Biological Treatment of Grey Water Using Sequencing BatchReactor

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ABSTRACT

The present study included the application of Sequence Batch Reactor SBR technology for the treatment of domestic grey water which represents (50-80%) of the households wastewater.

Different cycle times were used 6, 8 & 12 hrs. at each cycle time, The characteristics of (PO_4^{-1}, NO_3^{-1}, COD) were studied of influent, effluent and through interaction samples in the reactor to evaluate the efficiency of the treatment technology used.

It was concluded that removal efficiency of organic matters (COD) increases with increasing the cycle time. Nitrate (NO_3^{-1}) removal was dependent on the availability of nutrients for microorganisms. On the other hand, optimum removal of phosphate occurred when aerobic and anoxic periods were equal.

when comparing the values characteristics (S.S, pH) for treated grey water with the Iraqi specification, it was found that there was a fair convergence in values. As for the values of electrical conductivity (EC), they were considered suitable for good bearing salts plants according to U.S. Salinity Laboratory classification.

Key words: Grey Water, Sequence Batch Reactor, Nitrate Removal, Phosphate Removal.

المعالجة البيولوجية للمياه الرمادية باستخدام احواض ذات الجرع المتتابعة

الخلاصة

يتضمن البحث استخدام تقنية احواض الجرع المتتابعة (SBR) في معالجة المياه الرمادية في المنازل حيث تمثل (50-80٪) من مياه الصرف الصحي للمنزل. وقد تم استخدام أزمنة دورة مختلفة 6، 8 و 12 (ساعة) وعند كل زمن دورة تم دراسة الخصائص (PO_4^{-1}, NO_3^{-1}, COD) للعينات الداخلة، الخارجة من المفاعل وخلال التفاعل في المفاعل، لمعرفة كفاءة النظام في المعالجة.

وقد تم الاستنتاج بأن إزالة المواد العضوية COD تزيد مع زيادة زمن دورة. أما بالنسبة لإزالة النترات فقد اعتمدت على توافر كمية من الغذاء العضوي للإحياء المجهرية. بينما وجد بأن أفضل إزالة للفوسفات تكون في حالة تساوي مدتي الظروف اللاأوكسجينية والهوائية.

وتبين عند مقارنة خصائص القيم (S.S, pH) للمياه الرمادية المعالجة مع محددات العراقية، وجد بأن هنالك تقارباً في القيم، واما بالنسبة الى قيم التوصيل الكهربائي ECللمياه الرمادية المعالجة ووفقاً لتصنيف مختبر الملوحة في الولايات المتحدة فقد تم اعتبارها صالحة للنباتات جيدة التحمل للملوحة.

كلمات دالة: المياه الرمادية، حوض الجرع المتتابعة، إزالة النترات، إزالة الفوسفات.

INTRODUCTION

Grey water is defined as all wastewater discharged from a house, excluding black water (toilet water). Thus, it includes water from shower, bath , sinks, kitchen, dish washers, laundry and washing machines. Grey water makes up the largest proportion of the total wastewater discharged from households in terms of volume. Typically, 50-80% of the household wastewater is grey water [1].

The reuse potential of treated grey water is high and the acceptance by the public that it is considered better than treated mixed wastewater [2], and can be used for many activities such as toilet flushing, garden watering, irrigation, washing machines and other applications [1].

There are many kinds of grey water treatment and reusing systems, like rotating biological contactors (RBC), flotation, membrane bioreactors (MBR), trickling filter, anaerobic treatment systems and sequencing batch reactors (SBR) [3]. Treating grey water with (SBR) goes one step further [4], where the sequencing batch reactors (SBR) is a fill-and-draw activated sludge system for wastewater treatment. In this system, wastewater is added to single "batch" reactor, treated to remove undesirable components, and then the supernatant is discharged. The unit operations including equalization, aeration and clarification can all be achieved using a single batch reactor [5]. SBR system has been successfully used to treat both municipal and industrial wastewater [6]. Figure (1) shows the outline of the sequence of steps of SBR [6].

