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INVESTIGATION OF THE EFFICIENCY AND BIO-KINETICS OF INTERMITTENTCYCLE AEROBIC-ANAEROBIC GRANULAR ACTIVATED CARBON-BED REACTOR (ICAAGACR) IN REMOVAL OF ORGANIC COMPOUND FROM SEWAGE

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Abstract

Introduction: Utilization of novel biological purification systems, are demanded as the standards of releasing wastewater to the environment, gets more restricted. The purpose of current study is to investigate the efficiency and bio-kinetics of intermittent cycle aerobic-anaerobic with granular activated carbon-bed reactor (ICAAGACR) in removal of organic compound fromsewage.

Materials and methods: The study is of experimental-sectional type. Six months of study took place using an ICAAGAC reactor with effective volume of 4 L on sewage. To grow microorganisms and form a biofilm, commercial granular activated carbon which filled 20-50 % of the reactor volume was used. Following the hydraulic testing of the reactor, loading by raw sewage took place in 3-8 hydraulic staying time periods in two aerobic and anaerobic phases. The results were analyzed using Design expert software. The Monod equation was used to calculate the bio-kinetic removal of organic materials.

Results: The results showed that the maximum removal efficiencyof TCOD, SCOD, BOD, and CBOD were 95.71, 97.32, 97.83, and 98.16 respectively. The maximum efficiency of removal of organic compounds was acquired at 4 h aeration, 60 minutes mixing, and 35 % filling-in. The kinetic coefficients Y (gvss/gb COD), k_s(gb COD/m^3), k(gbs COD/gvss.d), k_d (gvss/gvss.d), and μ_m (gvss/gvss.d) for organic compounds and for 35 % filling-in were obtained as 0.059, 0.74, 81.37, 1.8, and 1.33 according to the amount of MLSS in the reactor without considering the formed biofilm on the media.

Discussion and conclusion: ICAAGAC system is considered as a superior purification process compared with similar methods in removal of organic compound due to unique properties of granular activated carbon in physisorption with high porosity.

Keywords: Sewage, removal of organic compounds, ICAAGAC, bio-kinetic coefficients, BGA.

Introduction: Sewages are considered one of the most important pollutants of the water resources. It is urgent to return them to water cycle in nature by correct collection and purification methods(1). There are various methods for sewage purification including physical methods (filtering, crushing, stabilization, sedimentation, and floatation), chemical methods (chemical precipitation, absorptions, disinfection, Dechlorination),and biological methods (Activated sludge, aerated lagoon, trickling filter, rotating biological contactor, stabilization pond, anaerobic digestion, and biological nutrient removal)(2). In 1974 the US Environmental Protection Agency introduced 154 organic compounds as pollutants in drinking water (3) and made the removal of organic compound from sewage stricter. Due to strict up of standards of sewage output, many combined systems were used for water purification (4). Among these systems, simultaneous application of activated carbon and biological processes (in particular activated sludge) increased the efficiency of the system considerably because of the mechanism and the type of functionality of GAC[1] when adding to the activated sludge system. In addition, simultaneous presence of aerobic and anaerobic in the biofilm allows the simultaneous removal of nitrogen and BOD (5). As Koppe*et al* found out, aerobic biodegradation of organic compound is accelerated in the vicinity of GAC (6). Totally, it can be said that biosorption functions considerably better that physisorption, as in the investigations of Xing *et al*the efficiency of DOC[1] removal in BTSE[1] kinetic increased from 29 to 96 % by increasing BGAC[1] from 0.1 g/L to 0.2 g/L. Furthermore, the bio-removal requires lower doses and has longer retention time compared to physisorption (7). In a study on textile industry waste, the percentage of COD removal by conventional activated sludge process and GACT were 90 and 95 %, respectively (8).

Various purification systems have been developed to increase the advantages of aerobic and anaerobic processes (9). ICEAS[5] technology is among the new biological processes. The modified activated sludge process is common and consists of three time phases: reaction, stabilization, and evacuation. The ICEAS process can be designed as a BNR[6] system for removal of organic materials. This goal can be achieved by applying an aeration period (AIR ON) and shutting down the aerators (AIR OFF) in a time cycle. In such situations, aerobic, unoxic, and anaerobic conditions are created. For bio-removal of nutrient (N and P) and carbon-containing material, aerobic, unoxic, and anaerobic biological processes have to be combined(10). In this system, the flow of raw sewage is not interrupted at any stage of the purification. This leads to monotony organic and hydraulic loading of the system in all working stages. Furthermore, by using a time controlling system, duration of each phase is easily varied. This by itself is considered one of the advantages of the system. Other advantages of the system include, simple navigation, high flexibility against the organic and hydraulic shocks, decrease of the volume of the stabilized sludge, and decrease in the growth of filamentous bacteria(11). Considering these advantages, more than 800 refineries are ran by ICEAS all over the world. In Iran the sewage refinery of Maraghe is operating with this system (12). Following the investigations of Ghahfarokhion evaluation of the removal of detergent and organic material from hospital sewage by ICEAS method, the optimum time period in terms of efficiency was obtained as 4 h with the flow rate of 2 L/h. The percentage of BOD and COD removal were 94.54 and 92.97, respectively. Studies in recent decades indicate the priority of using the reactors with a floating bed system compare to those with afixed one for sewage purification operations (14-15). Furthermore, the most important factors influencing the efficiency of biological processes of sewage purification is the convenient selection of kinetic factors which often takes place without experimental studies or pilot plant. Determination of kinetic parameters of sewage purification will make remarkable contribution to precise designing of sewage refineries and investigation of their functionality (16).

