Optimization of Wastewater Treatment Plant Design using Process Dynamic Simulation: A Case Study from Kurdistan, Iraq

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***Abstract*—Satisfactory effluent characteristics are indispensable to evaluate the performance of any wastewater treatment plant (WWTP) design. Dynamic simulation software has a great role in pursuing this objective, in which an efficient and cost-effective design is constantly performed. In this study, a dynamic simulator sewage treatment operation analysis over time (STOAT) has been used under certain influent conditions to optimize design possibilities for modifying an existing primary WWTP College of Engineering Wastewater Treatment Plant (COEWWTP) at Erbil, Kurdistan, Iraq. The optimization was established on the basis of total suspended solids (TSS) and biochemical oxygen demand (BOD) characteristics in the effluent. Two alternative design schemes were proposed; trickling biofilter and aeration basin. In the dynamic simulation for the investigated design schemes, the predicted effluent profile showed that each of the existing and trickling biofilter processes has failed to correspond to the valid effluent limitation, whereas predicted results of the aeration basin exhibited an effluent profile that meets TSS and BOD allowable limits. Different simulation models have been implemented by STOAT to simulate treatment processes in studied design approaches: ASAL 1 model; BOD model; BOD semi-dynamic model; and SSED 1 model. This study offers an additional understanding of WWTP design and facilitates the application of dynamic simulators as tools for wastewater treatment development in Kurdistan.**

***Index Terms*—Wastewater dynamic simulation, Sewage treatment operation analysis over time, Trickling biofilter, Activated sludge, Aeration tank.**

I. Introduction

The performance of units and processes in wastewater treatment plants (WWTPs) is regularly organized according to effluent profile parameters (Drinan and Spellman, 2015) and operation condition (Issa, 2016). Effluent limits have been built and sustained in respecting valid environmental regulations and legislation (Spellman, 2008). Respecting these regulations are obligatory for WWTPs to maintain the continuity of effluent discharge into diverse natural water bodies such as rivers, lakes, and seas (Davis, 2010). WWPTs have always structured programs for controlling the process units to eliminate any possible failure and to improve their performances (Matsuo et al., 2001; Williams, 2013).

Permanently, WWTPs are facing an important challenge when they try to reach optimal design and operation due to the stringent regulatory standards (Hreiz et al., 2015). Various design and assessment methods have been followed to perform a treatment process analysis and optimization of WWPTs units (Spiller et al., 2015). The uncertainty analysis by Monte Carlo simulations and multi-criteria assessment in wastewater treatment process development is often (Martin and Vanrolleghem, 2014; Spiller et al., 2015). Other techniques have also been implemented toward this objective, like artificial neural networks (Oliveira and Franca, 1998). Most of the established models in wastewater and sludge treatments are belonging to biological or physical treatments (Hakanen et al., 2013). Besides, the many conventional WWTPs proposed models (Kabouris, 1999), various predictive models have been also established for particular influent wastewater (Fung et al., 2012; Varank et al., 2014; Wang et al., 2014). The nature of mathematical models used in WWTP optimization is not the same, there are steady-state and dynamic based models (Rivas et al., 2008). Furthermore, the approach to reach the optimum design of WWTPs is different, some of the studies focus on particular parameters to be enhanced such as total suspended solids (TSS) (Verma et al., 2013), or solids retention time STM (Smith et al., 2014), whereas many other studies proposed a wider view of treatment evaluation by involving various controlling parameters for a single process such as the activated sludge process (Francisco et al., 2015) or the whole wastewater treatment process (Garrido-Baserba et al., 2012; Gillot et al., 1999; Guerrero et al., 2011; Khiewwijit et al., 2015; Revollar et al., 2017).