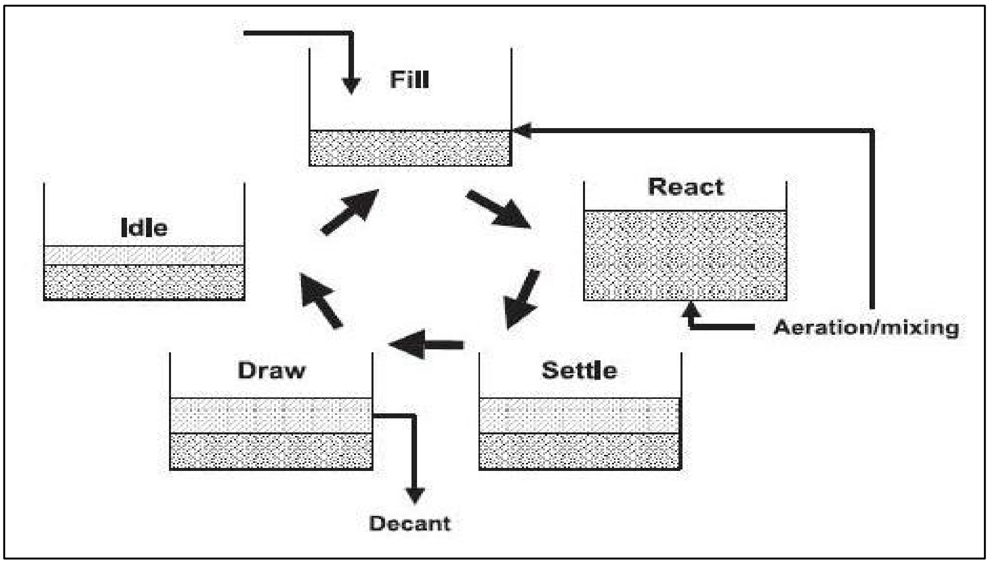


Figure (1) Sequencing Batch Reactor (SBR) Design Principle (EPA, 1997).

In a previous study in treating grey water collected from outlet of showers room of students by sequencing batch reactors (SBR) technology, it was found the performance of SBR was satisfactory as the effluent had respectively 20 and 50 mg/l of COD and BOD. Applied two hydraulic retention time (HRTs) showed that the nitrogen and phosphorus removed could be improved while adapting to load variations [4].

A study was performed by (Kalimuk and Kulikowska) about the influence of hydraulic retention time (HRT) in SBR and sludge age (SRT) on the effectiveness of nitrogen removal from leachate was investigated. Two series were performed, in each series experiments were carried out in four SBR operated in parallel at HRT 12hr, 8hr, 6hr and 2day, respectively. Each series differed in sludge age. In series 1, SRT decreased from 51 to 17d with shorting of HRT, while in series 2 it was about two times shorter, in each series found the amount of nitrogen used on biomass synthesis, removal of nitrogen in de nitrification and loss of ammonium during the aeration phase were estimated on the basis of material balance for all nitrogen forms in SBR cycle and shown that nitrogen consumption on biosynthesis was decreased linearly to the HRT increase [8].

In the literature, about treatment of grey water for irrigation, focusing on a treatment technology that is robust, simple to operate and with minimum energy consumption. The result is an optimized system consisting of an anaerobic unit operated in up flow mode, with a 1 day operational cycle, a constant effluent flow rate and varying liquid volume. Subsequent aerobic step is equipped with mechanical aeration and the system is insulated for sustaining winter conditions. The COD removal achieved by the anaerobic and aerobic units in summer and winter are 45%, 39% and 53%, 64%, respectively. Stability of sludge in the anaerobic and aerobic reactors is 80% and 93% respectively, based on COD [9].

The grey water treatment in the city of Mosul will reduce the pollutants that pose risk to Tigris river without any treatment, because it is the main source of water in it, and many regions of Mosul city suffer from shortage of water especially in summer.

The purpose of the present study is to investigate the application of sequencing batch reactors (SBR) technology for treating grey water collected from houses.

MATERIAL AND METHODS

Boot

The discussion dealt with domestic wastewater treatment (grey water) system using activated sludge SBR, where it was the work of Bench-Scale as reactor for the purpose of the study in the operating conditions represented by 6, 8 and 12 hours, was to take the necessary action to collect water samples from the grey houses. The experiment included collecting grey water from five houses, it was collected separately from four households activities: washing clothes, bathing, kitchen and other uses of tap water. Two processes of mixing were conducted, the first process included mixing each activity separately for the five houses, the second process included mixing activities at fixed proportions of (25%, 21%, 18% and 3%) respectively to form a composite sample[3], and studied the characteristics of (NO_3^{-1},PO_4^{-1}, COD) for influent, effluent and through interaction samples from the reactor to determine the suitability and efficiency of SBR system in the treatment of grey water, in addition to study the characteristics (pH, EC., S.S) of influent and effluent samples, as an indicator if treated grey water identical to Iraq specification at all operational conditions or no?.