Thus, utilization of intermittent cycle aerobic-anaerobic in the presence of activated carbon can reduce the oxygen consumption and needs for high amounts of energy as well as reducing the system running costs compared to the conventional activated sludge system. On the other hand, in the existing activated sludge systems, the output COD will be over 60 mg/L inn optimum condition (17). By addition of activated carbon and increasing the amount of biomass (microbial biomass) which will result in acceleration of biological reactions in food consumption, the output COD is expected to be less than the conventional systems. Hence, researchers are determined to study the kinetic and efficiency of intermittent cycle aerobic-anaerobic granular activated carbon-bed reactor in removal of the mentioned compound to find a way toward more practical applications of such technologies in addition to development of science.

2. Material and methods

In this experimental study, the reactor feed was supplied from sewage of Kermanshah.

2-1- Profile of the used sewage is shown in Table 1.

Table 2-1: **Profile of the raw feed sewage.**

Factor	TP	TN	N-Org	NH_4-N	TKN	BOD	SCOD	COD	Turbidity
Concentration (mg/L)	9.4±0.8	51.7±3.9	20±1.7	31.5±2.8	51.6±4	162±21	341.4±65	365.8±23.07	309±30

2-2- Profile of the reactor

To achieve the goals of the study, firstan intermittent current extended aeration activated sludge (ICEAS)reactor with 4 L effective volume was used which was already made by Pirsaheb*et al* in another research project (18). Granular activated carbon was put in the reactor to turn it to an intermittent cycle moving bed biofilm system. To investigate the effect of the added media on the efficiency of the reactor, three different amounts of the media (20, 35, and 50 v% of the reactor) were added. The reactor feed was supplied from raw sewage. In this project, activated sludge of sewage refinery of Farabi hospital was used as the bacterial seed. Cylindrical Plexiglas column bioreactor were of 8 cm interior diameter, 110 cm total height with 4 L effective volume, 5.5 L total volume and rector height of about 100 cm from the base up to overflow valve. An automatic evacuation system was installed to the upper part of the body of the reactor at height of 60 cm from the base of the reactor (75 % of the total volume) for drain withdrawal. Hence, the hydraulic retention time was calculated on the basis of 1 L as effective interchangeable volume. In each operating cycle, about 1 L of the upper clear liquid was removed and the same volume of fresh sewage was added to the reactor. This accelerated the dilution of the materials inside the reactor. During the habituation step and formation of biofilm in the system, MLSS and COD we measured once every 16 h until the COD reached a constant amount in the output. This step took almost two months. After stabilization of the system, the reactor with the hydraulic retention time of 3-8 h was started to be used. The operation of the bioreactor used in this research included phase mixing without aeration, aeration phase, stabilization, and finally removal of the purified wastewater. The needed air for the reactor was supplied by an air blower and four air diffusers of small bubble type which were placed at the base of the column. The consecutive mixing without aeration, aeration, stabilization, and wastewater removal operations were controlled by an automatic timer. For continuous supply of raw sewage of the system a peristaltic pump was used and for mixing the contents of the reactor a circulator pump was used. The schematic picture of the used reactor in this research is presented in Figure 2-1.

