Assessment Efficiency Evaluation of Al-Diwaniya Sewage Treatment Plant in Iraq

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ABSTRACT

This study aims to evaluate the performance of the sewage treatment plant in Al-Diwaniya, one of cities in the southern part in Iraq. This evaluation could be used to facilitate effluent quality assessment or optimal process control of the plant. The influent reaching the plant is considered a medium to strong in strength with BOD_5/COD ratio in the range 0.23 and 0.69 which can be considered an easily degradable sewage by the biological processes performed by the activated sludge unit. The quality of the effluent was found to be higher than the Iraqi standards for disposal to water bodies. The BOD_5/COD ratios of the treated sewage varied over a wide range as low of 0.13 to 1.48 indicating operational problems in the plant. Regression analysis was performed to estimate the removal percentages of BOD_5, COD, TSS and NO_3 that the plant should perform by to reach the disposal limitations.

Key words: sewage treatment plants, performance evaluation, wastewater characteristics, BOD_5, COD, TSS, NO_3, BOD_5/COD ratio.

تقييم كفاءة الاداء لمحطة معالجة مياه الصرف الصحي في الديوانية، العراق

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الخلاصة:

تهدف هذه الدراسة الى تقييم كفاءة الاداء لمحطة معالجة مياه الصرف الصحي في مدينة الديوانية احدى المدن في جنوب العراق . ويمكن من خلال هذه الدراسة تقييم وتخمين صفات المياه المطروحة او السيطرة المثلى في تشغيل المحطة . و تتغاير مياه الفضلات الداخلة الى المحطة من متوسطة الى عالية القوة وبنسبة طلب الاوكسجين الحيوي الى طلب الاوكسجين الكيمياوي 0,23 و 0,69 والتي تصنف هذه المياه بسهولة التحلل بواسطة الطرق البايولوجية (طريقة الحماة النشطة) . اما المياه المعالجة من هذه المحطة فقد وجدت بانها لا

تتطابق مع معايير المياه التي يمكن رميها الى المسطحات المائية، وان نسبة طلب الاوكسجين الحيوي الى طلب الاوكسجين الكيمياوي للمياه المطروحة من هذه المحطة تراوحت من 0,13 الى 1,48 والتي تؤشر الى وجود مشاكل تشغيلية في المحطة. وقد اجريت تحاليل احصائية لتخمين نسب الازالة للطلب الاوكسجين الحيوي، والاوكسجين الكيميائي و المواد العالقة والنترات بحيث يتم تشغيل المحطة بموجبها للوصول الى المعايير اللازمة لرمي المياه المعالجة الى المصادر المائية.

الكلمات الرئيسية: محطة معالجة المجاري، تقييم الاداء، خواص مياه الصرف الصحي، المتطلب الحيوي للاوكسجين، المتطلب الحيوي الكيميائي، كمية المواد الصلبة العالقة، نترات، نسبة طلب الاوكسجين الحيوي الى طلب الاوكسجين الكيمياوي.

1.INTRODUCTION

Sewage is created from different sources as residential, institutional, commercial and industrial activities. It is collected and transported via a network of pipes to a sewage treatment plant (STP). The main aim of this plant is the removal of pollutants from the wastewater and consequently the reduction of solids, organic matter and nutrients so it will be possible to discharge the treated effluent to natural water bodies, **Erbe et al., 2002.**

The proper operation and control of STPs is receiving increasing attention because of the rising concern about environmental issues. Improper operation of STPs may bring serious environmental problems, as its effluent is discharged to a water body. Sewage treatment plants are designed and operated in order to mimic the natural treatment processes to reduce pollutant loads to a level that nature can handle. In this regard, special attention is necessary to assess the environmental impacts of existing sewage treatment facilities **Jamrah, 1999**.

Performance evaluation of existing treatment plant is required (1) to assess the Existing effluent quality and/or to meet higher treatment requirements and, (2) to know about the treatment plant whether it is possible to handle higher hydraulic and organic loadings. The general yardstick of evaluating the performance of a sewage treatment plant is the degree of BOD_5 or COD and suspended solids reduction, which constitute organic pollution. The performance efficiency of the treatment plant depends not only on proper design and construction but also on good operation and maintenance, **Sundara et al., 2010.**