Preparation of sludge seeds

Seeds were taken from the bottom part of the septic tank for domestic use. The sludge was sieved by using micro-strainer for removing inert materials that may present in the sludge.

The seeds were placed inside a glass basin for acclimation to increase the concentration to 2500 mg/l by using nutrients and the period of acclimation was accomplished during a month.

Description of the laboratory unit

A glass basin with dimensions (20X20X35) cm length, width and height respectively was used in this research. the effective height of water inside the basin was 30 cm so that the maximum capacity was equal to 12 L. the basin contains three dedicated pipelines to draw samples through electric valves during anoxic, aerobic conditions and sedimentation stage. The electric valves were located at a height of 10 cm from the bottom basin.

The disposal of concentrated sludge was done through aside tube located at a height 5cm from the bottom to control the value of Food Microorganisms ratio (F/M) which ranged between (9-90) load gm BOD/d/MLVSS and Sludge Retention Time (SRT) was equal to 20day [6] , as shown in the Figure (2).

Figure (2) a photograph of the laboratory unit.

A mixer was used from slow mixing in anoxic conditions to maintain the sludge in homogenous and suspension case with the grey water [10]. Air pumps were used during the aerobic conditions, so that the concentration of supplied oxygen is not to be less than 2mg/l in any case. The continuous control and monitoring were done through programmable logic controls. The cycle time was programed and divided to fill, react, settle, draw and idle intervals. The programmable cycle also included the alternative from aerobic to anaerobic conditions and controlling the processes of the withdrawal of samples from the three electric valves through sending signs to the electrical valves to give order for electrical valves to control the work of both the mixer and pumps.

Startup of SBR

The system was operated at laboratory temperature (26-32.5)$^{\circ}$C with three cycles (6 hr, 8 hr and12 hr) , as for identifying the periods of filling, reaction, settling, draw and idle, converting the anaerobic conditions to aerobic depending on the ratios contained [11] and as shown below.

At cycle time=6hrs.

Fill	**React**		**Settle**	**Draw**	**Idle**
Anoxic	**aerobic**	**anoxic**			

0 0.75 3.0 4.0 5.0 5.5 6.0

At cycle time=8hrs.

Fill	**React**		**Settle**	**Draw**	**Idle**
Anoxic	**aerobic**	**anoxic**			

0 1.5 4.0 6.5 7.5 7.75 8.0

At cycle time=12hrs.

Fill	**React**		**Settle**	**Draw**	**Idle**
Anoxic	**aerobic**	**anoxic**			

0 2.0 6.0 9.0 10.0 11.5 12.0

ANALYTICAL PROCEDURES

The dragged samples were analyzed for Suspended Solids (S.S), chemical oxygen demand (COD), Nitrites (NO_3^{-1}), phosphates(PO_4^{-1}), Electrical conductivity (EC), (pH), according to the standard methods [12].

The samples were collected at the beginning and the end of each stage (filling, reaction, settling) for all cycle time applied.

The samples were taken every 0.75 hr from the reactor at the cycle time 6 hr, At the cycle time 8hr, the samples were dragged every 1. 5 hr and every 2hr at the cycle time 12hrs.

RESULTS AND DISCUSSION

Grey water characteristic

The characteristics of the collected grey water from the households which are used as feed to SBR as shown in Table (1).

Table (1) The characteristic of grey water.

Parameter	Unit	Range	Average
pH	-------	7.35-8.0	7.68
S.S	mg/l	50.0-332.8	191.4
EC	µmho/cm	643-876	759.5
COD	mg/l	208-384	296.0
NO_3^{-1}	mg/l	0.2-0.45	0.33
PO_4^{-1}	mg/l	1.853-6.33	4.09

In Table (1), it is clear that the COD concentration of organic matters is relatively low and this is due to the excessive use of clean water in various household activities [3].

The values of pH tend to be neutral toward the basic range (7.35-8.0) with an average value of 7.68, and this may be attributed to the frequent use of detergents and soaps for washing activities in the based home [13].

Theelectricalconductivity(EC)valueswerein the range of (643-876) µmho/cm which is considered relatively high due to the presence of inorganic dissolved salts, resulting from the various home activities, This is consistent with what was stated by [14].