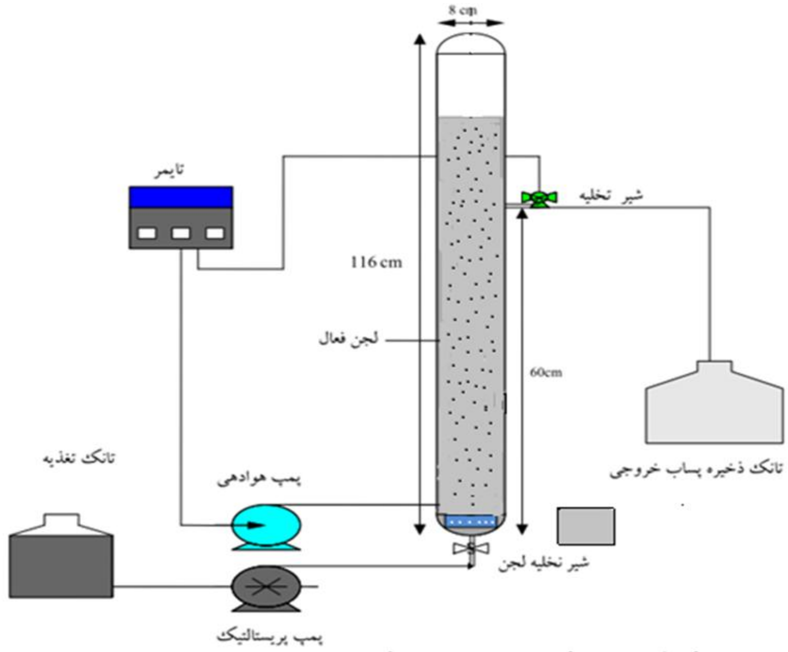


Figure 2-1: Schematic of ICAAGACR reactor

2-3- Properties of the used activated carbon: the properties of the used media are provided in Table 2-2.

Table 2-2: **Properties of the used media in the research.**

Media properties	Amounts	properties	Amounts
Total specific surface (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 (g/cm^3)	1.3		

2-4- Experiment design

RSM[1] is a collection of effective static and calculation methods for analysis of the effects of several independent variables on the function of the system which has an important application in design and optimization of a process. In current study, after passing the period of microorganisms compatibility with the existing condition, static design of the experiments took place using RSM method and by Design Expert software 7th edition. 20 experiments (1 central point, 7 pivot point, 7 variable points, and 5 repeated points in the center) were designed. Three independent variables including aeration time, mixing time (without aeration), and granular activated carbon percentage were considered at three levels which are shown in Table 2-3. Furthermore, the laboratory condition used in this research is presented in Table 2-4.

Table 2-3: **Experimented levels of independent variables.**

	Duration and Levels
Variable	-1 0 +1
Mixing time (min.)	30 60 90
Aeration time (h)	2 4 6
Media filling percentage (%)	20% 35% 50%

Table 2-4: **Operational condition of ICAAGACR reactor.**

Media filling percentage (%)	**Aeration time (h)**	**Mixing time (min)**	**operation**	**Media filling percentage (%)**	**Aeration time (h)**	**Mixing time (min)**	**Operation**
35	2	60	11	20	2	30	**1**
35	6	60	12	50	2	30	**2**
35	4	30	13	20	6	30	**3**
35	4	90	14	50	6	30	**4**
35	4	60	15	20	2	90	**5**
35	4	60	16	50	2	90	**6**
35	4	60	17	20	6	90	**7**
35	4	60	18	50	6	90	**8**
35	4	60	19	20	4	60	**9**
35	4	60	20	50	4	60	**10**

2-5- Bioreactor operation (formation of biofilm on activated carbon)

To begin the work in startup step, the microbial seed and raw sewage were used from the entry of urban sewage refinery. This step was repeated by complete aeration until reaching sTable condition and ICAAGACR system habituation.The period of formation of biofilm on the granular activated carbon surface and reaching the sTable condition took more than two months. Following the hydraulic test of the reactor for starting the system up, continuous raw sewage entered from the bottom of the reactor and the upper purified wastewater was removed at the end of each step. The operation of this system started with anaerobic step and continued with aeration cycles, stabilization, and removal. The time duration for each of the mentioned steps was controlled by an automatic timer. In all operational cycles, the stabilization time was considered 30 minutes and the removal time was considered 4 minutes.The variables studied in this project included aeration time (2-6 h), mixing time (30-90 min.), and activated carbon filling percentage (20-50 %). The amount of dissolved oxygen in the range of 3.5-5, considering the type of the system operation meaning presence of intermittent current in the system and aeration of the system after anaerobic step, the pH oscillations were not remarkable and were controlled in the range of 6.8-7.2. The mixed suspended solids (MLSS) of the system were kept constant as 4000 mg/L without considering the microbial film attached to the activated carbon.

2-6- Sampling process

To determine the efficiency parameters and biological constants, in each step of loading, the sampling took place from three places including the input, output, and the content of the reactor (height of 40 cm from the bottom of the reactor). It should be mentioned that to reach the sTable condition in each step, the sampling took place at fourth time after three times repeating. In this study on the basis of Design Expert (7^{th} edition) 20 steps of loadings were calculated.

2-7- Chemical analysis: The amounts of BOD, cBOD, COD, and cCOD were measured by using method standard book (19).