Silvia et al., 2011, evaluated the operational conditions to verify the existence of a relationship between design and operational parameters and the performance of the sewage treatment plants under study. The hydraulic retention time (HRT) was included in the evaluation, because this variable could be calculated for all units and it reflects in a simplified way loading conditions. The plants were classified as under loaded (actual BOD load less than the minimum recommended range), normally or usually loaded (BOD load within the range) and overloaded (BOD load higher than the maximum range). Additionally, in order to analyze whether there was a difference in the performance of smaller and larger plants, all systems were ranked by flow, and split into two groups: low flows (0 to 50 % of mean flows) and high flows (50 to 100 % of mean flows). Also a monitoring index (MI–average number of samples collected per year in each plant) was investigated as a possible indicator of the operational level in the plant (higher MI values could be associated with more operator's involvement and, therefore, possibly a better operation).

2.OBJECTIVE OF THIS STUDY

The main objective of this study is to evaluate the performance of the Al-Diwaniya sewage treatment plant, one of the southern cities in Iraq. This evaluation could be used to facilitate effluent quality assessment or optimal process control of the plant. A detailed characterization of the incoming sewage and a performance evaluation was carried out for this plant through the removal of BOD_5, COD, TSS and nutrients.

3.AL-DIWANIYASEWAGE TREATMENT PLANT (STP)

This plant is located on road 8 in the southern part of Al-Diwaniya city on Shut Al-Diwaniya, a branch of the Euphrates River **Fig.1**. The design capacity of this plant is 4DWF (dry weather flow) which is 80000 m^3/d. The plant consists of two identical stream lines that treat the sewage in two stages, Primary and Secondary treatment processes. The primary stage consists of a rack screen and the detritus for the sedimentation of inorganic suspended solids. The secondary treatment is an activated sludge process for the biological degradation of the organic content. The effluent from the primary treatment enters a distribution chamber that receives the return sludge from the secondary sedimentation tank. The mixture from this chamber is distributed to the aeration tanks of the two streams.

The final effluent from the secondary sedimentation tanks flows into the chlorine tank for disinfection before it is discharged to the river. The wasted sludge from the secondary sedimentation tanks is collected in a holding tank where the supernatant is pumped back to the distribution chamber and the settled sludge is pumped to the drying beds. The plant is designed to yield an effluent of 20 mg/L BOD_5 and 30mg/L suspended solids.

4.DATA COLLECTION AND ANALYSIS

The data used in this paper was provided from Al-Diwaniya STP for the period January 2007 to September 2008, which represented the average monthly values of the mainly parameters of the influent and effluent.

5.RESULTS AND DISCUSSION

1- Characteristics of the influent sewage

Fig. 2 shows the average monthly BOD_5, COD, TSS, NO_3 and PO_4 of the untreated sewage flowing into the plant. From these data, the influent reaching the plant is considered of a medium to strong strength according to the classification in **Table 1** given by Metcalf and Eddy, 2003. The BOD_5 ranged from 149 to 344.93 mg/L with an average of 199.11 mg/L, where COD ranged from 329.63 to 814.38 mg/L and 468.42 mg/L average. The concentrations of total suspended solids (TSS) were between 277.05 to 919.25 mg/L and an average of 455.81 mg/L. The detained BOD_5/COD ratio shown in **Fig. 3** for the influent wastewater in is study was in the range 0.23 and 0.69 and this ratio for untreated sewage could be considered as a normal case (0.3-0.8) according to **Table 2**. Hence this waste is considered to be easily degradable by the biological processes performed by the activated sludge process, **Metcalf and Eddy, 2003.** As for the nutrients, the recorded values were for 2008 only. PO_4 ranged from 31.25 to 72.0 mg/L with an average of 44.98 mg/L where NO3 ranged from 4.9 to 6.53 mg/L with an average of 5.56 mg/L as shown in **Table 3**.

2- Characteristics of the effluent

The quality of the effluent from the plant has been found to be higher than expected from the Iraqi effluent standards for disposal to water bodies. The BOD_5 exceeded 20 mg/L limit for disposal limitations over the whole period as shown in **Table 4**. The values of COD were in less than the limitation 100 mg/L in year 2008. These values of BOD_5 and COD could constitute potential pollution problems to the water bodies since it contains organic compounds that require large amounts of oxygen for degradation. As for the effluent (treated sewage) the BOD_5/COD ratio varied over a wide range 0.17 to 0.95, reaching 1.09 and 1.48 in 2008 as shown in **Fig. 3**, these values are very large than those shown in **Table 2** for the treated sewage. This may indicate problems in the treatment process which affects the performance and removal efficiency of different pollutants from the sewage being treated in this plant. As for the suspended solids most of the values exceeded 30 mg/L. High concentrations of nutrients in the form of PO_4 and NO_3 were observed in the effluent, with an average of 5 mg/L for PO_4 and 22mg/L for NO_3. These pollutants are the major parameters causing eutrophication in water bodies.