To achieve an accurate and adequate design of efficient WWTPs operating at optimum conditions, commercial simulation software has been developed in depending on previously proposed models (Gernaey et al., 2004). Software such as EnviroPro or SuperPro Designer built by Intelligen Inc., BioWin built by EnviroSim Associates Ltd., and sewage

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treatment operation analysis over time (STOAT) software built by WRc Plc. is useful for simulation purposes. The developed WWTP process simulator of EnviroPro emphasize mainly on the environmental requirement to control the heavy metals and volatile organic compounds (Petrides et al., 1998). SuperPro Designer simulator is suitable for the purpose of environmental applications: Economic and pollution parameters determination (Kotoupas et al., 2007). Whereas the dynamic simulator STOAT has been applied mainly to develop the biological and physical process of secondary treatment in WWTPs, focusing on treating high nutrient using various models like activated sludge models ASMs (Sarkar et al., 2010). BioWin wastewater simulator aids to configure the various activated sludge reactor dimensions (Oleszkiewicz et al., 2004).

This work shows the results of plant design and optimization for an abandoned WWTP COEWWTP in its current condition (without modification) scheme and in proposed condition (with modification) scheme, by means of dynamic simulation performed using STOAT software simulations. In the development of COEWWTP, particular importance has been paid on the requirement to maintain effluents within the integrated local wastewater environmental regulations in the Kurdistan region of Iraq.

II. Methodology

A. Description of Erbil Wastewater Characteristics and the Studied WWTP COEWWTP Processes

Erbil is a big city of one million inhabitants, located in the North of Iraq. Nearly, all the neighborhoods of Erbil city are covered by sewage networks of dozens of kilometers long. There is no main WWTP in Erbil city; there are only a few small WWTPs serve in a few residential districts. Without treatment for the greater part of the wastewater effluents, this main part of wastewater discharge is directed to a nearby channel southwest of the city. Shekha et al., 2016, have determined the mean values of Erbil wastewater characteristics at the site Southwest of Erbil. They found that the dissolved oxygen (DO), biochemical oxygen demand (BOD) 5 nitrates NO_3, and phosphates PO_4 are 1.2 mg/l, 75 mg/l, 650 (µg NO_3-N/l), and 720 (µg PO_4-P/l), respectively, at a mean temperature of 19.7°C, whereas Al-Barzingy et al., 2010, have found that the mean TSS of Erbil wastewater at the same previous site is 80.15 mg/l.

The WWTP in the University of Salahaddin, College of Engineering Compound COEWWTP is the first plant established at Erbil. It was designed and constructed by a Japanese company in 1979, and it then was operated by the staff of the college of engineering. The plant released the effluents to the main discharge channel. After 14–15 working years, nearly in 1994, COEWWTP was stopped working due to economic conditions. In the years 2001, the plant was maintained by the staff of college of engineering and started working for another 7 years and stopped again. COEWWTP has been constructed with a capacity of about 2000 M^3/d, involving only primary treatment of sedimentation basin, as shown in Fig. 1.

B. Design and Dynamic Simulation of COEWWTP Units and Processes

STOAT (standard for STOAT) is a software that uses modeling to simulate dynamically of WWTP performances (Dudley and Dickson, 1992). It has been developed by WRc plc, England. The software can be used to simulate individual treatment processes or the whole treatment plant. The simulator adopted models that enable optimization the response of WWTPs in the influent loads and operating conditions. It addressed various models for all common wastewater treatment processes and established standard methods for performing these evaluations. The bio-kinetic models include the common IWA models of ASMs of biological nitrification and denitrification processes (Siegrist and Tschui, 1992).

In this work, the design was carried out using STOAT for three different scenarios: The first is redesign and simulate the existing processes units of COEWWTP without any modification; the second and third are design and simulate a modified WWTP by adding two different secondary treatment units to the plant.

The complete design for the WWTP COEWWTP2 has been achieved for the secondary biological treatment proposing two approaches: A trickling biofilter with a secondary sedimentation basin (COEWWTP2) (Fig. 2) or an activated sludge aeration basin with secondary settling tank (COEWWTP3) (Fig. 3).

Verification of the design and simulation of COEWWTP, COEWWTP2, and COEWWTP3 processes by applying STOAT simulation software is preferable. The fact that the verification could be privileged makes no change since the obstacle of privilege is excluded as there is no main WWTP operating nowadays at Erbil city and the main objective of this work is to explore the upgrading and renovation possibilities for the abandoned COEWWTP.