3- Results

Estimation of the ratio of C:N:P is needed to determine the convenience of the situation for growth of microorganisms. This ration in the studied system was around 100:14:3. Furthermore, according to the obtained results, ratio of BOD_5/COD is an average of 0.44 which is decreased in the purification process and reaches 0.22 at output wastewater. To compare the overall functionality of the system in removal of organic material, the efficiency of the removal of BOD, COD, SCOD, and CBOD parameters were investigated. The input and output pollutants are provided in Table 3-1 according to the range.

Table 3-1: Amount of organic compounds in raw sewage entering the system and the output wastewater.

Parameters	SCOD(mg/L)	COD (mg/L)	CBOD(mg/L)	BOD (mg/L)
Raw sewage	427.8-269.7	445.7-283.7	150.8-102	188.6-127.5
Wastewater	44.6-9.4	65.1-15.6	2.9-15	3.4-18.9

As mentioned, the three variables in this study were, activated carbon percentage, aeration time, and mixing time. In investigation of the properties of the acquired regression model corresponding to removal of organic material, as the coefficient of a parameter becomes greater it means the parameter is more effective than the other parameters with smaller coefficients. In this study the activated carbon percentage with the coefficient of 3.85 was more effective than aeration time and mixing time parameters with coefficients of 0.9 and 1.55, respectively.

The three dimensional diagram of the influence of different aeration, mixing (without aeration) condition, and media filling percentage on the efficiency of organic compounds removal is investigated. The diagrams show negligible impact of aeration and mixing time. As observed, the removal percentage is influenced by the media percentage. The diagram shows remarkable increasing manner from 20 to 35 %, but from 35 toward 50 % a negligible decrease is observed. The sharp slope or curvature of the media percentage parameter in the diagrams indicate a more sensitive response to this parameter.

(a) (b)

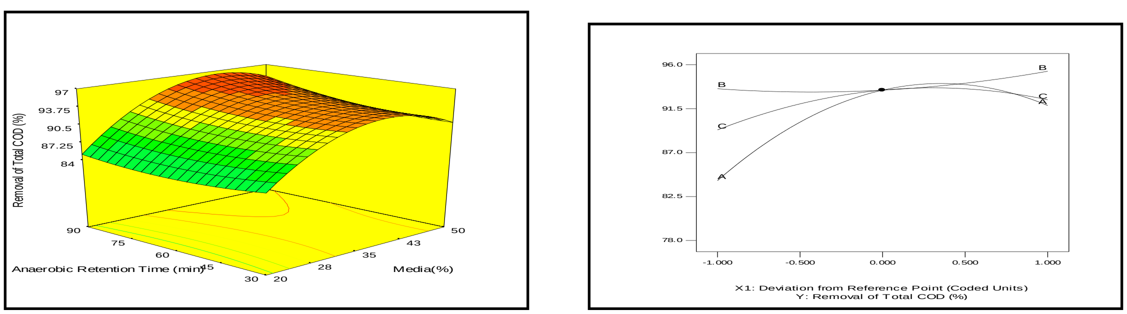
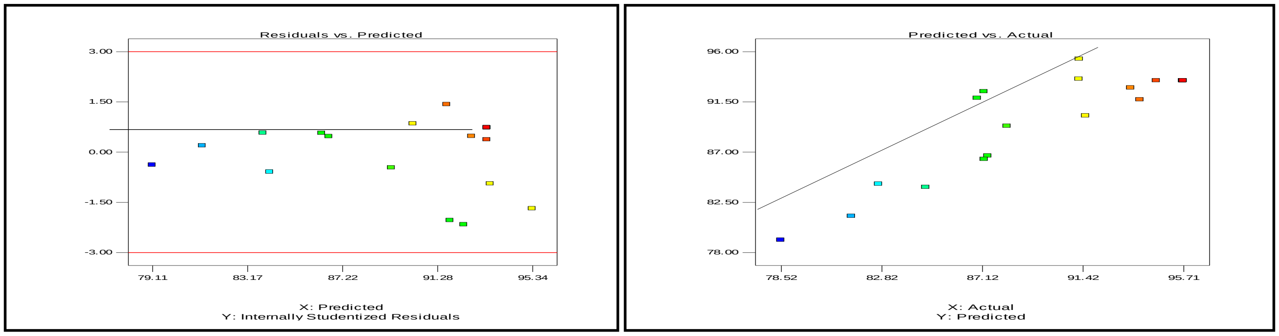


Figure 3-1: a) Three dimensional diagram of efficiency of total COD removal in maximum aerobic condition, b) Diagram of deviation from the central point in efficiency of total COD removal. [A: media (%), B: mixing (min.), and C: aeration (h)].