3- Overall efficiency of Al-Diwaniya STP

The average monthly overall removal of BOD_5, COD, TSS and NO_3 during the period 2007–2008 in Al-Diwaniya STP was 70.09, 73.15, 82.21 and 38.74% respectively as shown in **Table 5**. Low removal of organic matter (BOD_5, COD) may be due to the recycling of old sludge that contains fewer microorganisms, which may cause insufficient MLSS for aerobic decomposition of organic matter. Also the DO during aeration could be absorbed by the microorganisms due to less availability of fresh organic matter (Ravi et al., 2010).Also over loading due to increase in population, increase in water use and discharge of trade effluents reaching the plant may cause poor performance in WWTPs. The treatment efficiency may be badly affected if the system is hydraulically under loaded, **Sundara et al., 2010.**

4- Performance of Al-Diwaniya STP

From the previous analysis of the effluent from Al-Diwaniya STP, it is clear that the plant is not functioning in the proper design specifications, which maybe the result of operational problems in the working units. These problems affect the performance of the plant to remove different pollutants like BOD_5, COD, TSS and nutrients to the desired disposal limitations. All of the disposal limitations were exceeded, which will cause pollution threads in the receiving river. It is hard to specify which unit or units not working within the proper design criteria to yield the disposal limitations, as no water quality measurements are taken from each unit in the plant (before and after each unit). A major tool required for proper process control is frequent and accurate sampling and laboratory analysis ,**Sundara et al., 2010.**

The following is a brief discussion on how the working conditions of different units in the plant can affect the effluent quality.

1-High organic concentrations (BOD_5 and COD) maybe caused by:

a- Improper aeration in the aeration basin, where not enough dissolved oxygen (DO) is existed for aerobic decomposition. Continuous measurement for DO concentrations (which is not recorded) in the basin will provide a clear observation on the amount of DO supplied and consumed for aerobic decomposition of organic matter. The concentration of DO in the aeration basin depends on many factors; temperature, basin geometry, degree of mixing and wastewater characteristics. Where the main factor is the aeration method used, mechanical aeration or air diffusors, **Eckenfelder et al., 2002.**

b- Large masses of organisms grow in the aeration basin are to be settled in the secondary sedimentation tank (clarifier) and are returned to the aeration basin as Qr or wasted from the system as Qw, play the main operating factor in this system. If there is a problem in the settling procedure of the clarifier then high concentration of microbial mass is measured as BOD_5 or COD in the effluent, **Santo et al., 2005.**

2- High concentration of suspended solids (SS) are recorded in the effluent may be due to:

a- Insufficient removal of TSS in the primary treatment as in grit chambers and in primary sedimentation tanks. The removal of SS depends on size of the settled particles and their specific gravity. The main issue in this stage of treatment is the separation of organic from inorganic particles.

b- Improper settling in the secondary sedimentation tank for the removal of the microbial mass. This may be due to some problems in the aeration basin: excessive turbulence, anaerobic conditions and toxic shock loading ,**Qasim, 1999**. The ability of biological solids to flocculate due to the natural presence of exocellular enzymes and polymers creates flocs that settle rapidly enough allowing an economically sized clarifier to produce acceptable effluent quality. Smaller flocs that remain isolated and do not become incorporated into a larger floc mass report to the effluent instead of reporting to the underflow. These solids comprise a high percentage of the effluent suspended solids (TSS) and thus effluent particulate pollutant concentration, **Parker, 1983.**

3- High concentration of nutrient in the form of PO_4 and NO_3

The existing activated sludge system is not designed for nutrient removal. To improve the effluent quality, new units should be added or the development of the existing units for nutrient removal. The most common process for biological nitrogen removal consists of an anoxic tank (for denitrification) followed by the aeration tank (for nitrification), **Metcalf and Eddy, 2003**. Al-Diwaniya STP has to specify the operation problems of the working units by taking more water quality measurements for each unit. The performance and stability of the activated sludge process is affected by many parameters that should be considered in evaluating the plant. The effective parameters are: solid retention time SRT, specific biomass growth rate μ, specific substrate utilization rate U and the biomass yield coefficient (Y) (Metcalf and Eddy, 2003).