A comparison between the existing COEWWTP with two proposed alternatives of COEWWTP2 and COEWWTP3 has been made in terms of effluent quality. The returns of simulation analysis gave a valuable inside view of design criteria and opportunities to establish an extensive understanding of the prospected operating performance of the COEWWTP processes with and without modifications. The quality of effluent was employed to determine differences among the three WWTP processes.

Using STOAT for optimizing with dynamic simulating has been based on the soluble BOD and TSS profile in intended influents for the current COEWWTP and the proposing

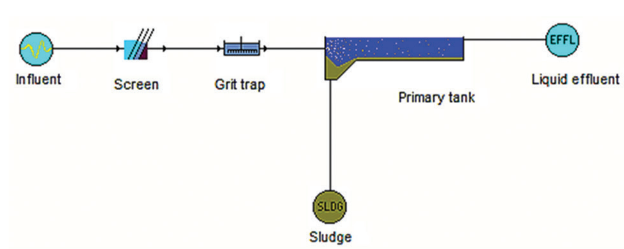

Fig. 1. Process flow diagram of COEWWTP using sewage treatment operation analysis over time simulator.

alternative schemes of COEWWTP2 and COEWWTP3. The ratios of nutrients were considerably low in the influent, and hence they were not taken into account in decision-making. The dimensions and some parameters for certain units were kept constant and default in all the scenarios to reach a reasonable cost similarity. Influent values used in the simulation were adopted from previous works on Erbil wastewater, as stated in Table I.

The influent and treated effluent volumetric flow rates are kept the same to match the efficiency of the tested schemes. Details on dimensions and streams of utilized units are presented in Table I. In COEWWTP3 scenario, the volumetric flow rate of recycle stream of the aeration tanks has been kept constant, and its ratio equals one, as shown in Table II.

In the STOAT dynamic simulation, the run in all wastewater treatment scenarios and the initial level of influent parameters are kept the same, where the processes runs were in a cold state with no previous operation. The initial influent is illustrated in Fig. 4, where some parameters were taken as default values in executed runs for a duration of 48 h and a profile of sinusoidal pattern. The initial data for the inlet stream to the primary treatment tank in the three examined simulation scenarios are displayed in Table III.

The performed dynamic simulation is depending on previously established models that are implied in STOAT for various units. Four models have been used in this work; BOD model in the primary and secondary treatment tanks; BOD semi-dynamic model in the trickling biofilter; ASAL1 model in the activated sludge aeration tank; and SSED1

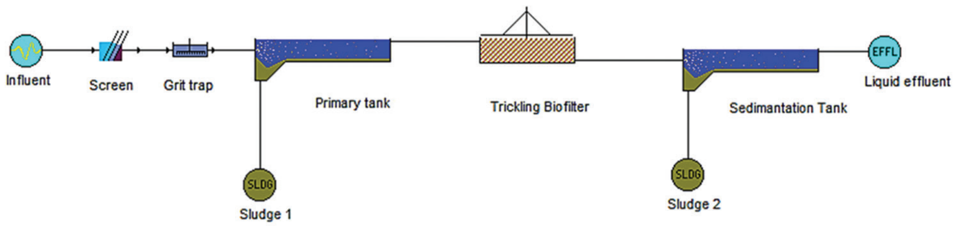

Fig. 2. Process flow diagram of COEWWTP2 using sewage treatment operation analysis over time simulator.