Furthermore, investigation of the results of the numerical optimization of analytic and descriptive parameters of TCOD, SCOD, TBOD, and CBOD removal in excel software on the basis of filling percentage indicate that there is a significant difference between the average amount of removal efficiency and different filling percentage (p-value < 0.001). In other words, it can be said that the percentage of media filling influences the efficiency of organic material removal. Post hoc test was used to determine the difference between the compared components. According to the obtained P, there is a significant difference between the efficiency acquired from 20 and 35 % filling percentage as well as 20 and 35 % (p-value < 0.05). Whereas, no significant difference was observed between 35 and 50 % (p-value > 0.05).

Graphical validation method was used to validate the predicted model for obtained results and according to the matching criteria of the mentioned method, the proposed models were in good agreement with the results obtained from the experiments (diagrams 3-2 and 3-3).

Diagram 3-2: difference (a) and match (b) of the real and predicted amounts for removal of total COD.



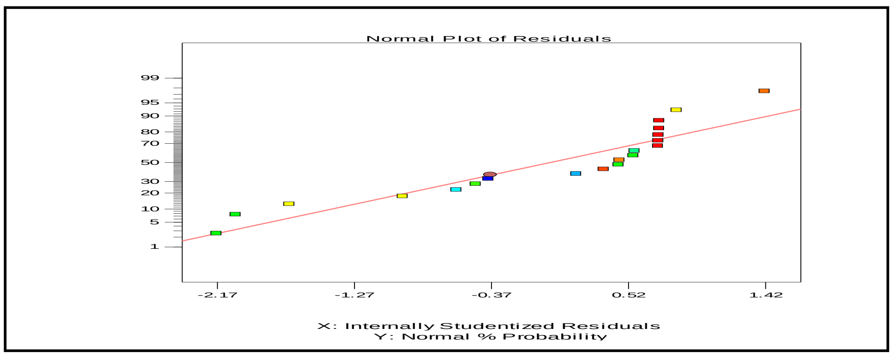


Diagram 3-3: **Normality possibility of the standardized remains (real and predicted difference) of total COD removal.**

Graphical optimization of a multilayer plan is for demonstration of the region where the response amount which are considered as standards are obtained. The optimum region is recognized according to the variables (removal of organic compounds) which are considered as the standards. The considered standard are shown.For BOD = 10-15 mg/L and COD = 20-30 mg/L the optimum region is the green region according to the investigated parameters (diagram 3-4).

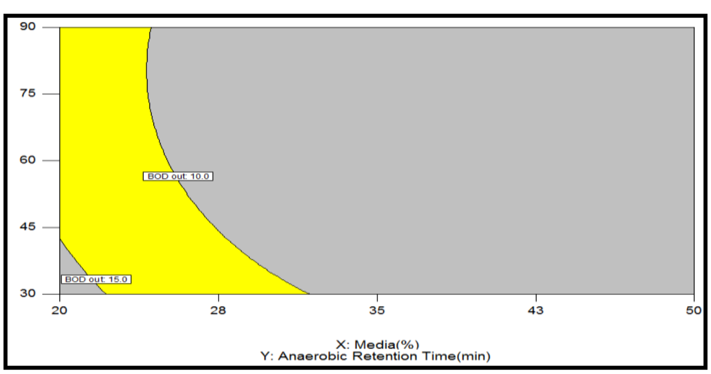


Diagram 3-4: **Optimization diagram on the basis of media percentage and anaerobic retention time for BOD.**

The suggested runs were obtained by DES software on the basis of optimum condition. In case the minimum amounts of media and aeration is considered, the output BOD is obtained as 12.5 from the runs with media percentage of 20, aeration time of 86 minutes, and mixing time of 2 h. In this study, at first the amounts of the considered parameters were calculated and then the kinetic coefficients were calculated by Monod balance model to determine the amounts of bio-kinetic coefficients.

Table 3-1: **Kinetic coefficients of organic material on the basis of Monod equation.**

Media percent age	$\mu_m(d^{-1})$	Y (mg_{vss}/mg_{bsCOD})	K_d (d^{-1})	K_s (mg_{bsCOD}/L)	K ($g_{bsCOD}/g_{vss}.d$)
20 %	1	0.65	0.028	75.06	1.54
35 %	1.3	0.74	0.059	81.37	1.8
50 %	1.5	0.815	0.077	86.35	1.92

Furthermore, the studied system obeys from second rate feed removal model (Diagram 3-5)

