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Optimizing Aeration Cycles for Enhanced COD and BOD5 Removal in Domestic Wastewater Treatment: A Case Study from Al-Hilla City, Iraq

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ABSTRACT

Eutrophication is a risk factor because wastewater has an excessive amount of organic matter, specifically chemical oxygen demand (COD) and biological oxygen demand (BOD5), which deplete dissolved oxygen (DO) in water bodies. Since the biological treatment of wastewater is reliable, affordable, and produces safe results, it has been a valuable technique for treating wastewater for centuries. This work discusses the treatment of actual domestic wastewater from Al-Hilla city in Babylon using a laboratory-scale batch reactor with several input-characterized samples to forecast the elimination of COD and BOD5 together. Different cycle times were used 6, 8, and 12 hrs. The removal efficiency of organic matter (COD, BOD5) from wastewater increased when the aeration time (A) of cycles increased. The removal efficiency of organic matters (COD, BOD5) was increased when there was an increase in aerobic conditions (A) during the fill and react phases, because of the aerobic degradation of the incoming organic matters as a result of microorganism activity, where; the removal efficiency of COD ranged from (43.3-88.8), while for BOD5 was (58.8- 91.2).

1. Introduction

Every community generates air pollution as well as liquid and solid waste. Wastewater, often known as liquid waste, is essentially the community's water supply after it has been put to use for various purposes. When considering the sources of generation, wastewater can be characterized as a mixture of the liquid or water-carried wastes that are extracted from homes, businesses, and institutions, together with any

potential groundwater, surface water, and storm water. [1, 2]. In terms of quantities, the organic matter found in wastewater is often separated into four categories: soluble, granular, superglue, and precipitant. The removal of these compounds involves a range of phenomena, such as coagulation, sedimentation, direct representation, adsorption, and sedimentation. [3, 4].

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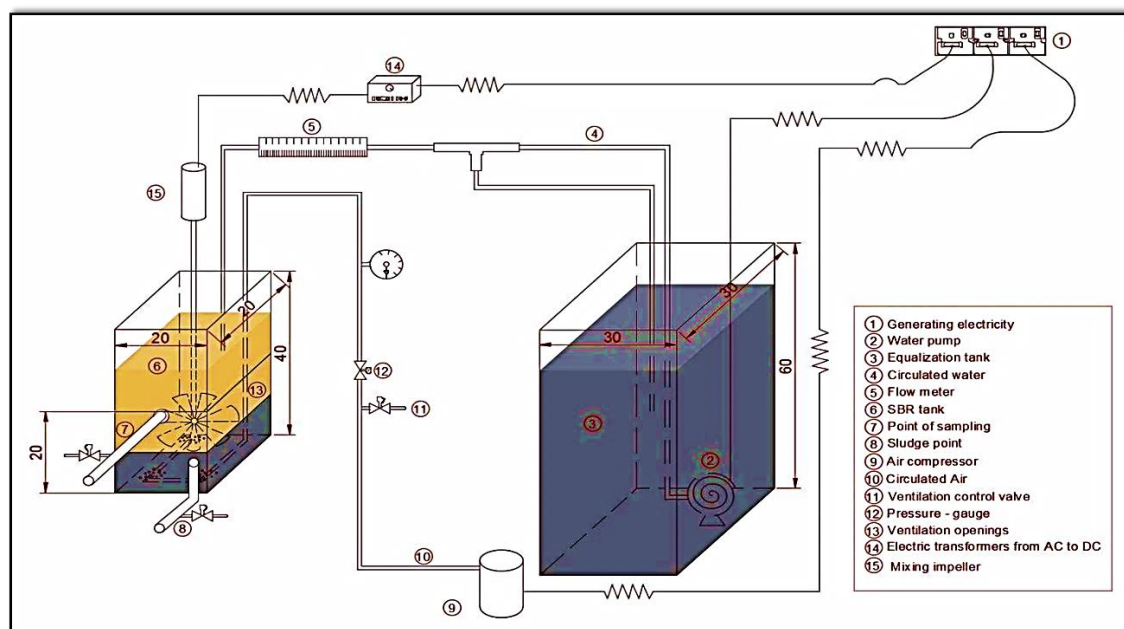
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The Sequencing Batch Reactor (SBR) concept was created for the use of batch reactors in wastewater treatment. According to this theory, following the reaction, the activated sludge settles, the effluent is removed, and fresh influent is introduced. A cycle is the interval of time between two successive influent additions. One or more tanks can make up an SBR system. Each tank in the biological waste treatment system has five fundamental operational times. [5, 6]. In chronological order, these phases are FILL, REACT, SETTLE, DRAW, and IDLE (Commission for New England Interstate Water Control, 2005). [7]