4- Regression analysis for removal efficiency

A regression study was performed for each parameter to estimate the removal efficiency with respect to the disposal limitations with high correlations (R^2). The equations estimating the removal percentage were as follows:

BOD_5: y = 0.0004x + 0.816, R^2:0.93, Fig.4

COD: y = 0.0004x + 0.5993,R^2:0.95, Fig.5

TSS: y = 0.0001x + 0.8745, R^2:0.88, Fig.6

NO_3: y = 0.0004x + 0.9568, R^2:0.92, Fig.7

These equations could help to upgrade the units so the performance of the plant will give better effluents for disposal.

6.CONCLUSIONS

1-The influent to Al-Diwaniya STP is considered medium to high in strength. The BOD_5/COD ratio of this wastewater ranged 0.23 to 0.67 which is normal and the wastewater is easily degradable by biological processes.

2- The quality of the effluent was found to be higher than the Iraqi standards for disposal to water bodies. The BOD_5/COD ratios of the treated sewage varied over a wide range as low of 0.13 to 1.48 indicating poor performance in the plant.

3-The average removal percentages for BOD_5, COD, TSS and NO_3 were 70.09, 73.13, 82.21 and 48.74% respectively, which were not enough to treat the sewage to disposal limitations of 20, 100, 30 and less of 1 mg/L respectively .

4-Regression analysis was performed to estimate the removal percentages of BOD_5, COD, TSS and NO_3 that the plant should perform by to reach the disposal limitations.

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Table 1. Strength classification of untreated sewage, **Metcalf and Eddy, 2003.**

Parameter (mg/L)	Weak	Medium	Strong
Total dissolved solids	270	500	860
Total suspended solids	120	210	400
BOD5	110	190	350
COD	250	430	800
TOC	80	140	260
Total N	20	40	70
Total P	4	7	12
Chloride	30	50	90
Sulfate	20	30	50

Table 2. Ratios of various parameters used to characterize wastewater,**Metcalf and Eddy, 2003.**

Type of wastewater	BOD_5/COD	BOD_5/TOC
Untreated	0.3 – 0.8	1.2 -2.0
After primary settling	0.4 – 0.6	0.8 – 1.2
Final effluent	0.1 – 0.3	0.1 – 0.5

Table 3. Influent wastewater characteristic of Al-Diwaniya STP (2007-2008).

Month	BOD_5 mg/L	COD mg/L	TSS mg/L	Temp.	pH	NO_3 mg/L	PO_4 mg/L
Jan.07	150.00	380.00	400.00	15.70			
Feb.07	344.93	706.00	919.25	21.10			
Mar.07	190.87	814.38	749.00	22.66			
Apr.07	150.00	430.00	573.50	26.40			
May.07	158.75	409.70	311.64	30.73	7.26		
Jun.07	149.00	407.17	368.71	30.98			
Jul.07	175.71	404.67	392.15	31.20			
Aug.07	174.00	403.50	361.00	31.40			
Sep.07	173.33	407.13	488.88	21.36	7.09		
Oct.07	149.00	380.00	311.64	15.70	7.09		
Nov.07	344.93	814.38	919.25	31.40	7.26		
Jan.08	234.25	561.53	481.61	13.11	7.16	46.75	
Feb.08	234.14	585.63	495.25	15.63	7.05	72.00	
Mar.08	218.78	552.11	451.44	20.36	7.07	52.50	
Apr.08	169.25	375.06	338.50	24.71	7.18	46.60	
May.08	185.33	359.00	367.35	28.06	7.12	39.60	
Jun.08	201.67	352.05	321.29	29.80	7.16	31.25	4.90
Jul.08	166.25	329.63	279.63	30.13	7.07	33.14	6.53
Aug.08	225.80	337.05	277.05	31.10	7.14	45.00	5.48
Sept.08	186.25	359.50	309.11	31.43	7.18	38.00	5.33
Min	149.00	329.63	277.05	13.11	7.05	31.25	4.90
Max	344.93	814.38	919.25	31.43	7.26	72.00	6.53
Mean	199.11	468.42	455.81	25.15	7.14	44.98	5.56
Typical concentration (mg/L)	250	700	250	6.5	6.5	<1	10

Table 4. Effluent (treated) wastewater characteristic of Al-Diwaniya STP (2007-2008).