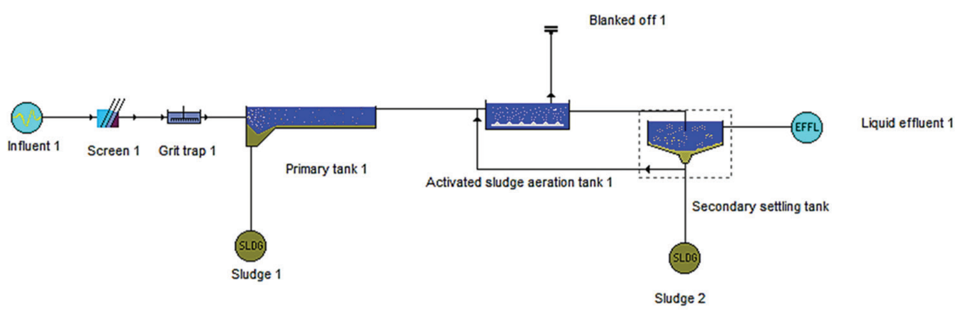

Fig.3. Process flow diagram of proposed COEWWTP3 with an activated sludge aeration basin with secondary sedimentation basin using sewage treatment operation analysis over time simulator.

TABLE I
Dimensions and Volumetric Flow Rates of Proposed Three Scenarios for Wastewater Treatment

Parameters	Scenario 1 (COEWWTP)	Scenario 2 (COEWWTP2)	Scenario 3 (COEWWTP3)
Wastewater temperature (°C)	19.7	19.7	19.7
Screen bar spacing (m)	0.3	0.3	0.3
Grit trap volume (m^3)	30	30	30
Primary treatment tank volume (m^3)	600	600	600
Primary treatment tank surface area (m^2)	200	200	200
Primary treatment tank stages	1	1	1
Trickling biofilter surface area (m^2)	-	500	-
Trickling biofilter depth (m)	-	1.5	-
Secondary treatment tank volume (m^3)	-	600	-
Secondary treatment tank surface area (m^2)	-	200	-
Secondary sedimentation tank stages	-	1	-
Activated sludge aeration tank volume (m^3)	-	-	300
Stages of activated sludge aeration tank	-	-	1
Secondary sedimentation tank surface area (m^2)	-	-	250
Secondary settling tank stages	-	-	1
Secondary settling tank depth (m)	-	-	3
Secondary settling tank feed depth (m)	-	-	2

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model in secondary settling tank. BOD based model handles the biomass in the influents.

TABLE II
Operational Data of the Secondary Settling Tank in the Scheme of Coewwtp 3

Parameters	Value
Change at time (h)	0.0
RAS flow (m^3/h)	112.0
RAS ratio	1.0
Sludge wastage flow (m^3/h)	5.0
Wastage pump run time (h)	24.0
Wastage cycle time (h)	24.0
MLSS set-point (mg/l)	0.0

MLSS: Mixed liquor suspended solids, RAS: Return activated sludge

TABLE III
The Initial Condition of the Primary Treatment Tank in all Executed Dynamic Simulation Runs Using STOAT for All Wastewater Treatment Scenarios

Parameters	Value
Soluble BOD (mg/l)	75.00
Soluble inert COD (mg/l)	0.00
Ammonia (mg/l)	0.01
Nitrate (mg/l)	0.65
Soluble organic nitrogen (mg/l)	1.00
Soluble phosphate (mg/l)	0.72
Dissolved oxygen (mg/l)	1.20
BOD of volatile fatty acids (mg/l)	0.00
Settable particulate BOD (mg/l)	35.00
Non-settable particulate BOD (mg/l)	15.00
Settable particulate inert COD (mg/l)	0.00
Non-settable particulate inert COD (mg/l)	0.00
Settable volatile solids (mg/l)	45.00
Non-settable volatile solids (mg/l)	15.00
Settable non-volatile solids (mg/l)	14.00
Non-settable non-volatile solids (mg/l)	6.00
Settable particulate organic N (mg/l)	0.00
Temperature (°C)	19.7

STOAT: Sewage treatment operation analysis over time, BOD: Biochemical oxygen demand, COD: Chemical oxygen demand

