Performance Evaluation of Sequencing Batch Reactor and Conventional Wastewater Treatment Plant based on Reliability assessment

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ABSTRACT

Baghdad city has been faced numerous issues related to freshwater environment deteriorations due to many reasons, mainly was the discharge of wastewater without adequate treatment. Al-Rustamiya Wastewater Treatment Plant (WWTP) have been constructed among many plants in Baghdad city to reduce the amount of wastewater discharged into natural environment and its subsequent adverse effects. This study was conducted to evaluate the performance of the plant which consist of a conventional activated sludge (CAS) and sequencing batch reactors (SBR) systems as secondary treatment units and its ability to meet Iraqi specifications. A reliability level determination and analysis also were conducted to find the plant's stability and its capability to produce effluents that met the local standards. Coefficient of Reliability (COR) determination was done for effluent's concentrations of BOD_5, COD, and TSS obtained from Al-Rustamiya WWTP for two years' data operation (2015-2016), using Iraqi standards concentrations. Generally, the results showed the effectiveness of Al-Rustamiya WWTP-(CAS and SBR system) was a major concern due to inadequate sewage treatment and that the plant effluents of both systems selected parameters BOD_5, COD and TSS are not meeting the Iraqi standards due to many problems mainly were operational problems result in overall poor performance.

Keywords: performance, reliability, sequencing batch reactor, Al-Rustamiya, wastewater treatment plant.

مقارنة بين المفاعل ذو العمليات المتسلسلة ومحطة معالجة مياه المجاري التقليدية استنادا إلى تقييم الموثوقية

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الخلاصة

تواجه مدينة بغداد العديد من التحديات فيما يتعلق بالحفاظ على البيئة المائية من التدهور نتيجة الى العديد من الاسباب اهمها هو طرح مياه المجاري الغير معالجة بصورة مناسبة. مشروع الرستمية هو واحد من بين العديد من المحطات المنشأه لمعالجة مياه المجاري وتقليل الاثار الكارثيه الناتجه عن طرحها بدون معالجة، لذلك كان من الضروري تقييم اداء هذه المحطة التي تستخدم كل من نظام الحماءة النشطه التقليدي ومفاعل العمليات المتعاقبه كمعالجة ثانوية وكذلك معرفة مدى قدرتها على طرح مياه مجاري معالجة مطابقة للمواصفات العراقية. لقد تم دراسة قابلية المحطة على ازالة او تقليل ثلاث مؤشرات للتلوث (BOD_5, COD and TSS)، و قد كانت النتائج غير مرضية للعديد من الاسباب اهمها كانت مشاكل تشغيلية سببت جميعا ضعف الاداء بصورة عامة.

الكلمات الرئيسية: تقييم الأداء، الموثوقية، مفاعل ذو العمليات التسلسلة، الرستمية، محطة معالجة مياه الصرف الصحي.

1. INTRODUCTION

Wastewater disposal without adequate treatment have been made numerous issues of health hazards and freshwater environment deterioration that depended on the plant failure type and its duration especially when population explosion and increasing water requirements, **Rasheed, 2016**.
Reliability may be defined as a time percentage at which the effluent concentrations under stated conditions for a specified time fulfilled with certain discharge standards or treatment requirements, **Metcalf** and **Eddy, 2003**. The reliability is often related to the investigation of an object's effectiveness and its ability to function in an acceptable way, **Młyński, et al., 2016**. The reliability analysis is associated with the occurrence of partial damage that limits the objects' performance but does not necessarily result in breakdown, **Nowakowski, 2011**.
Wastewater treatment plant can be described as completely reliable if the process performance response has no failure, **Gupta** and **Shrivastava, 2006**, that is to say, if the limits established by the targets or environmental legislation are not violated, **Kottegoda** and **Rosso, 2008**. The treatment process fails when the required effluent discharge standards or targets are exceeded, **Oliviera** and **Sperling, 2008**. Whether the assumed wastewater treatment efficiency can be achieved strongly depends upon the design and execution of a good system in accordance with technical design guidelines, **Chmielowski, 2009**. In cases where there is a poor quality of effluent, it is important to determine the origin of operation problems and eliminate them in order to prevent risks associated with environmental pollution. Thus, the reliability and performance study is one of the methods used to determine failures or malfunctions of the wastewater treatment process, **Krzanowski, et al., 2006**.

Baghdad city had been challenged number of difficulties related to freshwater environment decline, in general, the plants have been received quantity of wastewater more than its design capacity may even reach double or triple its capacity in recent years, **UNEP, 2003**. So, more wastewater was released directly to the river and more pollution contribution was introduced. On the other hand, even the pollution indicators of treated effluent (BOD_5, COD and TSS) were not within the Iraqi standards, **AbdulRazzak, 2013**. Evaluation of the plant's performance helps in investigating the situation and identify possible risk of the negative assessment of work of the plant, **Sudasinghe, et al., 2011**. Thus, the goal of this study was performed a quantitative analysis of the reliability and functionality evaluation of the conventional activated sludge (CAS) and sequencing batch reactors (SBR) systems at Al-Rustamiya WWTP. Based on the results of their effluents' physico-chemical analysis, coefficient of reliability and the overall efficiency of wastewater treatment, to assure that the treated effluent meets the Iraqi standards, doesn't threaten the water resources and to find whether or not that these units have been operated efficiently.