Month	BOD_5 mg/L	COD mg/L	TSS mg/L	NO_3 mg/L	PO_4 mg/L
Jan.07	62.20	300.00	217.00		
Feb.07	48.00	374.67	152.67		
Mar.07	50.00	140.13	71.11		
Apr.07	96.25	142.00	108.50		
May.07	89.00	101.20	70.71		
Jun.07	78.57	125.85	90.56		
Jul.07	54.00	117.83	104.00		
Aug.07	25.00	91.75	72.25		
Sep.07	25.00	68.89	54.11		
Oct.07	96.25	68.89	54.11		
Nov.07	62.88	374.67	217.00		
Jan.08	40.88	114.47	92.06	18.25	
Feb.08	37.71	84.75	59.00	24.30	
Mar.08	30.22	74.83	40.22	28.50	
Apr.08	34.83	74.13	37.38	30.00	
May.08	38.33	67.41	33.94	28.00	
Jun.08	50.33	107.76	64.33	15.50	5.55
Jul.08	40.13	67.95	37.74	16.00	5.23
Aug.08	52.80	46.74	21.26	29.00	4.63
Sept.08	75.00	50.75	28.44	14.00	4.63
Min	25.00	46.74	21.26	14.00	4.63
Max	96.25	374.67	217.00	30.00	5.55
Disposal limits	20	100	30	<1	<1

Table 5. Average monthly overall removal of BOD_5, COD, TSS and NO_3 in Al-Diwaniya STP

Month	%BOD	%COD	%TSS	$\%NO_3$
Jan. 7	58.53	21.05	45.75	
Feb.07	86.08	46.93	83.39	
Mar.07	73.80	82.79	90.51	
Apr.07	35.83	66.98	81.08	
May.07	43.94	75.30	77.31	
Jun.07	47.27	69.09	75.44	
Jul.07	69.27	70.88	73.48	
Aug.07	85.63	77.26	79.99	
Sept.07	85.58	83.08	88.93	
Oct.07	35.40	81.87	82.64	
Nov.07	81.77	53.99	76.39	
Jan.08	82.55	79.62	80.89	60.96
Feb.08	83.89	85.53	88.09	66.25

Mar.08	86.19	86.45	91.09	45.71
Apr.08	79.42	80.24	88.96	35.62
May.08	79.32	81.22	90.76	29.29
Jun.08	75.04	69.39	79.98	50.40
Jul.08	75.86	79.39	86.50	51.72
Aug.08	76.62	86.13	92.33	35.56
Sept.08	59.73	85.88	90.80	63.16
Min	35.40	21.05	45.75	29.29
Max	86.19	86.45	92.33	66.25
Mean	70.09	73.15	82.21	48.74

Figure 1. Google earth photo for Al-Diwaniya STP, Diwaniya project, Iraq.

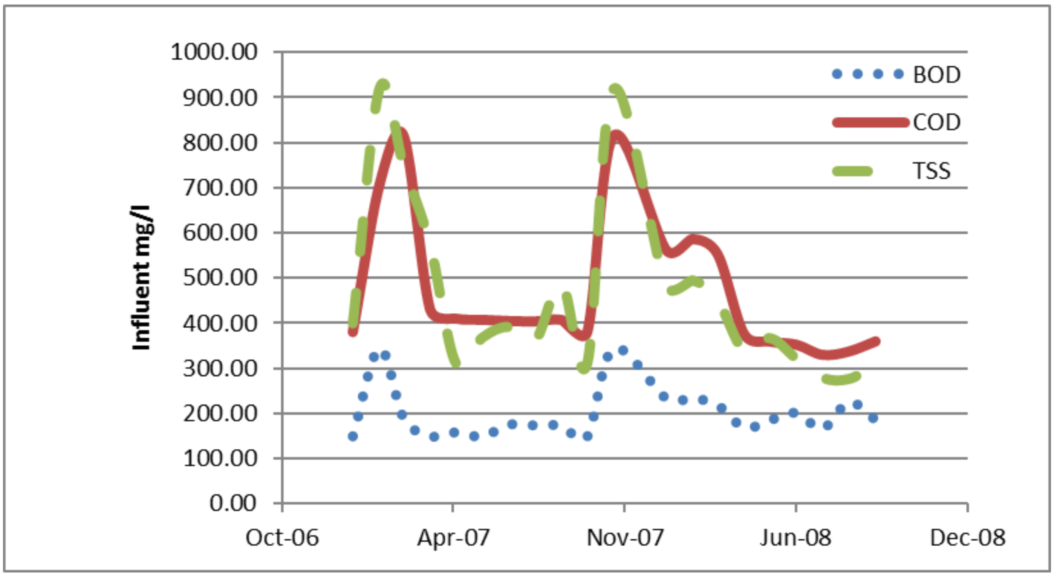

Figure 2. Influent variation for BOD_5, COD and TSS.