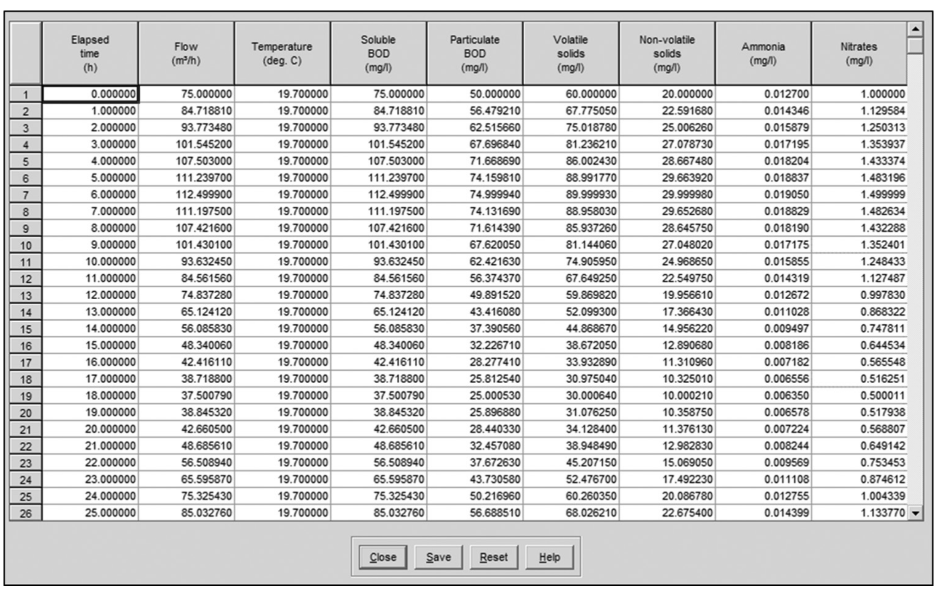
The ratio of phosphates, nitrates, and ammonia are very low in influent wastewater according to Iraqi environmental limitations of sewage discharges (Ministry of Environment, 2010). The key factors that were considered in the study to design and optimize the studied COEWWTP are the TSS and BOD. Therefore, the ASAL 1 model has been implemented to simulate the operation of activated sludge aeration tank in COEWWTP3 scenario. This model handles mainly the BOD removal in the influents, whereas the other processes such as nitrification or denitrification are not clearly embedded in it (Stokes et al., 2000). To facilitate the simulation in this work, ASAL 1 dynamic model has been used as it does not distinguish viable or nonviable biomass (Stokes et al., 2000).

The existing condition of COEWWTP contains only a primary treatment stage, which is currently out of work. Therefore, this work examines any intended essay to recommence or renovate this plant that must indubitably take into account the treatment efficiency. This step may require redesigning the current WWTP that can be separated into various scenarios. A dynamic simulation software STOAT has been used to perform and optimize the design scenarios. The optimization of design using the implemented models for investigated scenarios is established depending on the BOD and TSS outcome in the predicted effluent. The simulation for each design scenario has been conducted with implementing several models that mainly determine BOD behavior as an indicator of biomass strength like ASAL 1. The reason for exploring COEWWTP case study scenarios is to predict an optimum design regarding TSS and BOD removal capacities.

III. Results and Discussion

A. Dynamic Simulation of the Existing COEWWTP (Scenario 1)

Considering the characteristics presented in Fig. 4 as a proposed influent comes from Erbil city sewage, the dynamic simulation using STOAT of the existing COEWWTP's processes (Fig. 1) generated an effluent profile shown