The concentrations of suspended matter (50-332.8) mg /l are relatively high due to the presence of residue of foods and dirts resulting from cleaning of houses. These results are argument with[15]

The concentrations of phosphate were higher than nitrate, and this is due to the use of soaps and detergents which represents a major source of phosphate [2].

SYSTEM EFFICIENCY IN THE REMOVAL OF NUTRIENTS

NITRATE (NO_3^{-1})

In Figures (3, 4 & 5) it is clear that the removal efficiency of nitrate during fill interval at anoxic conditions is decreasing with a rapid speed.

The minimum value of nitrate concentration approach 0.02 mg/l at anoxic fill time (2 hrs.) for the cycle time (12 hrs.) Figure (5). This is due to the occurrence of de-nitrification where the nitrate is converted to nitrogen gas under the effect of anoxic condition [7]. At the beginning of the aeration stage the concentration of nitrate is increasing due to the converting of ammonia to nitrate by Nitrosomonas and Nitrobacter bacteria [16]. A gradual decrease in the concentration of nitrate begins under anoxic conditions and the decrease continues to the end of the reaction interval in spite of the end of anoxic conditions. The concentration of nitrate in the effluent reaches 0.17 mg/l at the cycle time 6 hrs., 0.24 mg/l at the cycle time 8 hrs. and 0.13 mg/l at the cycle time 12 hrs. . This may be attributed to the absence of organic matters and the end of reaction interval [17]. The removal efficiencies of nitrate were (29%,37%,57%) at 6, 8 and 12 hrs. Respectively and it is clear to record that the best removal was at the cycle time 12 hrs.

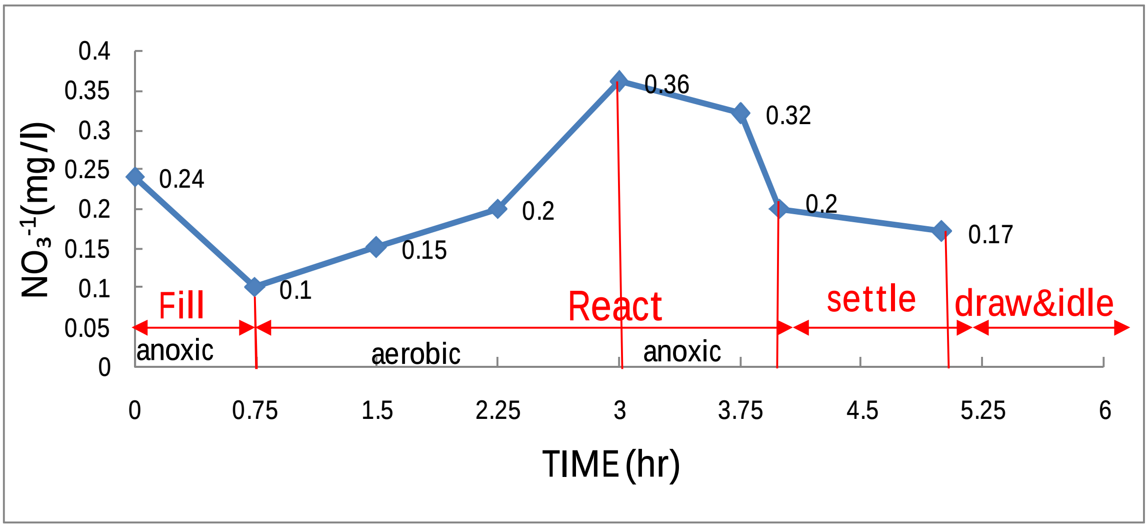


Figure (3) Variation of No_3^{-1} concentrations at cycle time 6 hrs.