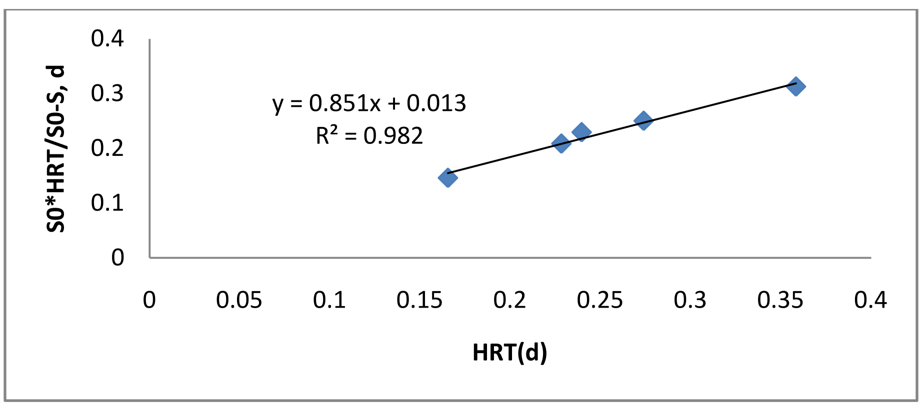


Figure 3-5: **Amounts of $COD_{in*}HRT/(COD_{in}-COD_{out})$ according to HRT in 35 % filling of the ractor volume by the media.**

Results and Discussion

In this research extended aeration process with granular activated carbon-bed was used for removal of organic compounds. One reason for using continuous aeration system in the presence of activated carbon is that according to 10-40 mg/L absorption of oxygen of GAC (20) more oxygen needs to be supplied for the system. Hence, the continuous aeration system is favored. And the reason for using activated carbon is its capability of absorption of all organic compound in a very sensitive level (21). Activated carbon provides special condition for adherence and growth of biofilm which is due to its highly coarse surface and its ability in absorption of organic compound and supplying the food needed for bacteria (12). Of course the amount of specific surface does not influence the formation and expansion of the biofilm according to some references (23-24) whereas according to some other references, it improves the process (25). The sizes of 12-42 mesh activated carbon are suitable for absorption in liquid phase and this range was used for current study. In these applications, the carbon filters usually are totally effective in removal of organic compounds in low concentrations(12). Presence of carbon in the system in addition to providing a high surface area creates a pressure decrease which is overcome by entering the input current from the bottom of the reactor and floatation of the activated carbon. The optimum functionality of any biofilm-containing reactor requires a completely grown biofilm (22). The environmental condition, temperature, and pH have important impact on survival and growth of microorganisms. This study was performed at room temperature (20 ˚C) and there was no problem regarding the temperatures over and below the convenient temperature range for activities of bacteria. Because the optimum temperature range for the activity of bacteria is 25-35 ˚C. The pH of a biological process is one of the most important factors in controlling the functionality of an anaerobic system. Bacteria cannot bear the acidic environments with pH <4 as well as alkaline environments with pH > 9.5. Majority of aerobic biofilms also function in pH range around 7 (22). In this system, since a 30 minutes stabilization takes place after aeration time, a relatively anaerobic condition dominates and the pH decreases. However, even in an aerobic condition a negligible decrease was observed and the pH stayed at the range of 7-7.4 due to existence of an intermittent current.

According to the obtained results from this study, the maximum removal of TCOD, SCOD, BOD, and CBOD were 95.71, 97.32, 97.83, and 98.16 %, respectively which were acquired in 35 % activated carbon, 4 h aeration, and 60 minutes mixing time. These amounts of removal efficiency are higher than those obtained by advanced biological sewage purification methods by activated sludge (26).

In different filling percentages, the maximum removal percentage of organic material happened at 35 % and the minimum amount at 20 %. Furthermore, there is a significant difference between the efficiency induced by filling percentages of 20 compared with 35 as well as 20 with 50, while negligible difference was observed between 35 and 50 % (p-value>0.05).This indicates the fact that using 50 % media for removal of organic compounds by this reactor is not cost effective and the same efficiency is obtained by 35 % media. On the other hand, the aerobic retention time is ineffective on the removal parameters and there is only a significant difference between 2 and 4 h in removal of total COD. Furthermore, no significant difference existed between the studied parameters and the mixing time (p-value>0.05). In investigation of the reason for ineffectiveness of the retention time in removal of the contaminants and why only the activated carbon has impact on the subject, it can be said that the time duration required for removal of organic carbons depends on the ability of the bacteria of activated sludge in degradation of these compounds. The compound with low molecular weights are removed from the sewage input current as soon as entering the reactor. This takes about 1-2 h. These group of compounds are those which are easy to be removed biologically and are referred to as soft BOD. The compound which have heavier molecules require more times to be degraded. Some of these compounds which are harder, will remain in the sewage even after several days. These compound which are less than the first group of compounds are referred to as hard BOD. The carbon-containing molecules which are harder and more complex find their ways into the output current of the refinery since they cannot be biologically degraded within the available time in the refinery. However, this happens in normal condition and activated carbon is an effective absorbent for removal of non-biodegradable compounds (27).