2 MATERIAL AND METHODS

2.1 Study Area Description

Al-Rustamiya WWTP is located on the banks of the Diyala River south of Baghdad city and considered the wastewater collected through the sewerage network of Al-Rusafa part as shown in **Plate 1**. The conventional compartment of the plant comprised of preliminary treatment as screens, grit chambers and primary aeration tanks. Next, the primary treatment units as primary sedimentation tanks. Then, the secondary biological treatment as conventional activated sludge systems which consisted of three production lines (F0, F1, F2), each line consisted of aeration tanks and subsequent secondary sedimentation tanks with total capacity of (175000 m^3/d). The other compartment of the plant comprised of preliminary treatment as the inlet chamber with coarse screen, the intermediate pit and the compact pre-treatment unit. Then, the wastewater sent to the biological treatment as SBRs system, the new technology in Iraq, which consisted of five compacted units (U1, U2, U3, U4, U5) with total capacity of (75000 m^3/d) and controlled by a matrix, **WATERLEAU, 2009**. Both of CASs and SBRs final effluents ran through the chlorination contact tank for disinfection before final discharge. Flow diagrams of the two systems are shown in **Fig. 1 (a)** and **(b)**.

2.2 Data Collection and Analysis

Data were collected from Baghdad Mayoralty and Al-Rustamiya WWTP office for CAS and SBRs systems for two years (2015-2016). **Table 1** and **2** showed the average yearly concentrations of influent and effluent of selected parameters and removal efficiency for the systems. In addition to the data collection, the plant was visited several times during the study to accomplish the performance index by completing a checklist from observation and discussion with employees who working at the plant. The checklist consisted of several criteria: general, technical, physical, personal responsibility, operation and maintenance.

3. WWTP RELIABILITY ASSESSMENT

The WWTP process behavior was the base for the reliability assessment and should be discharged an effluent with selected parameters that would not exceeded discharge's threshold. **Niku, et al., 1979** model was used and recommended, which based on a probabilistic analysis to determine the threshold by relating the average concentration of a parameter with the threshold value supposed to be met, **Crites** and **Tchobanoglous, 2000, Metcalf** and **Eddy, 2003**. So, when required standards to the discharged effluent were exceeded failure of treatment plant process happened, **Al Saleem, 2007**. The mathematical model proposed by **Niku, et al. 1979** was adopted for assessing the reliability of Al-Rustamiya WWTP and for stepping toward a first valuation of critical components of the wastewater treatment process. The failure of WWTP can be determined by a Eq. (1):

$$F = C_e > C_s \qquad (1)$$

Where:

F : Failure

C_e : Specified effluent parameter concentration

C_s : Specified effluent parameter concentration identified by standards.

Since, probability of success or probability of acceptable performance was the essential concept of reliability. Then, the reliability would be equaled to:

$$R = 1 - P(F) \qquad (2)$$

Where:

R : Reliability

$P(F)$: Probability of failure

From Eq. (1) the value of R is equal to:

$$R = 1 - P(C_e > C_s) \qquad (3)$$

The probability distribution function of the required treated effluent quality parameters concentration was extremely related to the probability of failure. Therefore, when this distribution function was identified, an analytical countenance can be used to find the portion of time that a specified concentration was exceeded in the past. Assuming that the process situations and governing parameters were reserved unchanged, that expression can be used to expect future performance of an WWTP, **Dean** and **Forsythe, 1976**. The threshold (mx) for a specified treated effluent quality parameter average component could be derived from the Eq. (4):

$$m_X = COR \times C_s \tag{4}$$

Where:

m_X : average concentration of the component; regulation for a required treated effluent parameter concentration.

COR: Coefficient of reliability.

The coefficient of reliability (COR), could be processed via the following mathematical model, **Niku, et al., 1979**:

$$COR = (C_{VX}^2 + 1)^{1/2} \times e^{\left\{-Z_{1-\alpha}\left[\ln\left(C_{VX}^2+1\right)\right]^{1/2}\right\}} \tag{5}$$

Where:

C_{VX} : Coefficient of variation for required treated effluent parameter Concentration.

$Z_{1-\alpha}$: Standardized normal variation (gotten from the standard normal variation tables) equivalent to the probability of no exceedance at a confidence level of (1-α);

α : Significance level

4. RESULTS AND DISCUSSION

4.1 Reliability Application of Al-Rustamiya WWTP

4.1.1 Preliminary statistics used for verification of selected data distribution

The theoretical expressions mentioned above was used to calculate the reliability of Al-Rustamiya WWTP of the CAS and SBR systems. It was employed using the daily measured concentrations of selected parameters for tracking the treated effluent quality. The reliability model of, **Niku, et al., 1979**, can be applied to data have a lognormal distribution. Thus, the first step is to determine the probability distribution function of the required treated effluent parameters. Three parameters: Five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and total suspended solids (TSS) have been widely used to assess the quality of the plants effluents as shown in **Table 3**, using the daily measured concentrations of selected parameters.

A preliminary check of data's normality was done by finding the coefficients of skewness and kurtosis for treated effluents parameters as shown in **Table 3**, which showed positive values of skewness that indicated that data were skewed to the right and were not symmetrical. The coefficient of kurtosis on the other hand, had values varied from that of normal distribution (three). Thus, the pre-check indicated the non-normality of data. In addition, the histogram is an effective graphical technique for showing both the skewness and kurtosis of data set, **Helsel** and **Hirsch, 1992**.