	Elapsed time (h)	Flow (m^3/h)	Temperature (deg. C)	Soluble BOD (mg/l)	Particulate BOD (mg/l)	Volatile solids (mg/l)	Non-volatile solids (mg/l)	Ammonia (mg/l)	Nitrates (mg/l)
1	0.000000	75.000000	19.700000	75.000000	50.000000	60.000000	20.000000	0.012700	1.000000
2	1.000000	84.718810	19.700000	84.718810	56.479210	67.775050	22.591680	0.014346	1.129584
3	2.000000	93.773480	19.700000	93.773480	62.515660	75.018780	25.006260	0.015879	1.250313
4	3.000000	101.545200	19.700000	101.545200	67.696840	81.236210	27.078730	0.017195	1.353937
5	4.000000	107.503000	19.700000	107.503000	71.668690	86.002430	28.667480	0.018204	1.433374
6	5.000000	111.239700	19.700000	111.239700	74.159810	88.991770	29.663920	0.018837	1.483196
7	6.000000	112.499900	19.700000	112.499900	74.999940	89.999930	29.999980	0.019050	1.499999
8	7.000000	111.197500	19.700000	111.197500	74.131690	88.958030	29.652680	0.018829	1.482634
9	8.000000	107.421600	19.700000	107.421600	71.614390	85.937260	28.645750	0.018190	1.432288
10	9.000000	101.430100	19.700000	101.430100	67.620050	81.144060	27.048020	0.017175	1.352401
11	10.000000	93.632450	19.700000	93.632450	62.421630	74.905950	24.968650	0.015855	1.248433
12	11.000000	84.561560	19.700000	84.561560	56.374370	67.649250	22.549750	0.014319	1.127487
13	12.000000	74.837280	19.700000	74.837280	49.891520	59.869820	19.956610	0.012672	0.997830
14	13.000000	65.124120	19.700000	65.124120	43.416080	52.099300	17.366430	0.011028	0.868322
15	14.000000	56.085830	19.700000	56.085830	37.390560	44.868670	14.956220	0.009497	0.747811
16	15.000000	48.340060	19.700000	48.340060	32.226710	38.672050	12.890680	0.008186	0.644534
17	16.000000	42.416110	19.700000	42.416110	28.277410	33.932890	11.310960	0.007182	0.565548
18	17.000000	38.718800	19.700000	38.718800	25.812540	30.975040	10.325010	0.006556	0.516251
19	18.000000	37.500790	19.700000	37.500790	25.000530	30.000640	10.000210	0.006350	0.500011
20	19.000000	38.845320	19.700000	38.845320	25.896880	31.076250	10.358750	0.006578	0.517938
21	20.000000	42.660500	19.700000	42.660500	28.440330	34.128400	11.376130	0.007224	0.568807
22	21.000000	48.685610	19.700000	48.685610	32.457080	38.948490	12.982830	0.008244	0.649142
23	22.000000	56.508940	19.700000	56.508940	37.672630	45.207150	15.069050	0.009569	0.753453
24	23.000000	65.595870	19.700000	65.595870	43.730580	52.476700	17.492230	0.011108	0.874612
25	24.000000	75.325430	19.700000	75.325430	50.216960	60.260350	20.086780	0.012755	1.004339
26	25.000000	85.032760	19.700000	85.032760	56.688510	68.026210	22.675400	0.014399	1.133770

Fig. 4. The hourly influent profile in all executed dynamic simulation runs using sewage treatment operation analysis over time.

in Fig. 5. This effluent profile of seven parameters with simulation run time elapsed (48 h) is displayed by way of graphs, as shown in Fig. 5. Table III presents that the mean values of effluent parameters are generated from the existing COEWWTP scheme employing the STOAT dynamic simulation. The investigated effluent parameters are flow rate, TSS, soluble BOD, particulate BOD, volatile suspended solids (VSS), non-VSS, and DO. After a run time of 48 h, the dynamic simulation shows that the wastewater plant operation reached an agreeable steady state, as shown in Fig. 5. The fluctuation of effluent's flow rate and parameters values that appear in Fig. 5 is due to the divergence between daytime and nighttime loads corresponding to the sinusoidal simulation profile.

Both Table IV and Fig. 5 show that the concentrations of TSS and BODs in the COEWWTP effluent are much higher than the Iraqi and the WHO environmental allowable limits.

From Table IV, it can be seen that performance of COEWWTP scheme (scenario 1) is not satisfactory as stated by valid legislation and standards regarding the wastewater effluent disposal, and hence this scenario is out of consideration. It can be said that these results are expected as the COEWWTP involves only a primary treatment which is simply convenient for physical treatment to remove heavy solids. No remarkable influence of this treatment was found on the soluble and particulate biological matter. Even though there is no lower limit of DO of WWTP's effluent, DO of COEWWTP's effluent is quite low which may disturb the DO level of any receiving water body.