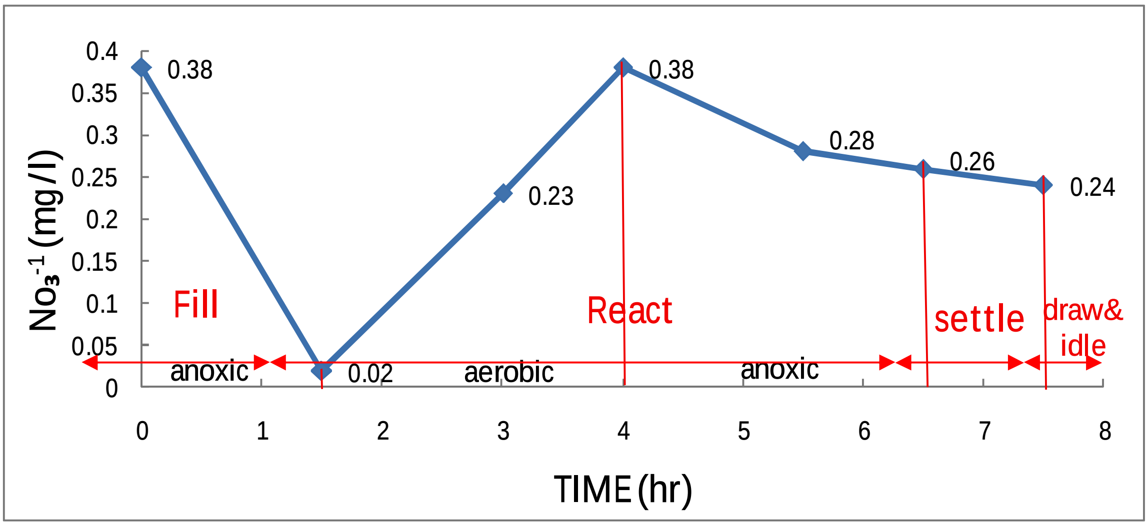


Figure (4) Variation of $No3^{-1}$ concentrations at cycle time 8 hrs.

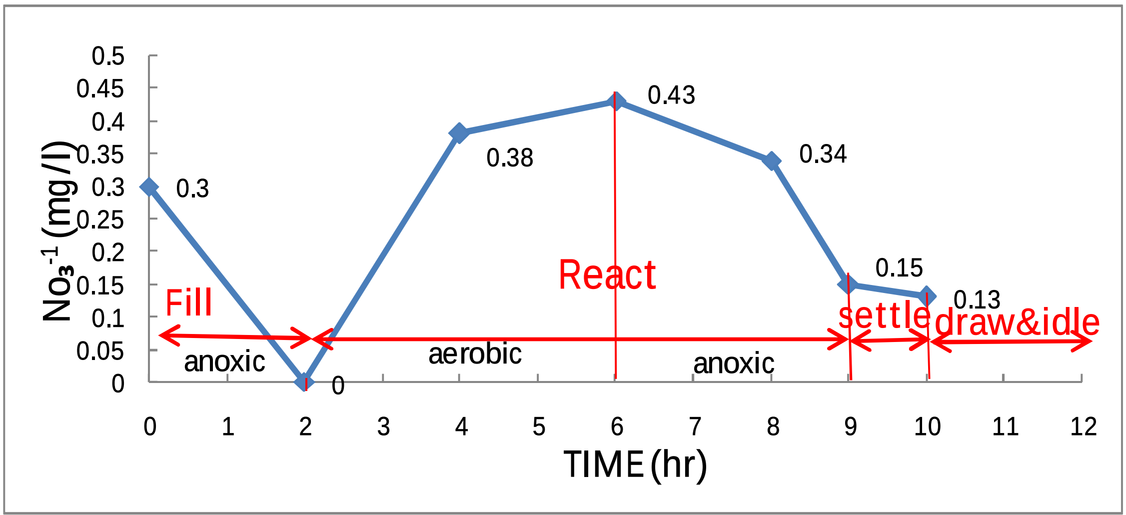


Figure (5) Variation of No3^{-1} concentrations at cycle time 12 h.

Phosphate (PO_4^{-1})

In Figures (6, 7&8), it is obvious that there were an increase during Fill anoxic stage due to the accumulation and release of by the microorganisms. From the beginning of aeration to the end of reaction interval, it is clear that there were a decrease in phosphate concentration due to the presence of microorganisms responsible for reducing phosphate and storage it as poly phosphate in the cells.

The concentrations of phosphate in treated discharges reached (2.3,1.3,2.72) mg/l respectively for cycle times (6, 8 & 12 hrs.). This reduction may be attributed to the change from aerobic to an aerobic conditions that yield reach groups of microorganisms responsible for extraction phosphate from waste water [4].

From the figures below it is clear to see that the minimum value of phosphate occurs at the fill anoxic time equals to aerobic time. The minimum recorded value was 1.49 mg/l after fill anoxic time equals to 2 hrs. and aerobic time equal to 2 hrs. at cycle time 12 hrs. [10].