4.1.2 Distribution laws of selected parameters

Variability of concentrations for selected parameters were used for finding the effluent quality can be revealed and analyzed by defining the histogram and probability density function of each parameter concentration. **Fig. 2** and **3** showed historical daily measured concentration data histograms and the Probability Distribution Function (PDF) of the CAS and SBR effluent's BOD_5, COD, TSS concentrations for the year (2015-2016), which showed that the data are generally skewed to the right, as illustrated in **Table 1**. Normal, lognormal, and gamma distribution laws for concentration of BOD_5, COD, and TSS were tested. The tests used to check the goodness-of-fit of these effluents concentrations data. The "software" used to perform the tests was STATGRAPHICS Centurion XVI.I. The probability plots of effluents' parameters: BOD_5, COD and TSS concentration were shown in **Fig. 4** and **5**. MINITAB 17 "software" was used to perform the probability plots.
Results showed that the lognormal distribution is the most representative of the behavior of selected effluent parameters (BOD_5, COD, and TSS) for CAS and SBR WWTP. Also, results obtained are reliable with the observations which indicated that it was useful to employee the most widely applicable, the lognormal distributions for effluent parameters to assess the water quality, **Charles, et al., 2005, Oliviera** and **Sperling, 2008, Bugajski, 2014** and **Górka, 2015**. Since the model applied for data had lognormal distribution, then, data were applicable for reliability assessment.

4.2 Application of Coefficient of Reliability (COR)

The data collected for two years of the specified effluent quality parameters (BOD_5, COD, and TSS) for CAS and SBR WWTP, were tabulated, monthly average and standard deviation were found and analyzed for 95% confidence. Values of the coefficient of variation (Cv) and coefficient of reliability (COR) were processed for a confidence level equal to 95% (α = 5%, significance level), Eq. (5) and (subsequently 1-α values) leads to the equivalent cumulative probability of the standard normal distribution (Z-distribution).

The COR was processed based on the original data properties (monthly average effluent concentrations) and not on the logarithms of the data. **Fig. 6** and **7** showed that a higher value of the Cv which indicated that data did not represent their population adequately, results in a lower COR and a lower (mx), for the same level of reliability (95%). In general, most of (Cv) for the effluent concentrations were lower than 1 and for all selected parameters (BOD_5, COD and TSS) the lowest COR values were gotten. Microsoft office Excel 2016 was used to perform the analysis mentioned above.

4.2.1 Application for setting operational guidelines

The theoretical background mentioned above leads to get operational limits (mx) for selected parameters employed for tracking the treated effluent quality. Those operational limits were achieved using Eq. (4) of the model, which combines the average of parameter concentration in the effluent with the standard values in the effluent and the probability of their occurrence. The values of the variable Cs were derived from the Iraqi standard adopted at Al-Rustamiya WWTP in strength: Cs (BOD_5) = 40 mg/L; Cs (TSS) = 60 mg/L; Cs (COD) = 100 mg/L. Results of the numerical applications are presented in **Table 4** and **5**. The method applied for identifying operational guidelines produce more specific thresholds than the regulation in force. In other words, if the attention is on the reliability then, the plant should be designed and operated in such a way that the average concentration of selected parameter is kept below the regulation limit.

4.3 Determination of Reliability Level for CAS and SBR at Al-Rustamiya WWTP

The reliability level was processed using Eq. (3). In the model, the calculated (mx) concentration substitute the value of the variable Cs concentration. The collected data of the WWTP provides the ability for calculating the probability of failure P(Ce>Cs=mx). First, a comprehensive analysis of data was made to collect all required data. Then, a comparison was made between monthly average effluent concentrations of WWTP and the range of average concentration conferring to the different reliability level to find the proper reliability for the selected parameters. The calculations of monthly average reliability level of Al-Rustamiya WWTP for effluent BOD_5, COD and TSS are shown in **Fig. 8 and Fig. 9.**
As observed that WWTP had a variable level of reliability which indicated failures or malfunctions in the treatment process. Many factors were the reason of this variability that effected the performance of the plant (reliability). In such case, it was important to identify the source of issues and eliminate them in order to prevent environmental pollution hazards. A discussion of the present situation and possible issues that maybe the CAS and SBR at the plant were faced, which may help to evaluate the overall performance of Al-Rustamiya WWTP.

4.4 WWTP Operational Performance Index

The observed criteria were compared with ideal one and the result was used to decide if the performance was good, satisfactory or poor. If the index value was greater than 70% the performance was considered as good. The performance was considered as poor and satisfactory if the index values of lesser than 50% and between (50 – 70) %, respectively, **Sudasinghe, et al., 2011**. First, the index was calculated for each of the performance criteria. Then, the overall performance was determined by dividing the number of good performing criteria observed by the overall number of criteria investigated. The mentioned criteria were discussed below:

a) **General Criteria:** The general performance criteria specify whether the management is careful to keep records of general information of WWTP such as funding agency, cost, wastewater generation number of connection, water supply and make annual reports at regular intervals. An indication about the availability of such information by the management of the WWTP is provided by this index.
b) **Technical criteria:** These criteria specify whether the WWTP have an appropriate design and functional characteristics to treat the wastewater. A higher index value gives an indication that the WWTP has the ability to treat the wastewater effectively.
c) **Physical criteria:** This criterion gives an indication about the existing physical status of the WWTP to perform its technical functions effectively and efficiently. A higher index value means that the physical condition is good and the plant do not require repairs.
d) **Personal responsibility criteria:** Personal responsibility criteria give an indication of whether workers have the sufficient responsibility and skills to perform various functions of the WWTP. A higher index value means that there are adequate, trained staffs who have the ability to carry out various activities in operating and maintaining the plant.
e) **Operation and maintenance criteria:** By these criteria, a knowledge would be had about the plant whether it is operated and maintained properly so it could perform its

function efficiently. Many reasons are responsible of getting a lower value of this index such as lack of funds, structural and functional flaws and carelessness of the maintenance staff to carry out their responsibilities.

