(2), P: 109-122.
29. Chandra R, Bharagava R.N, Kapley A, & Purohit, H.J. Bacterial diversity, organic pollutants and their metabolites in two aeration lagoons of common effluent treatment plant (CETP) during the degradation and detoxification of tannery wastewater. Bioresource technology, 2011, 102(3), P: 2333-2341.
30. Sison N, Hanaki K and Matsuo T. High loading denitrification by biological activated carbon process. Water research, 1995, 29(12), P: 2776-2779.
31. Zhang Z, et al. Nitrat removal by diobacillus denitrification immobilized on poly carrier. hazard mater. 2009, 163, P:1090-1095.
32. Ma L and Yang B. Removal of H2S by thiobacillus denitrification immobilized on different matrices. bioresour technol. 2006, 97, P:2041-2046.
33. Sirianuntapiboon S and Manoonpong K. Application of Granular Activated Carbon-Sequencing Batch Reactor (GAC-SBR) System for Treating Wastewater from. Thammasat Int. J. Sc. Tech, 2001, 6(1).
34. Majlesi Nasr M and Yazdanbakhsh A.R. Study on wastewater treatment systems in hospitals of Iran. Iranian Journal of Environmental Health Science & Engineering. 2008, 5(3), P: 211-215.
35. Pishrafti H. Evaluate of performance of urban waste water treatment with USBF process, Tehran University of Medical Sciences: School of Public Health and Institute of Health Research. 2007, P:1343-1354.
36. Mahvi A.H, Mesdaghinia A and Karakani F. Feasibility of continuous flow sequencing batch reactor in domestic wastewater treatment. American Journal of Applied Sciences, 2004, 1(4), P: 348.
37. Karakani F and Mahvi A.H. Wastewater phosphorus removal in an intermittent cycle extended aeration system. Pakistan. J. Bio. Sci. 2005, 8(2), P:335-337.
38. Lee K.H, Lee J.H and Park T.J. Simultaneous organic and nutrient removal from municipal wastewater by BSACNR process. Korean Journal of Chemical Engineering. 1998, 15(1), P:9-14.