Fill: In the fill phase, influent wastewater is introduced into the basin. The activated sludge's microorganisms receive nourishment from the influent, which fosters the environment necessary for biochemical reactions to occur [8]. The three distinct scenarios can be produced by adjusting the mixing and aeration during the fill phase. Aerated, Mixed, and Static Fill [9]. **React:** In this stage, the aeration and mechanical mixing devices are running and no wastewater is allowed to enter the basin. The rate of organic elimination rises significantly since there are no more volumetric and organic loadings. In the react phase, the majority of the carbonaceous BOD removal and further nitrification takes place. During the react phase, some more phosphorus in addition to that released during mixed fill is taken up. [10, 11]. **Settle:** Activated sludge is permitted to settle in a quiescent state during this phase. There's no aeration, no mixing, and no flow into the basin. **Draw:** The clear supernatant effluent is eliminated at this stage using a decanter. Clear supernatant is released as effluent when the settle phase is over, and this is done by sending a signal to the decanter to open an effluent-discharge valve[10]. **Idle:** This stage takes place in between the subsequent cycle's fill and decant phases. The operation strategy and influent flow rate determine the idle time. In this stage, the cycle's excess sludge, or concentrated solids, are pumped out of the SBR basin's bottom for additional processing and disposal. [12, 13].

2. Materials and Methods

The primary sedimentation tank (equalization process), SBR tank (fill, react, settle, draw, and idle operations), ventilation unit, and mixing unit comprised the pilot plant where the experimental experiments were carried out. Fig. (1) displayed the experimental apparatus's schematic diagram. The equalization tank, which stood in for the source of untreated wastewater, was thirty, thirty, and sixty centimeters in length, width, and height, respectively. The SBR tank measured 20, 20, and 40 cm in length, width, and height, in that order. The SBR tank's effective depth was 35 cm. Two ports are present in this tank: one at the bottom, which was used to remove extra sludge; the other, located around 20 cm from the bottom, was used to remove samples for testing and to release the supernatant fluid. An air compressor and an air pressure control meter make up the ventilation unit, and 0.2 MPa of pressure was needed. The ventilation unit concludes with a tube that extends all the way to the bottom of the SBR basin. The tube is fitted with tiny perforations that allow small bubbles to enter the basin, providing oxygen to the microorganisms during the aerobic phase. The alternating current source and the voltage and electrical resistance regulator make up the mixing unit. An impeller that is mechanical completes this device. This impeller was made to run at the lowest possible speed. Maintaining the activated sludge suspended in all areas of the waste water was the goal of this minimum speed in order to accomplish biological treatment. Sludge seeds from Al-Hilla City's waste water treatment plant were used in the experiments. The seeds had grown to a concentration of about 3895 mg/l, which was within the range of 2000–4000 mg/l. Sludge seeds were placed in an SBR basin with a sequence of aerobic and anaerobic conditions, and wastewater from the original waste water treatment facility was periodically added as part of the development mechanism. This procedure ran nonstop for a month. Following that, daily samples of raw wastewater were brought in for SBR treatment under various chosen settings and times.

**Fig. 1:** Experimental setup

3. Results and Discussion

The study's objectives, which include a description of the SBR's performance assessment, are discussed and the results are presented. Table 1 contains a list of these samples' attributes. Samples, both raw and processed, were preserved at 4°C as required by adding preservatives such chloroform. Every parameter was measured by adhering to the specifications and guidelines provided in the tests and procedures of the AWWA, WPCF, and APHA.

Table 1: The Characteristics of Raw Wastewater

parameter	unit	Rang	Average
Temperature (T)	°C	18-25	21.50
Potential of hydrogen (pH)	---	8.45-8.65	8.55
Electrical conductivity (EC)	µs/cm	2212-2500	2356
Total dissolved solid (TDS)	mg/l	1073-2141	1607
Dissolved oxygen (DO)	mg/l	2.62-3.5	3.06
Total suspended solid (TSS)	mg/l	450-612	531
Chemical oxygen demand (COD)	mg/l	150-450	300
Biological oxygen demand (BOD ₅)	mg/l	170-227	199