CAS systems at Al-Rustamiya WWTP were designed efficiently for treating the expected domestic sewage influents. So, technically criteria were very good, it got 90% scores. However, population explosion, increasing water requirements and legal and illegal connection to the collection system caused overloading of the designed capacity of the CAS leading to the treatment process' malfunctioning. As a result, CAS discharged partially treated or raw wastewater (overflow) to the environment, which enhance the pollution of soil and water resources. The bad odor due to malfunctioning of the treatment process was also observed during the study, which could be resulted in health issues, environmental deteriorations, property devaluation, and overall quality of life, **Witherspoon, et al., 2002**.

In general, WWTP life time is 30 years, **Tchobanoglous, et al., 2003**, whereas the latest extension of CAS system (F2) was since (1974). All of these observations result in poor physically criteria with 10% scores indicate a very bad condition. Thus, the WWTP management which generally got 60% satisfactory scores, had been faced equipment's' aging besides issues of the funds' lack. Personality criteria were satisfactory which got 65%, whereas the workers had been in the field for many years. In addition, the CAS system can be operated and controlled easily, less time sensitive and less sophisticated if compared with SBRs system at the plant for the same employees. As mentioned above, lack of funds and functional flaws resulted in poor operation and maintenance criteria with 15% scores. The CAS effluent had been discharged without disinfection rather than the other issues illustrated above. This resulted in overall CAS poor performance with 48% scores as shown in **Fig. 10 (a)**.

Fig. 10 (b) showed the overall performance of the SBR system at Al-Rustamiya WWTP which reveals that the system is in very bad conditions with overall poor performance of 16% scores. It produces effluent does not meet the adopted standards that are even less than the limits according which SBR was designed. Where general criteria with a score of 10% show that the officers do not possess the required efforts to operate the plant to the highest standards, assure to provide educate operators and equip them with the important skills, develop the management skills and improve maintenance practices. Technical criteria with a score of 30% also showed a deficit due to many operational reasons. Actually, the units were designed in such a way that if a unit faced an issue then the access to solve this issue would be very difficult and costly. In addition, the plant was designed to treat domestic wastewater only but in fact, number of factories and storm sewer have been connected legally and illegally to the collection system. This fact resulted in a flow variability and their characteristics, the treatment nature, mechanical failures and overall deterioration in the treatment process.

Physically the index value in SBR of 30% was also poor where some units were even out of serves for several months without repairing. The units were faced many issued due to the gasses emissions present in the ambient air at the plant. These emissions cause equipment's corrosion and failure subsequently. In addition to the quantity of grit carried out by the wastewater that seems to be more than amount that a unit can tolerate. Recently, SBRs discharge effluents without disinfection, again due to lack of funds result in receiving waters contamination and health hazards. The observed operational problems and conversations with the staff responsible of operating the units. Personal criteria with 5% index value showed a weakness due to lack of knowledge and skill to run out such systems. Non-repair of damaged parts of the SBR system as soon as they happened, non-repair of already existing operational and functional flaws at the whole plant and for sure the main effective factor that is lack of funds, all of these factors were responsible of getting lower value of operation and maintenance criteria index of 5%.

5. CONCLUSION

The study of biological treatment system at Al-Rustamiya WWTP by the data collected for two years, contributes information that can be used by the operators of the plant to evaluate the reliability level, understand the biological treatment's performance, and consider the effluent's quality to develop discharge's standards that are suitable, operative and technically achievable. The study also reveals that both systems have overall poor performance. Indicate that technically perfect WWTP alone does not assure its successful operation and reliability over time. Funds are essential to pay personnel and cover other operational costs. In addition, regular maintenances need to be done to provide the best possible performance.

WWTP effluent's quality is variable because of varying organic loads, changing environmental condition and new industrial discharges. Sewage overflow is found to be a common experience in the plant. Rate and volume of sewage overflow of the plant should be evaluated to address this problem.

Operation and maintenance of WWTP should prepare odor managing plan by identifying causes of odor, finding failure of treatment process and its subsequent problems, taking the action to reduce odor, keeping records and settling the communities complains. For sure, it is a necessity to use chlorination in the plant to save the water resources. Providing of trained staff, developing a plan for operation and maintenance and construction of primary sedimentation tank prior to SBR system may be recommended to save the system from regression downward, big loss of money and loss of an international important technology.

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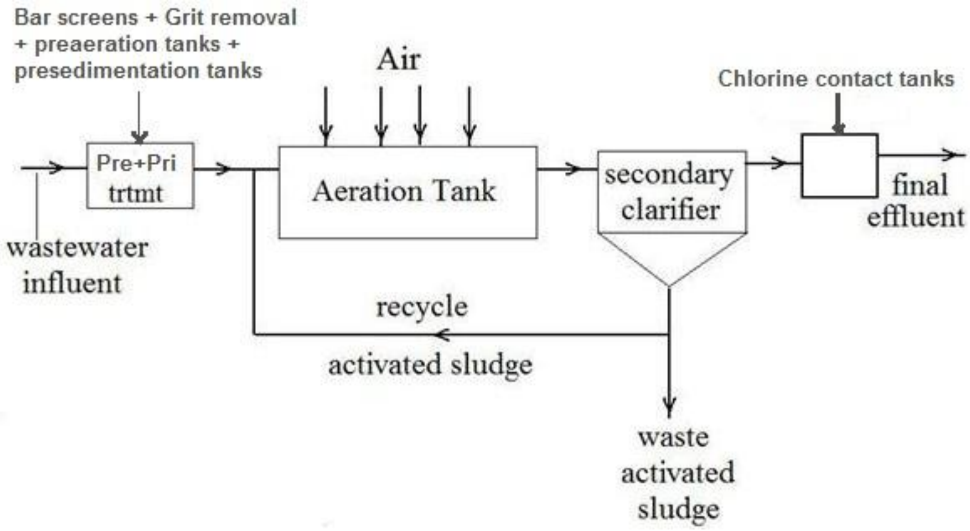
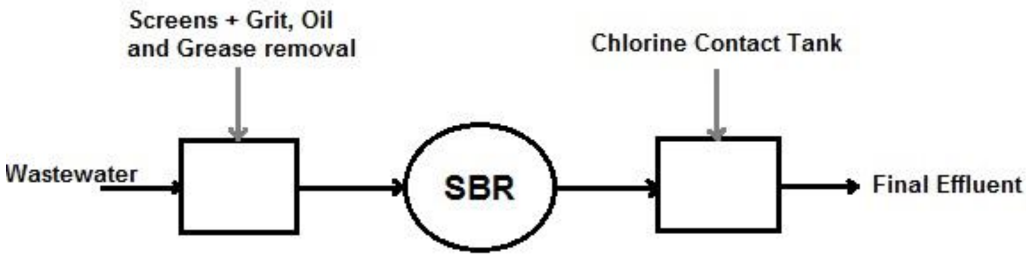
Plate 1. Al-Rustamiya WWTP location.