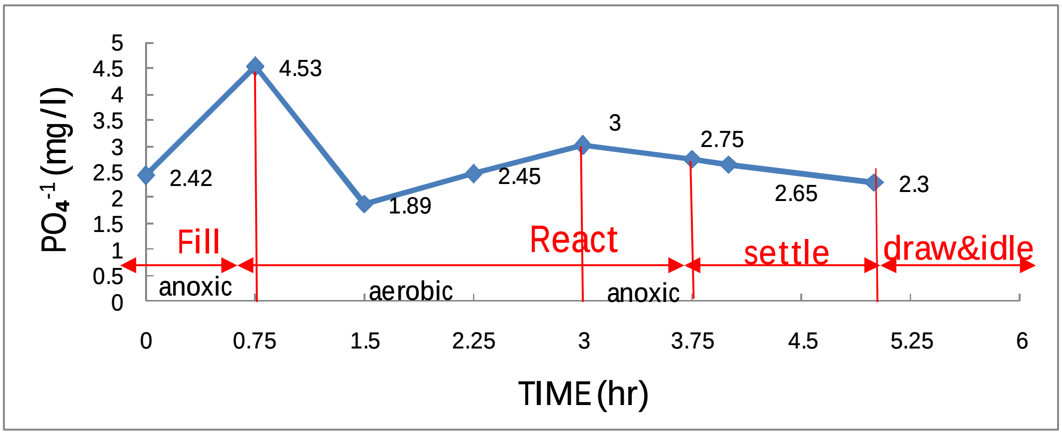


Figure (6) Variation of PO_4^{-1} concentrations at cycle time 6 hrs.

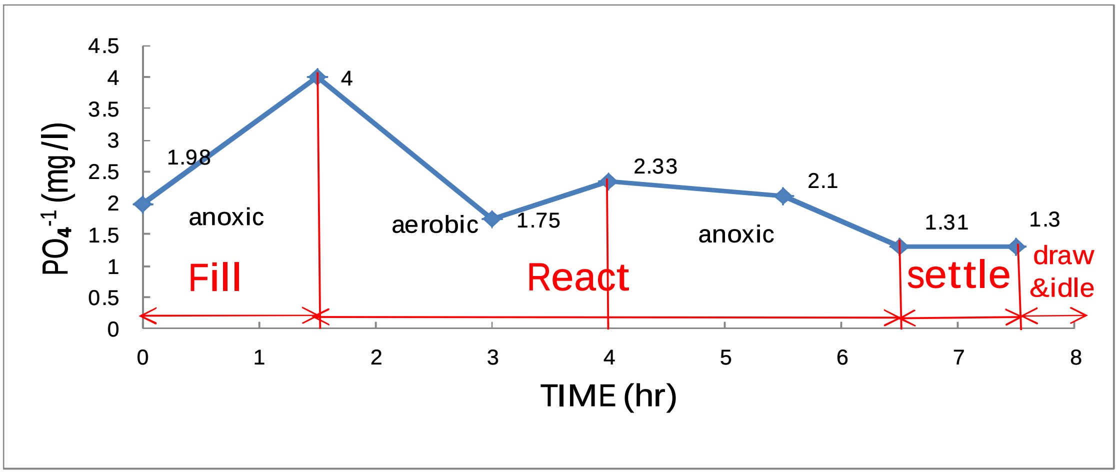


Figure (7) Variation of PO_4^{-1} concentrations at cycle time 8 hrs.