The single changing that has been made through this scenario is the TSS and VSS mean values was slightly lowered, where about 13% has been removed for both. It can be said that this scenario is useful only for an influent with low BOD and biomass levels. It is interesting to see that the solute BOD level was increased instead of to be decreased after the primary sedimentation. This increase might happen because more biological activities took place in the primary tank. From these results of primary sedimentation, it can be understood that the biomass is in a soluble state and with a small size in which a primary sedimentation tank makes no significant improvement in the wastewater situation.

B. Dynamic Simulation of the Proposed COEWWTP2 (Scenario 2)

Fig. 6 and Table V present the effluent profile produced by the suggested treatment scenario of COEWWTP2. In this option, a biofilter and secondary sedimentation tank were added to the primary sedimentation tank, as shown in Fig. 2. In Fig. 6, it is clear that biological treatment has been accomplished successfully. As an indicator of this achievement, the DO has been elevated substantially to reach a maximum level that can be made according to water solubility limit to DO. This means no extensive demand for oxygen exists in the effluent any more. Moreover, so the BOD mean value was declined accordingly to 30.29 mg/l. All these signs imply that the created biofilm on filter bed is performing the treatment positively.

On the other hand, as presented in Table V, the TSS is still high. In this proposed scheme, a secondary sedimentation tank was recommended to remove the suspended solids created in the trickling biofilter. However, according to the dynamic simulation results generated by STOAT, it can be seen that high levels of various kinds of solids still occur in the effluent. The cause of these high levels is most probably due to the shape, size, and state of the solids, which makes it difficult for the sedimentation tank to trap and remove them.

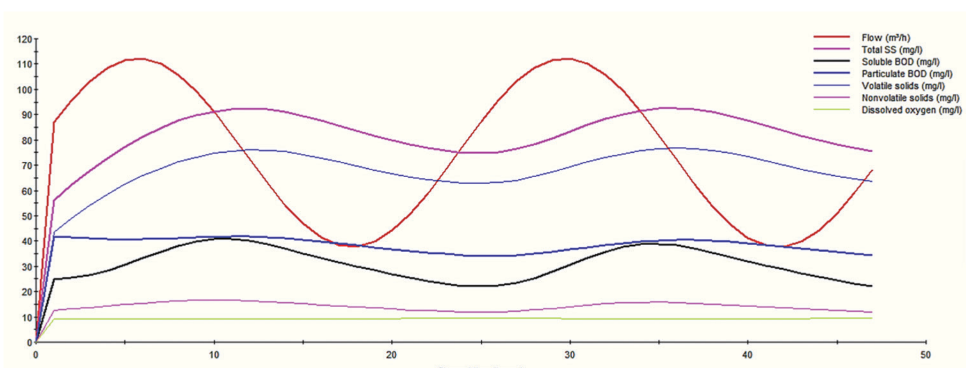


Fig. 5. Effluent profile from COEWWTP scheme (Scenario 1) as simulated by sewage treatment operation analysis over time along 48 h run time.

TABLE IV
Characteristics of the Effluent Generated from Ceewwtp Scheme

Parameters	Flow (m≥/h)	TSS (mg/l)	BOD (mg/l)	VSS (mg/l)	Non VSS (mg/l)	DO (mg/l)
Mean±Standard deviation	73.36±28.71	69.83±16.01	82.0±15.77	52.34±11.99	17.49±4.01	0.15±0.24
Total mass (kg)	-	261.95	301.22	196.34	65.61	0.65
Peak load (g/s)	-	2.71	2.95	2.03	0.68	0.024
Iraqi sewage disposal limits	-	60	40	-	-	-
WHO disposal guidelines*	-	30	20	-	-	-

*WHO guidelines limits as presented by (Chipofya and Avramenko, 2010). TSS: Total suspended solids, BOD: Biochemical oxygen demand, VSS: Volatile suspended solids, DO: Dissolved oxygen

From another point of view, the simulation results displayed in Fig. 6 show that the trickling biofilter is working perfectly on the soluble BOD, in which BOD mean value has been lowered by 60%. Whereas the performance of trickling biofilter on particulate BOD is not in the same way, as the VSS in the effluent was increased instead to be decreased. A part of this increase might come from the waste generated from the biological treatment in the trickling biofilter itself. However, for this scenario, the TSS is too high and cannot be accepted according to Iraqi limits or the WHO guidelines; therefore, this scheme was ignored.