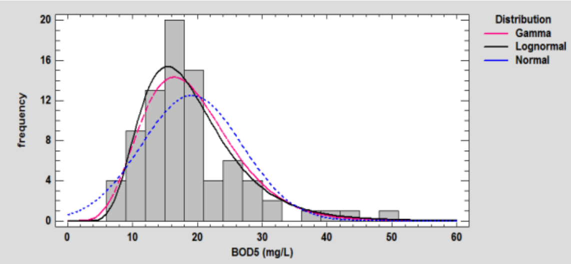


(a) CAS Treatment process

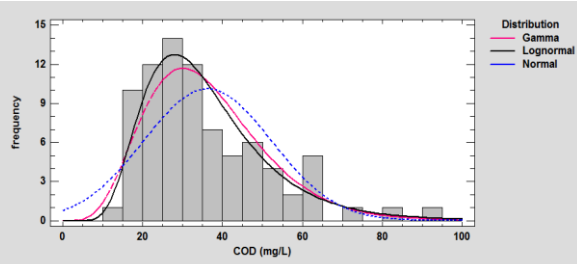


(b) SBR Treatment process

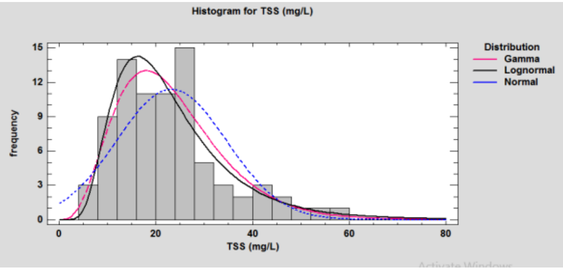
Figure 1. Al-Rustamiya WWTP flow diagram.



a) BOD_5 concentration

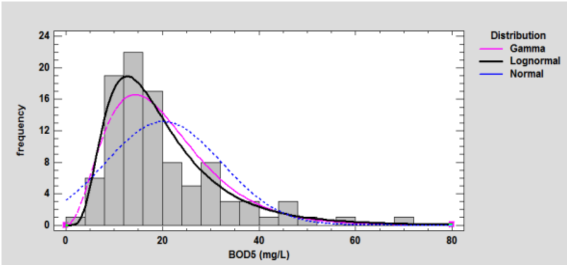


b) COD concentration

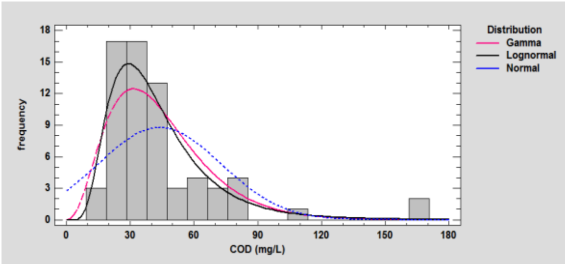


c) TSS concentration

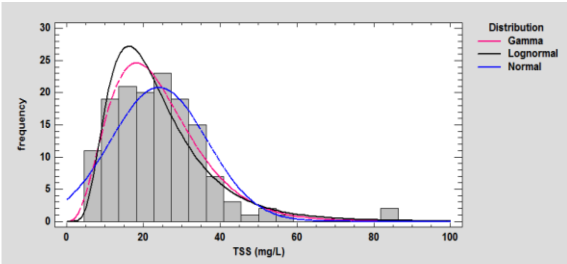
Figure 2. Histogram and PDF of Al-Rustamiya WWTP-CAS effluent's (2015-2016).



a) BOD_5 concentration

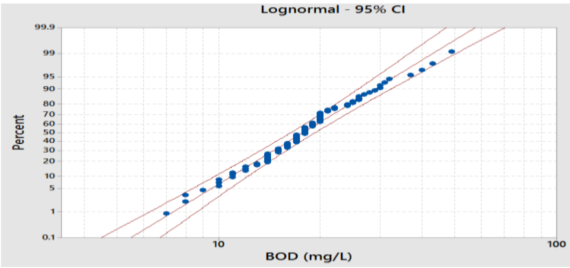


b) COD concentration

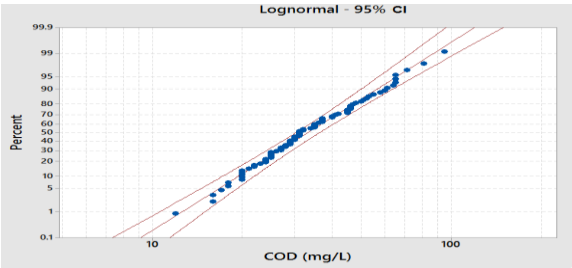


c) TSS concentration

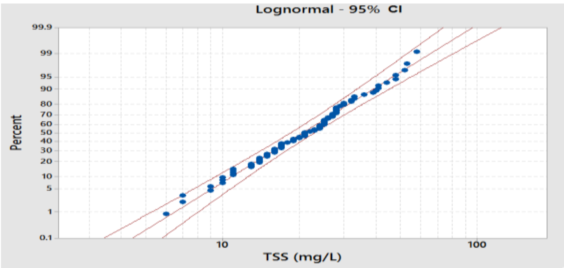
Figure 3. Histogram and PDF of Al-Rustamiya WWTP-SBR effluent's (2015-2016).