3.1 SBR Efficiency for Chemical Oxygen Demand (COD) Removal

The quantity of energy and carbon that is accessible to the heterotrophic microbial population inside the reactors is indicated by the Chemical Oxygen Demand (COD). The amount of COD that is utilized should be maximized in a biological reactor that is well-designed and managed. The term "COD" refers to the amount of oxygen needed in wastewater for the organic components to totally oxidize. The COD concentration fell between 150 to 450 mg/L, which is the usual range for effluent from regular municipal sewage systems. Rainwater diluting of swage wastewater was the cause of several COD data points near 150 mg/L, indicating that a sizable portion of the sewage wastewater collection system was affected. The SBR operating method for treating wastewater involves choosing

from a variety of cyclic modes of operation. By optimizing one cyclic mode, one can lower the content of COD in the effluent by achieving a high removal efficiency.

The cycles that operated for 6, 8, and 12 hours, respectively, are shown in Tables 2, 3, and 4. This helps to explain why the concentration of organic materials rose during the fill phase, which was static fill. There was no deterioration of the incoming organic materials at this point. COD concentration began to drop during the react phase at the start of the aeration stage, and this phenomena persisted in the subsequent stage (the anoxic stage). The intermediate compounds, such acetic acid, could degrade biologically. For the operating cycles of 6, 8, and 12 hours, respectively, the COD effluent concentrations decreased to (68, 67, and 66) mg/l, with an average effluent value of 171 mg/l.

Table 2: Variation COD Concentration at Cycle with 6hrs.

Fill	React			Settle	Draw	Idle
non A & AN	A	AN	A			
182 (mg/l)	88 (mg/l)	85 (mg/l)	71 (mg/l)	68 (mg/l)		
0hr	1.5hr	2.2hr	2.9hr	3.6hr	4.8hr	5.7hr 6.0hr

Table 3: Variation of COD Concentration at Cycle with 8hrs.

Fill	React				Settle	Draw	Idle
non A non AN	A	AN	A	AN			
184	68	68	57	61	67		
0	2.0	2.7	3.4	4.1	4.8	6.4	7.6 8.0

Table 4: Variation of COD Concentration at Cycle with 12hr.

Fill	React				Settle	Draw	Idle
non Anon AN	AN	A	AN	A			
158	163	88	83	68	66		
0	3.0	4.05	5.1	6.15	7.2	9.6	11.4 12.0

The cycles with operating hours of 7.5 and 11 hours, respectively, are displayed in Tables 5 and 6. During the fill phase, which functioned in anoxic conditions, the concentration of organic substances increased (mixed fill). Anaerobic degradation of the entering organic materials was occurring at this point. Because of the predominately aerobic settings, there was a noticeable decline in COD concentration during the respond phase. For the operational cycles of 7.5 and 11 hours, respectively, the effluent concentration of COD decreased to (29 and 77) mg/l, with an average influent value of (280) mg/l.

Table 5: Variation of COD Concentration at Cycle with 7.5hr

Fill	React	Settle	Draw	Idle
AN	A			
272	55	29		
0	1.875	4.5	6.0	7.125 7.5

Table 6: Variation of COD Concentration at Cycle with 11hr

Fill	React	Settle	Draw	Idle
AN	A			
315	78	77		
0	1.5 2.75	6.6	8.8	10.45 11.0

The cycles with operating hours of 7.5, 9 and 12 hours, respectively, are displayed in Tables 7, 8, 9. During the fill phase, which was conducted in an aerobic environment, the concentration of organic materials decreased (aerated fill). For the operating cycles of 7.5, 9 and 12 hours, respectively, the effluent concentration of COD decreased to 75, 103 and 77 mg/l, with an average influent value of 263.7 mg/l.

Table 7: Variation of COD Concentration at Cycle with 7.5hr

Fill	React	Settle	Draw	Idle
A	AN			
78	83	75		
0	1.875	4.5	6.0	7.125 7.5

Table 8: Variation of COD Concentration at Cycle with 9hrs

Fill	React	Settle	Draw	Idle
A	AN			
102	107	103		
0	2.25	5.4	7.2	8.55 9.0

Table 9: Variation of COD Concentration at Cycle with 12hr

Fill		React		Settle	Draw	Idle	
A	AN	A					
86	89	75		77			
0	2.0	3.0	5.1	7.2	9.6	11.4	12.0