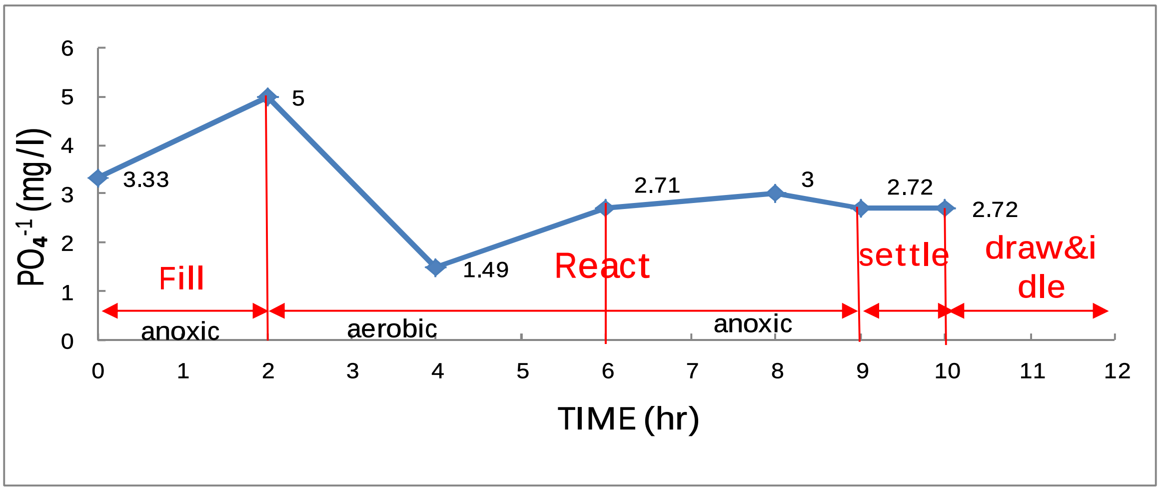


Figure (8) Variation of PO4[-1] concentrations at cycle time 12 hrs.

SYSTEM EFFICIENCY IN THE REMOVAL ORGANIC MATTERS (COD)

In Figures (9, 10 &11), it is obvious that the concentration of organic matters increases through the first stage (fill stage) which operates under anoxic conditions. In this stage an aerobic degradation for the incoming organic matters occurs. The intermediate products such as acetic acid are capable of biological degradation. At the beginning of aeration stage, the degradation value of COD begins to decrease and this phenomenon is also continued in the following stage (anoxic stage) during the reaction interval. This phenomenon may be attributed to the occurrence of nitrogenous process during the aeration stage, that converts ammonia to nitrate by the microorganisms which consume dissolved oxygen present in the residual organic matter [18].

The efficiency of removing COD at 6, 8, 12 hrs. reaches (65%, 80%, 83%) respectively, and the highest removal was at cycle time 12 hrs. This is my be attributed to a complete oxidation of the refractory organic matters present in the incoming grey water [19].

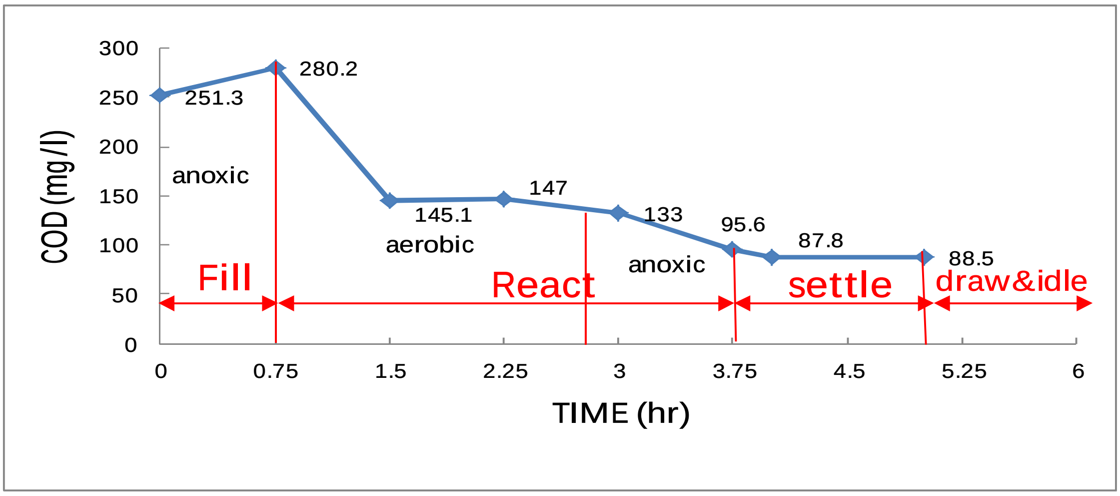
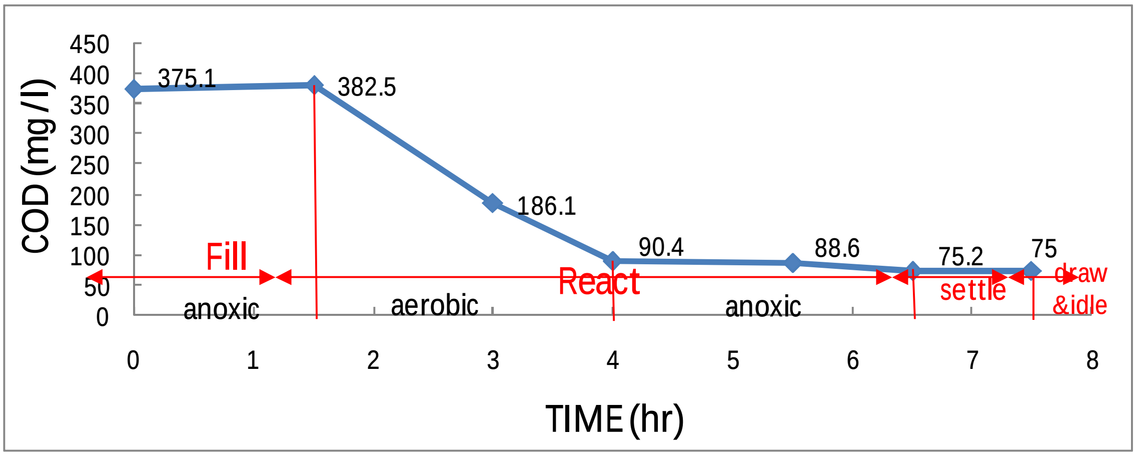