a) BOD_5 concentration

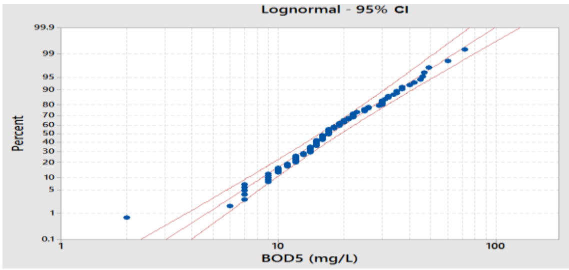


b) COD concentration

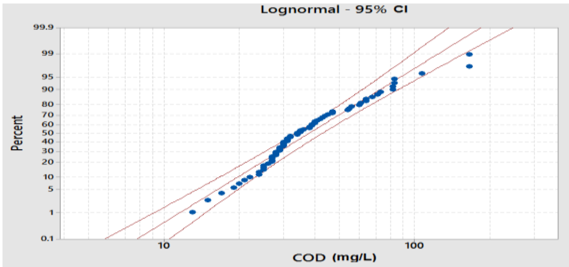


c) TSS concentration

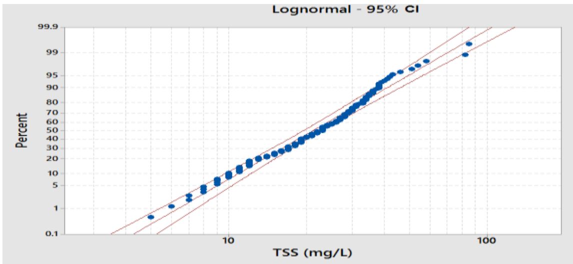
Figure 4. Lognormal probability plot with curve offset at 5% significance level of Al-Rustamiya WWTP-CAS effluent (2015-2016).



a) BOD_5 concentration

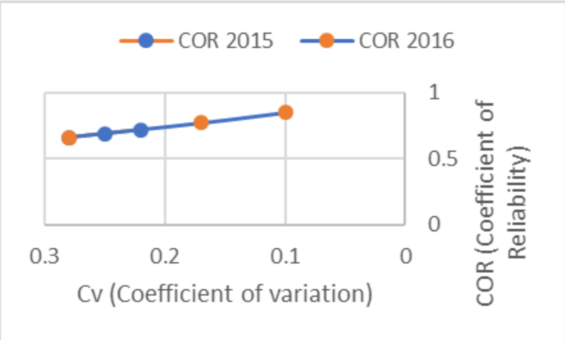


b) COD concentration

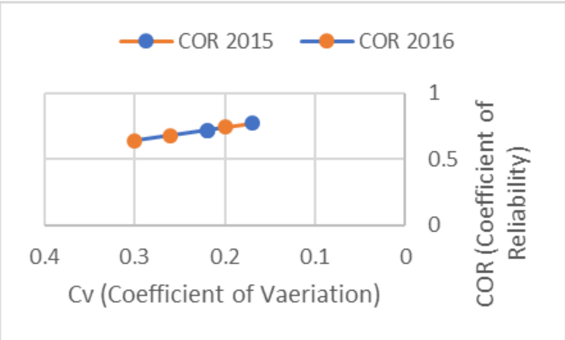


c) TSS concentration

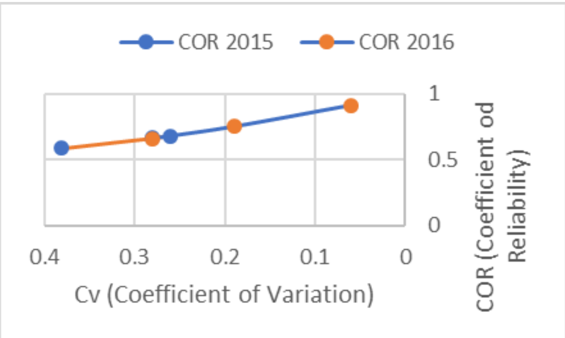
Figure 5. Lognormal probability plot with curve offset at 5% significance level of Al-Rustamiya WWTP-SBR effluent (2015-2016).