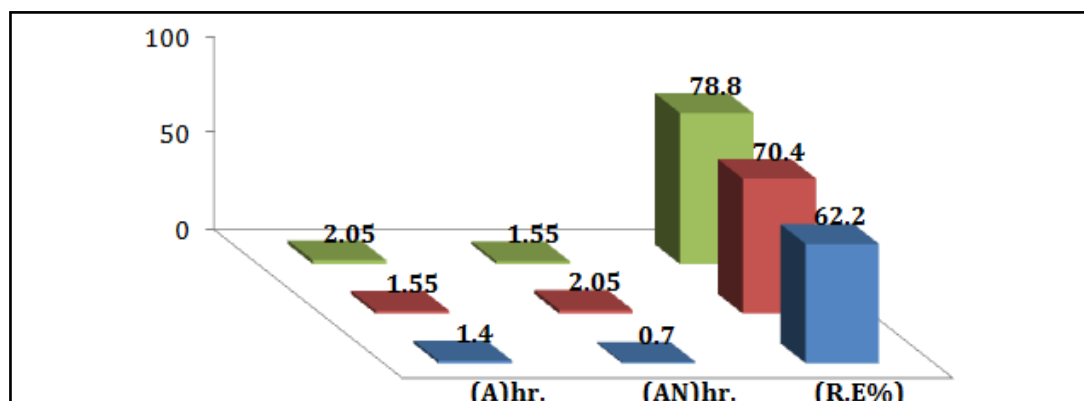
Table 10: Variation of COD Concentration at Cycle with 6hrs

Fill		React		Settle	Draw	Idle	
AN		AN	A				
287	135	130	88	77			
0	1	1.5	2.55	3.6	4.8	5.7	6.0

Table 11: Variation of COD Concentration at Cycle with 6hrs

Fill		React		Settle	Draw	Idle	
A	AN	A	AN				
73	71	62	59	55			
0	1	1.5	2.55	3.6	4.8	5.7	6.0

The removal efficiency of COD for cycles with times of six and fifteen hours, respectively, is displayed in Figs. (2 and 3). It is possible to explain why there was an increase in removal efficiency during the fill and react cycle phases when the aeration time (A) was increased.

**Fig. 2: Removal Efficiency of COD at Cycles with 6hrs. (Different Aeration Time)**

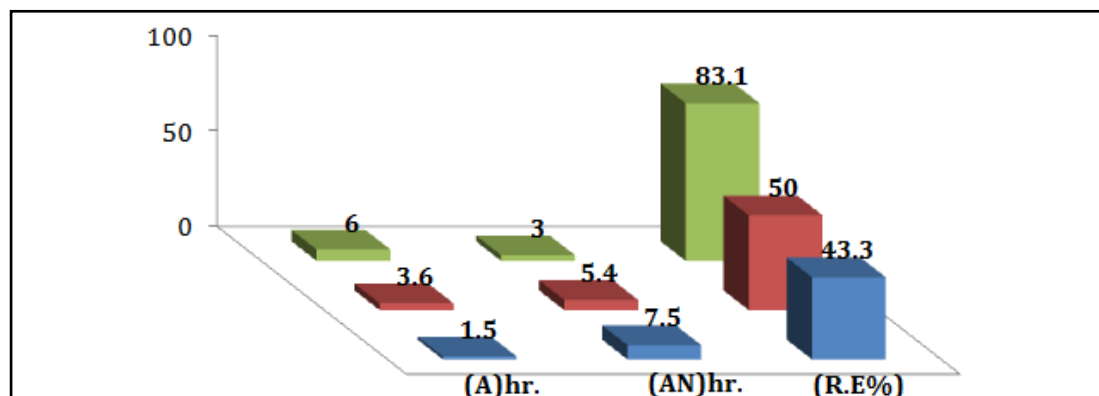


Fig. 3: Removal Efficiency of COD at Cycles with 15hr. (Different Aeration Time)

3.2 SBR Efficiency for Biochemical Oxygen Demand (BOD) Removal

Microorganisms in the wastewater are used by most wastewater treatment plants to break down trash. The amount of dissolved oxygen consumed by these bacteria is known as the Biochemical Oxygen Demand, or BOD, and it is generally equal to the amount of "food" (organic matter) present in the wastewater. The BOD test, also referred to as "BOD5" since it is based on an accurate measurement of DO at the start and finish of a five-day period during which the sample is kept in dark, incubated conditions, can be used to determine the BOD of wastewater. The BOD value is frequently used as a reliable proxy for the level of organic pollution in water. It is most usually stated as milligrams of oxygen used per liter of sample during five days of incubation at 20 °C. The

biological oxidation process is a very sluggish one in which certain microbes use dissolved oxygen to oxidize organic contaminants into carbon dioxide and water. Therefore, the foundation of BOD is the idea that aerobic decomposition, or the stabilization of organic matter, by microbes, will persist until all waste has been consumed if there is enough oxygen available.