Figure (9) Variation of COD concentrations at cycle time 6 hrs.



Figure(10) Variation of COD concentrations at cycle time 8hrs.

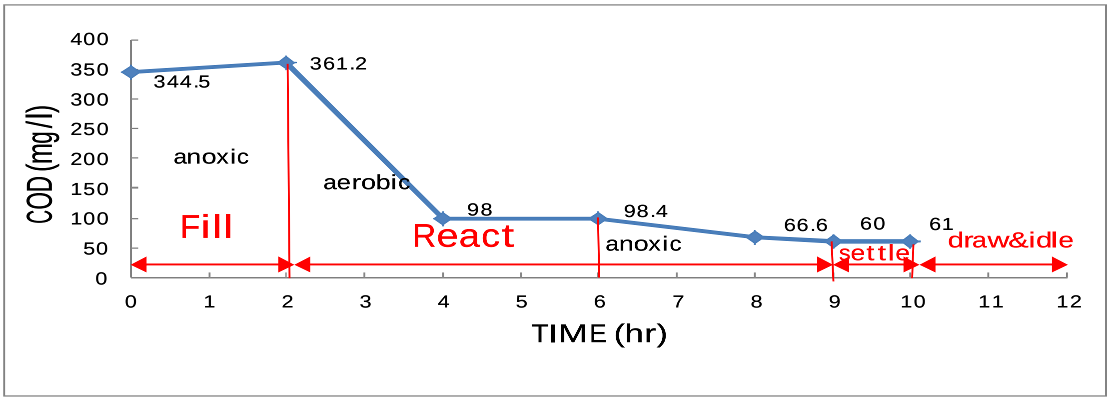


Figure (11) Variation of COD concentrations at cycle time12hrs.

COMPARISON BETWEEN THE CHARACTERISTICS OF TREATED GREY WATER WITH THE PARAMETERS

Table (2) shows that the characteristics of grey water (pH, S.S, NO_3^{-1} ,PO_4^{-1} ,COD) at all cycle times (6 hrs., 8 hrs.,12 hrs.) were comparable to the Iraqi specification [20], As for the values of electrical conductivity (EC), they were according to the U.S. Salinity Laboratory classification, considered suitable for good bearing salts plant [21] & [22].

Table (2) Comparison of the characteristics of treated grey water with Iraqi specification and U.S. Salinity laboratory.

Characteristics	Treated grey water	Parameters
pH	8.36-7.26	*6-9.5
S.S	45-25	*60
COD	88.5-59.7	*Less than 100
PO_4^{-1}	2.7-1.30	*3
NO_3^{-1}	0.27-0.13	*50
EC	760-1138	**750-2250

* Iraqi specification.
** U.S. Salinity Laboratory

CONCLUSIONS

1. The highest removal of organic matters by using SBR was at cycle times 12hrs. the removal efficiency of organic matter increased with increasing the cycle time.
2. The removal efficiency of nitrate depends up on the abundance of organic food for microorganisms, the minimum removal was 0.02mg/l for fill anoxic time 2hrs. at cycle time 12hrs.
3. The maximum removal of phosphate happens when the fill anoxic time equals to aeration time for all cycle times. The maximum reduction was at 2hrs. for both of fill anoxic time and aeration time for cycle time 12hrs.
4. The characteristics of treated grey water approached to the values listed by Iraqi specification.
5. The characteristics of treated grey water are suitable for irrigating good bearing salts plants according to the laboratory of U.S. Salinity depending up on EC. Value.

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