In a study on textile industry waste, the removal percentage of COD by conventional activated sludge and GACT were 90 and 95 %, respectively(8). In the investigations of Sirianuntapiboon *et al* the efficiency of BOD and COD removal by combined GAC-SBR were 91 and 82 %, respectively (28). In another study performed by Sirianuntapiboon *et al* on textile industry waste using granular activated carbon and sequencing batch reactor which took place at concentration of 7500 mg/L of granular activated carbon, the efficiency of COD and BOD removal obtained as 86.2 and 84.2, respectively(4). Mohd Hafizuddin *et al* in 2013 reached a removal efficiency of 100 % in the study of combined sequencing batch biofilm reactor and granular activated carbon system by response surface methodology for optimum removal of COD from sewage of a paper recycling factory(29). Yousefi *et al* in a study on the functionality of combined GAC-SBR system in removal of color from textile waste concluded that, in a reaction time of 14 h and 1 g granular activated carbon in SBR and GAC-SBR system, COD removal efficiencies were as 98 and 98.5 %, respectively and the removal efficiency by the combined system was higher in lower reaction times compared to higher reaction times. Hence, considering the relatively lower reaction times the efficiency of COD removal in combined GAC-SBR system was much higher (30). According to the results obtained from investigations of Asadi *et al*, a remarkable difference was not observed in efficiency of COD reactors following the addition of GAC(31).

In studying the three dimensional diagram, total COD removal efficiency was observed as an ascending slope from 20 % to 35 % and then descending from 35 % to 50 %. The reason for decrease of efficiency by increasing the percentage of activated carbon can be said that by exceeding media percentage from 35 %, the surface contact of the granular activated carbon increases due to mixing induced by aeration. Hence, by separation of a part of media can lead to decrease of efficiency. The mixing time under the maximum aerobic condition is totally ineffective and the slope of the curve is almost zero. The aerobic condition from 2 to 4 h is ascending and in higher times it is ineffective. Because the presence of media decreases the hydraulic retention time remarkably according to similar investigations.

By studying the three dimensional diagrams of SCOD removal, the mixing time impact is as follows; with the increase of mixing time the removal efficiency decreases at first and then increases. The mixing time in is considered for organic compounds in this reactor. About the organic compounds, it is more convenient for higher concentrations of organic compounds and in domestic sewage the concentration of organic compounds is mediocre. The increase of removal efficiency by increasing the mixing time may be due to providing the sufficient time for denitrification in which condition, the consumption of organic materials by denitrifiers increases.

By increasing the aeration time to 4 h, at first increase and then decrease of removal efficiency was observed. More detachment of in higher aeration times and unavailability of the substrate for bacteria is the reason for decrease of the efficiency. In studying the three dimensional diagram and deviation from the central point of BOD removal, the media percentage was effective as the previous parameters and the mixing and aeration time don’t have a considerable impact on the removal. By increasing the aeration and mixing time, the efficiency increased negligibly. About the efficiency of CBOD removal, the curve increases at first and then decreases by increasing the anaerobic time. This can be because the denitrifiers consume NBOD and don’t have an impact on decrease of CBOD.

Choosing an appropriate contact time results in use of all of GAC potential and hence, influences the lifetime of the media and amount of GAC consumption. Increase of contact time decreases the GAC consumption and reaches the minimum amount. The most important parameter in costs of biological refinery systems is the hydraulic retention time (HRT) (5).

The impact of phsisorption is little since in kinetic experiments of GAC absorption, DOC was absorbed quickly in 90 minutes and then stayed constant. In other words, in first 90 minutes the available sites of GAC were prevalent. When all of the absorption sites were occupied and the absorption-desorption reached a balance, the DOC removal remained constant (7).

4-1-1 Validation of the model and optimization of the process

The suggested models by Design Expert software are valid in case they meet the defined standards. According to the graphical validation by Design Expert software, when the difference of the values obtained from the experiments with those predicted by the model is between -3 to +3 units, the proposed model is acceptable and valid. Thus, all the presented models for removal of organic compound were placed in the defined range for the system under study. To optimize the processed and decrease the costs of the system, the efficiency of contaminant removal was defined by Design Expert software on the basis of providing international output standards. The solutions were presented considering these goals. Performing further experiments and spending more costs can be avoided by considering the presented solutions.

The relation between the variables and the obtained results was obtained using SPSS software and ANOVA statistic test. No significant difference was observed by studying the difference of average removal efficiency and output waste of organic compounds with various aeration time periods (2,4, and 6 h) individually. This indicates lack of impact of increasing the aeration time in these time periods on the removal of the mentioned contaminants.

The mixing time (without aeration) was another variable which was studied. Insignificant differences were observed between the average removal efficiency and output waste of contaminants in any conditions of mixing time. This indicates ineffectiveness of the variable in removal of organic compounds from the system. The last variable which was studied was media filling percentage of the system in which case a significant relationship was observed between the removal percentage and the activated carbon percentage.