The relationship between the rate of aeration and BOD removal efficiency is demonstrated in Figs. (4 and 5), where an increase in aeration time (A) through the fill and react cycle phases resulted in an increase in BOD removal efficiency due to the activity of microorganisms resulting from an increased concentration of dissolved oxygen.

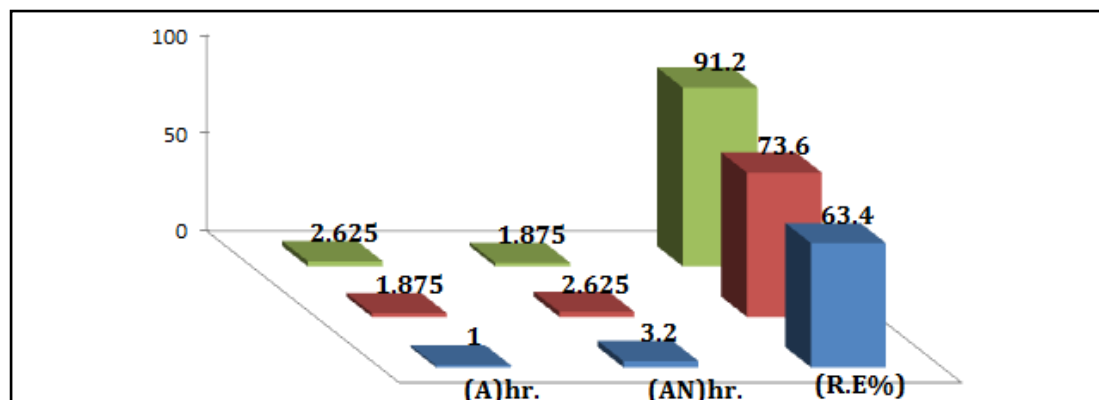


Fig. 4: Removal Efficiency of BOD at Cycles with Time (7&7.5)hr.

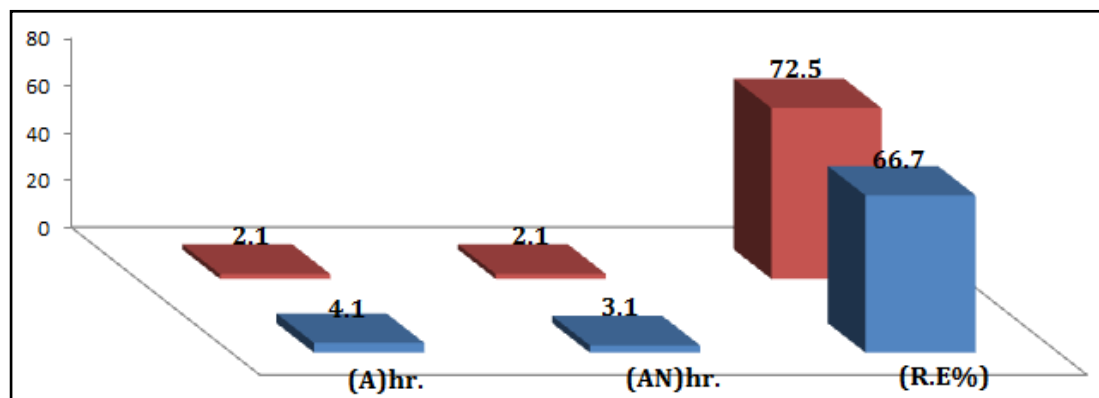


Fig. 5: Removal Efficiency of BOD at cycles with time 12hr.

3.3 Oxygen Consumption

The dissolved oxygen consumption in the SBR tank indicates the existence of aerobic bacteria during the transition from anoxic to aerobic conditions. When a cycle begins, microorganisms take advantage of the nutrients that are entering the system, which lowers the concentration of dissolved oxygen to its lowest value. However, when a cycle ends, microorganisms examine the food that is stored inside their cells, which prevents dissolved oxygen from being consumed and causes its concentration to rise in the effluent treated waste water, as illustrated in Fig. (6).