a) BOD_5 concentration

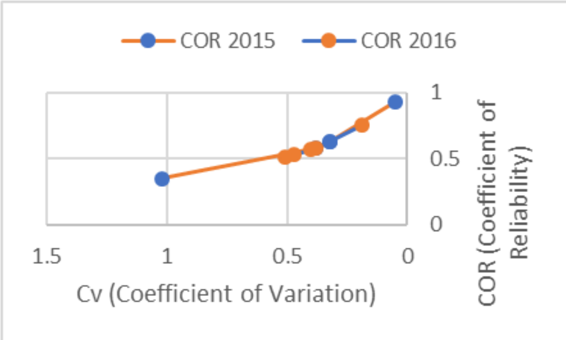


b) COD concentration

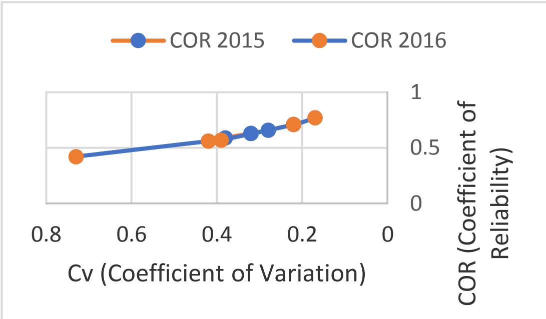


c) TSS concentration

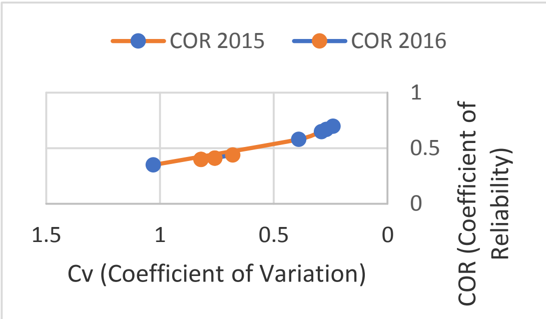
Figure 6. Coefficient of reliability (COR) as a function of the coefficient of variation (Cv)
(CAS/Al-Rustamiah WWTP, 2015-2016).



a) BOD_5 concentration

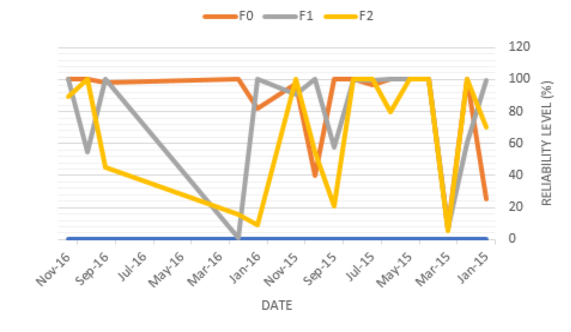


b) COD concentration

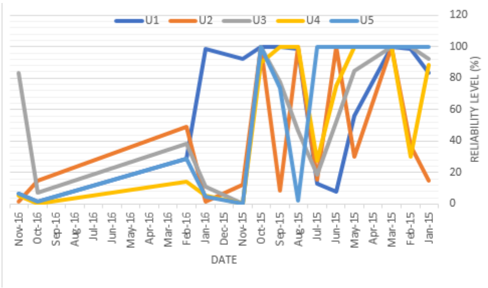


c) TSS concentration

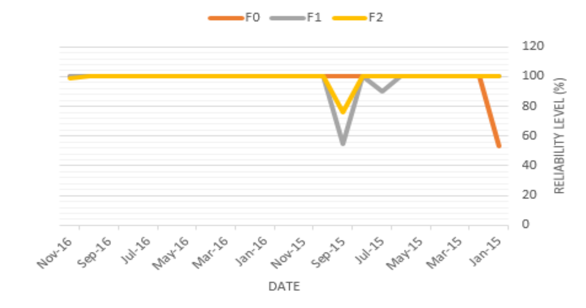
Figure 7. Coefficient of reliability (COR) as a function of the coefficient of variation (Cv)
(SBR/Al-Rustamiah WWTP, 2015-2016).