4-1-2- Validation of bio-kinetic coefficients of organic compounds

Kinetic studies are highly important for determination of the possibility of using results of the researches in real scales and controlling the environmental condition in degradation of organic compounds. Usually the amount of K_d is less than other bio-kinetic coefficients which is also true in this study. As can be inferred from results ofthe study for organic compounds, the amount of K_d decrease by increase of total solid load (increase of media percentage). In other words, this kinetic parameters show the amount of self-destruction that the suspended solids of the mixture undergo. The self-destruction coefficient is calculated for representation of biomass induced by oxidation of intracellular stored products which store the energy needed for survival of the cell, cell death and being hunted by upper organisms in the food chain. In other words, microorganisms use their cellular storage in case of food shortage and increase the self-destruction coefficient. The self-destruction coefficient had a revers relationship with the efficiency of contaminant removal. In the system under study, with the increase of efficiency of organic compound removal, microorganism undergo less self-destruction. This trend was accompanied by increase of media percentage from 20 to 50 % and consequent increase of efficiency of contaminant removal. In addition to removal of extra sludge, continuous feeding of the system was another factor for controlling the self-destruction. A main advantage of ICEAS system over SBR is the continuous sewage feeding.

The Y coefficient is another kinetic constant which shows the conversion amount of contaminant to biomass and is directly related to the amount of sludge. Considering the fact that concentration of the contaminants is in a certain range and can be considered almost constant, by increasing the concentration of biomass, the amount of substrate available for microorganisms decrease. As a result, microorganisms begin their slippery process and the amount of Y decreases. This fact is true for conventional activated sludge systems and for heterotrophic bacteria. Hence, in case of continuous feeding of microorganisms and avoiding the exposure to stress and lack of substrate, Y has a revers relationship with K_d. this fact is in agreement with the results of the study. The values of Y in the system under study was higher compared to conventional activated sludge due to various reasons such as; the value of Yfor biological growth and kinetic is related to the concentration of active cellular mass (X) in the reactor. While the VSS existing in the reactor was more than active cellular mass a portion is related to cellular debris and other inactive organic compounds. Furthermore, due to presence of non-biodegradable organic compound in the input sewage and unavailability of a primary stabilizing pool in addition to single tank being of ICAAGACR system, the amount of Y in the system under study is more than conventional activated sludge. The K coefficient represents the maximum speed of substrate consumption. In current study, the relatively low values of K compared to conventional activated sludge systems is due to utilization of granular activated carbon media for increasing bacteria population.

The specific growth speed of bacteria is related to the maximum consumption of specific substrate. In other words, growth of biomass is a function of the amount of substrate consumption. When the speed of substrate consumption is high, bacteria grow fact as well. Thus, the maximum growth of biomass is called μ_{max}. The value of this coefficient increases by increase of media percentage due to increase of cellular retention time. K_s represents the concentration of food in half of the maximum speed of food consumption. As the value of this coefficient is lower, the degradability of the contaminants by microorganisms is higher in the system. The relatively high values of the coefficients in the current study compared to other studies was due to various reasons. The most important of them is the high efficiency of the system under study compared to their used systems (conventional activated carbon) in removal of organic compounds.

4-2- Conclusion

The results of RSM showed that media percentage was recognized as the most important variable for removal of organic compounds. The maximum removal efficiency region included 4 h aeration, 60 minutes mixing time (without aeration), and 35 % media filling percentage of the reactor volume. The maximum efficiency of TCOD, SCOD, BOD, and CBOD removal were obtained as 95.71, 97.32, 97.83, and 98.16 %, respectively. With the increase of MLSS (media percentage) it is possible to decrease the aeration and mixing time and hence, make the process more cost effective. The kinetic coefficients Y (gvss/gbCOD), k_s (gbCOD/m^3), k (gbsCOD/gvss.d), k_d (gvss/gvss.d), and μ_m (gvss/gvss.d) were obtained as 0.059, 0.74, 81/37, 1.8, and 1.33, respectively for organic compounds based on values od MLSS inside the reactor and without consideration of biofilm formation on the media.

4-3- Suggestions

As any research can lead to scientific and professional advances and enlighten many mysteries, dealing with numerous problems and issues in the process of the research and trying to achieve sufficient knowledge can also lead to other titles and subjects of research. On the other hand, any research will provide a direction for more comprehensive investigation of the area. Hence, it is suggested that more research takes place in;

- Investigation of relationship between the biomass and the media percentage
- Investigation of other domestic absorbents in the system under study
- Investigation of the system in microbiological terms
- Utilization of the system for purification of industrial and combined sewage

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