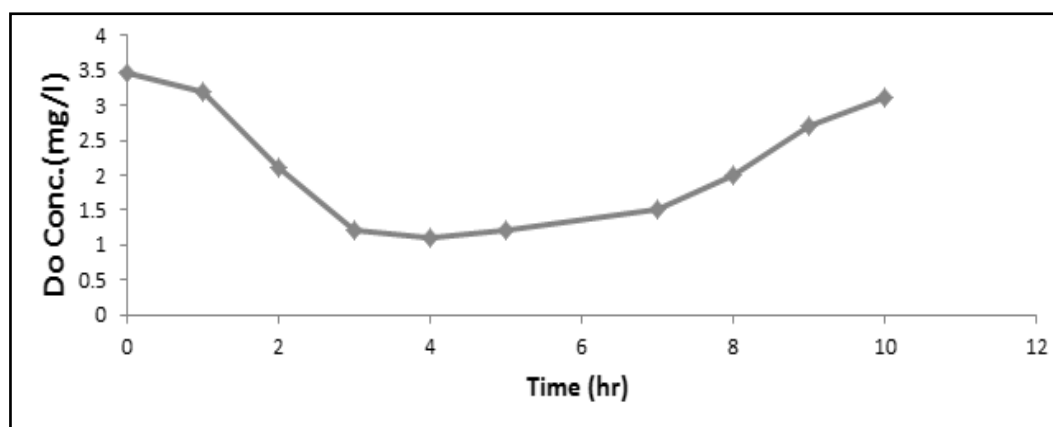


Fig. 6: Variation of Do conc. during the operation of SBR cycles

3.4 Total Suspended Solid Removal (TSS)

The influent and effluent of wastewater were used to calculate the total suspended solids. The effluent had a very high proportion of total suspended solids, roughly (270-602). It is noticeable that hardly no removal was seen when compared to the influent values. Over time, the removal efficiency grew. As seen in Fig. (7), the maximum removal efficiency was 45.7%.

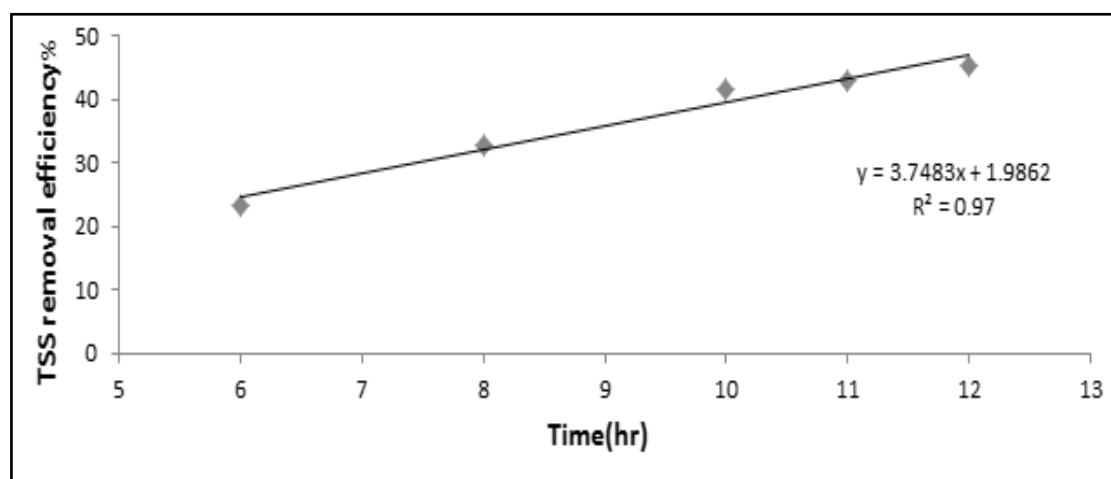


Fig. 7: Effect of Time on TSS Removal Efficiency.

4. Conclusion

Domestic wastewater from AL Hilla City in Babylon was used to provide the system with untreated wastewater for it to treat. The experimental study consisted of 50 practical experiments with aerobic and anoxic conditions and different operational times ranging from 6-15 hours and over 6 months, and it calculated the efficiency of a system in the removal of organic substances measured in the form of COD and BOD5. The study showed that the removal efficiency of organic matter increases with increasing aeration time. The removal efficiency of organic matter (COD, BOD5) was increased when there was an increase in aerobic conditions (A) during the fill and react phases, because of the aerobic degradation for the incoming organic matter as a result of microorganism activity, where; the removal efficiency of COD ranged from (43.3-88.8), and for BOD5 was (58.8- 91.2).

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