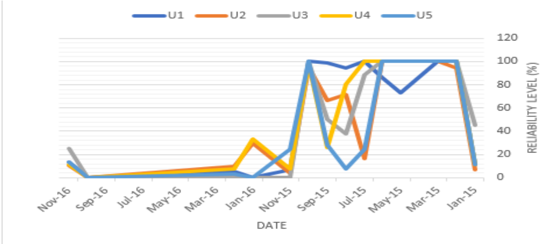
a) BOD_5 concentration



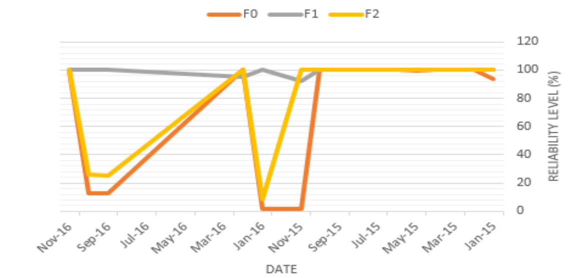
a) BOD_5 concentration



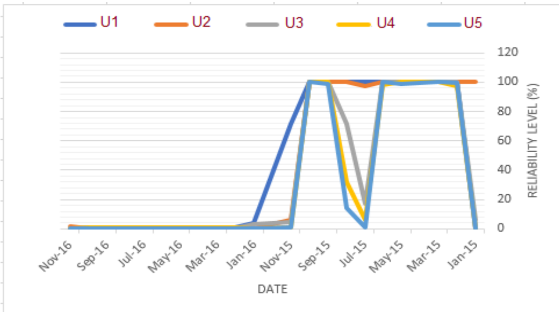
b) COD concentration



b) COD concentration



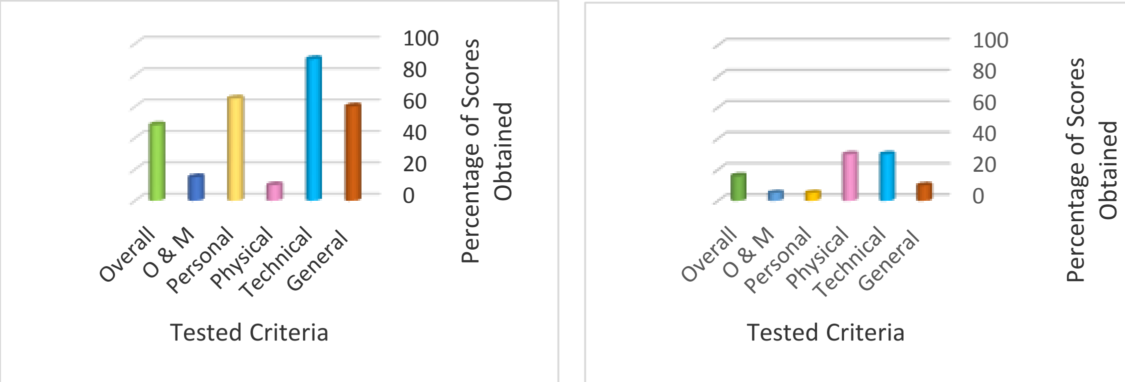
c) TSS concentration



c) TSS concentration

Figure 8. Reliability level of CAS effluents at Al-Rustamiya WWTP (2015-2016).

Figure 9. Reliability level of SBR effluents at Al-Rustamiya WWTP (2015-2016).



(a) **(b)**

Figure 10. Major performance criteria and the overall performance of Al-Rustamiya WWTP (a) CAS and (b) SBR (2015-2016).

Table 1. Average concentrations of influent and effluent with removal efficiency at Al-Rustamiya -CAS WWTP during (2015-2016).

			2015				2016		
			F0	F1	F2		F0	F1	F2
BOD_5 mg/L	Influent 216.7 mg/L	Effluent	20	19	20	Influent 205.6 mg/L	18	20	23
		Removal efficiency (%)	91	91	91		91	90	89
COD mg/L	Influent 436.2 mg/L	Effluent	37	35	36	Influent 440.6 mg/L	37	38	41
		Removal efficiency (%)	92	92	92		92	91	91
TSS mg/L	Influent 207.6 mg/L	Effluent	24	19	19	Influent 197 mg/L	31	21	26
		Removal efficiency (%)	88	91	91		84	89	87

Table 2. Average concentrations of influent and effluent with removal efficiency at Al-Rustamiya -SBR WWTP during (2015-2016).

			2015						2016				
			U1	U2	U3	U4	U5		U1	U2	U3	U4	U5
BOD_5 mg/L	Influent 213.3 mg/L	Effluent	20	22	15	23	25	Influent 199 mg/L	26	26	28	44	31
		Removal efficiency (%)	91	90	93	89	88		87	87	86	78	85
COD mg/L	Influent 430 mg/L	Effluent	39	48	49	45	41	Influent 480 mg/L	69	99	93	96	89
		Removal efficiency (%)	91	89	89	90	91		86	79	81	80	81
TSS mg/L	Influent 244 mg/L	Effluent	32	24	24	28	30	Influent 204.5 mg/L	153	169	149	166	158
		Removal efficiency (%)	87	90	90	89	88		25	17	27	19	23

Table 3. Statistic descriptive of effluent's parameters during (2015-2016).

Statistical parameter	BOD_5 (mg/L)		COD (mg/L)		TSS (mg/L)	
	CAS	SBR	CAS	SBR	CAS	SBR
Average	19.15	20.24	36.23	43.91	23.22	24.03
Standard deviation	7.75	12	15.97	28.81	11.35	12.55
Coefficient of variation %	40.48	59.27	44.09	65.61	48.78	52.21
Minimum	7	2	12	13	6	5
Maximum	49	72	95	165	58	85
Range	42	70	83	152	52	80
Skewness	1.44	1.69	1.23	2.54	1	1.71
Kurtosis	2.96	3.69	1.68	7.99	0.84	5.82

Table 4. Average coefficient and operational guidelines values at Al-Rustamiya -CAS WWTP during (2015-2016).

		2015			2016		
		F0	F1	F2	F0	F1	F2
BOD_5 mg/L	C_V	0.25	0.22	0.28	0.17	0.28	0.1
	COR	0.69	0.78	0.66	0.77	0.66	0.85
	m_x	27.5	28.6	26.4	30.7	26.4	34.1
COD mg/L	C_V	0.22	0.17	0.22	0.2	0.3	0.26
	COR	0.72	0.77	0.72	0.74	0.64	0.68
	m_x	71.5	76.8	71.5	73.6	64.3	67.8
TSS mg/L	C_V	0.38	0.26	0.28	0.28	0.06	0.19
	COR	0.58	0.68	0.66	0.66	0.91	0.75
	m_x	35	40.7	39.6	39.6	54.4	44.8

Table 5. Average coefficient and operational guidelines values at Al-Rustamiya-SBR WWTP during (2015-2016).

		2015					2016				
		U1	U2	U3	U4	U5	U1	U2	U3	U4	U5
BOD_5 mg/L	Cv	0.38	0.32	0.05	0.32	1.02	0.38	0.51	0.47	0.4	0.19
	COR	0.58	0.63	0.93	0.63	0.35	0.58	0.51	0.53	0.57	0.75
	m_x	23.2	25.2	37.2	25.2	14	23.2	20.4	21.2	22.8	30
COD mg/L	Cv	0.28	0.32	0.38	0.22	0.32	0.22	0.39	0.42	0.73	0.17
	COR	0.66	0.63	0.59	0.71	0.63	0.71	0.57	0.56	0.42	0.77
	m_x	66	63	59	71	63	71	57	56	42	47
TSS mg/L	Cv	1.03	0.24	0.27	0.29	0.39	0.82	0.76	0.82	0.68	0.76
	COR	0.35	0.7	0.67	0.65	0.58	0.4	0.41	0.4	0.44	0.41
	m_x	21	42	40.2	39	34.8	24	24.6	24	26.4	24.6