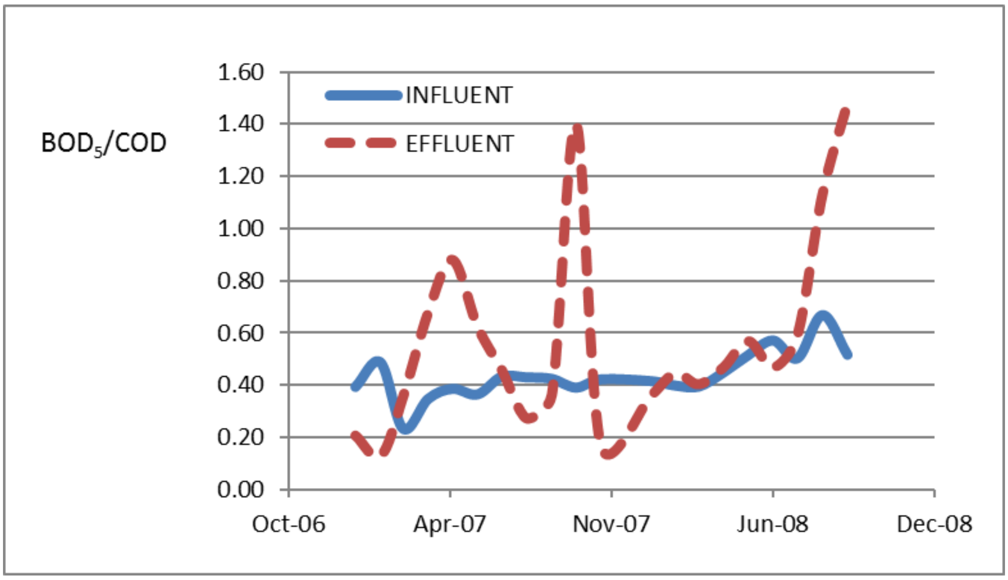

Figure 3. Variation of BOD_5/COD ratios for the influent and effluent.

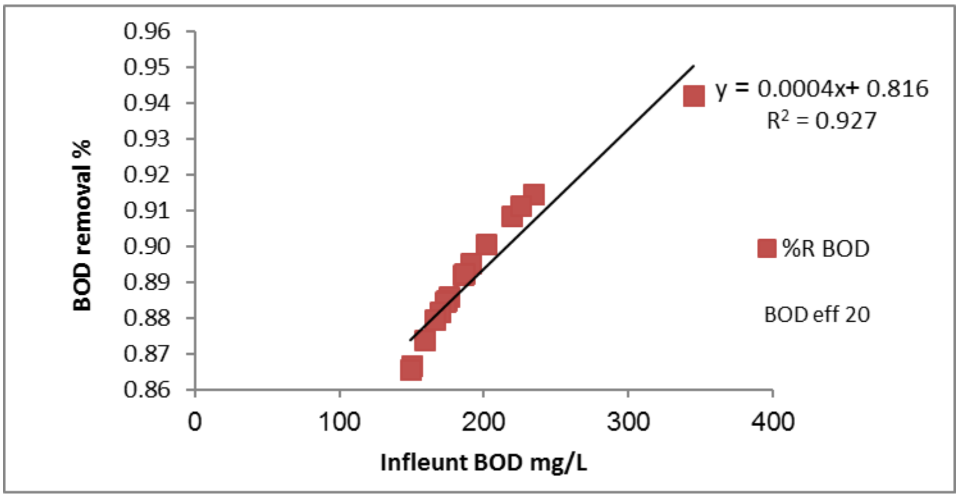

Figure 4. Regression equation for BOD_5 removal.

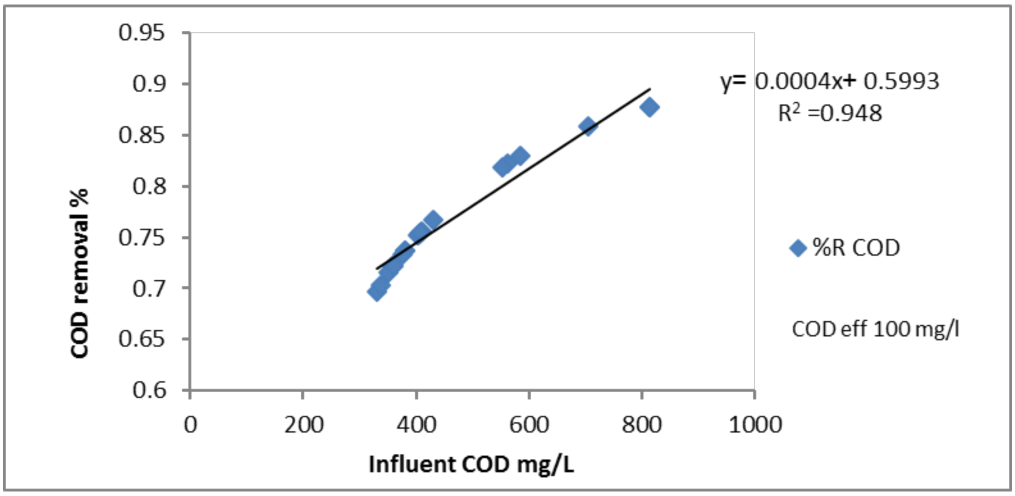

Figure 5. Regression equation for COD removal.

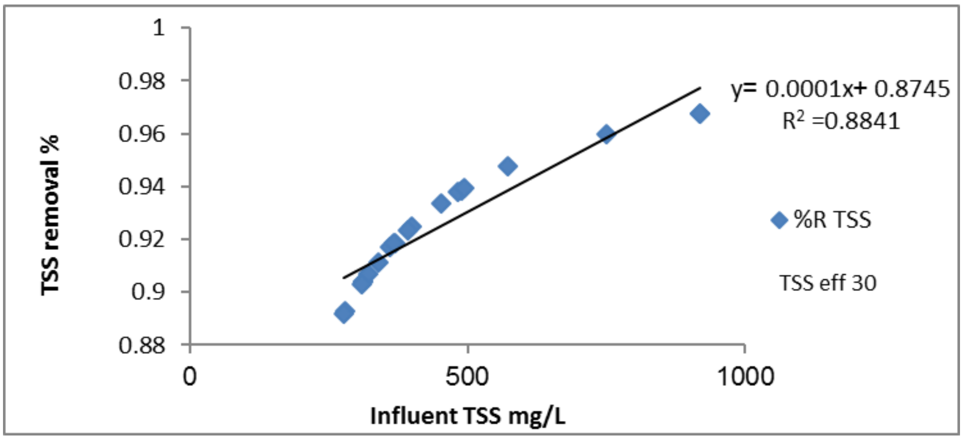

Figure 6. Regression equation for TSS removal**.**

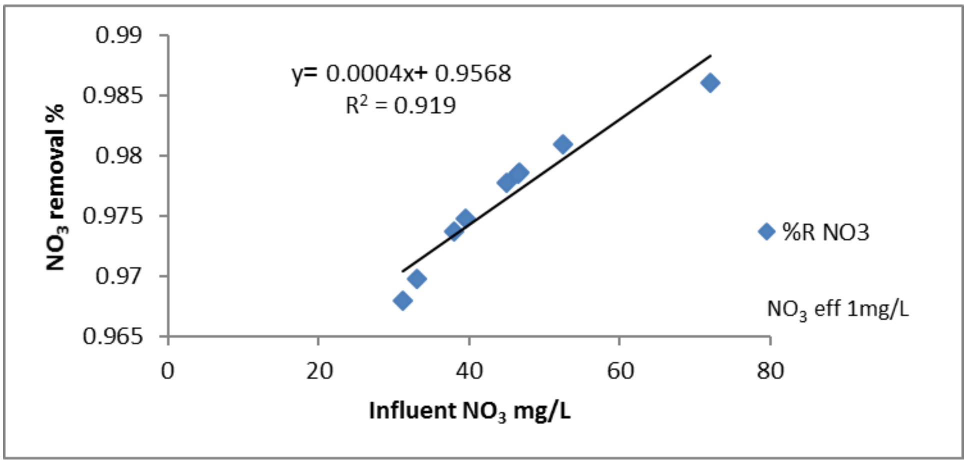

Figure7. Regression equation for NO_3 removal.