C. Dynamic Simulation of the Proposed COEWWTP3 (Scenario 3)

To optimize the design of COEWWT to obtain an effluent that agrees with the permissible limits for both BOD and TSS, an alternative design scheme of COEWWTP3 (scenario 3) was proposed. The flow diagram of this scheme is illustrated in Fig. 3. In this scheme, an activated sludge aeration tank has been used to achieve the biological treatment and followed by a secondary settling tank to remove the suspended solids with a recycle stream. The operation parameters of the secondary settling tank are demonstrated in Table II.

The effluent profile as shown in Fig. 7 reveals that significant biological treatment has been accomplished for both soluble and particulate biomass along the time of simulation run of 48 h. It is shown in Fig. 7 that low levels of volatile and non-volatile solids have been reached even at early hours of the simulation which means a successful removal was attained by the secondary settling tank of produced flocks in the aeration tank. Only BOD took more time to be lowered in this proposed scheme; this looks to be reasonable as the activated sludge biomaterials need a specific period to reach an efficient activity in treating the included soluble and suspended organic mass in the influent. As shown in Fig. 7, the BOD starts to drop after passing 24 h, this gives an idea of the time required by the activated sludge in the aeration take to reach a suitable treatment level. DO profile in the generated effluent shows that it has reached a steady state according to the ongoing treatment occurring in the activated sludge aeration tank. This process prevents the DO to increase because the working activated sludge biomaterials originate a high demand on the existed oxygen to accomplish their work. Off course, the oxygen transfer in the tank is affected by many factors such as flow pattern and tank configuration (Issa, 2017).

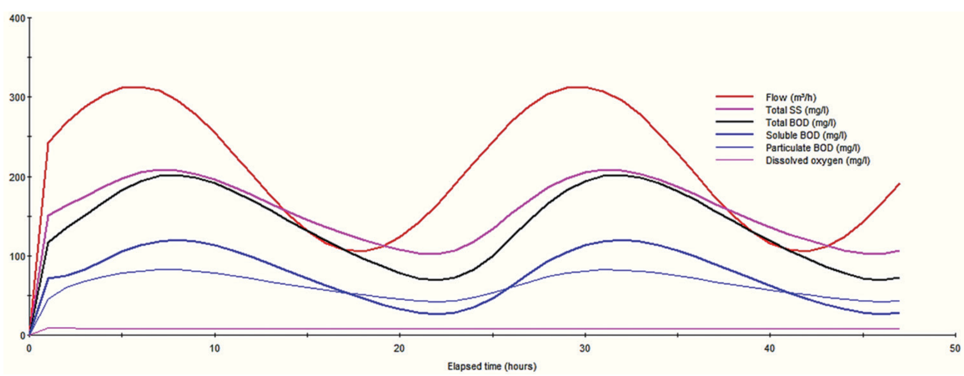


Fig. 6. Effluent profile from COEWWTP2 scheme (Scenario 2) as simulated by sewage treatment operation analysis over time along 48 h run time.

TABLE V
Characteristics of the Effluent Generated from Ceewwtp2 Scheme (Scenario 2)

Parameters	Flow (m≥/h)	TSS (mg/l)	BOD (mg/l)	VSS (mg/l)	Non VSS (mg/l)	DO (mg/l)
Mean±Standard deviation	73.36±28.71	80.87±14.44	30.29±7.45	66.96±12.16	13.89±2.52	9.10±1.34
Total mass (kg)	-	288.69	109.61	238.43	50.26	32.70
Peak load (g/s)	-	2.63	1.21	2.18	0.49	0.29
Iraqi sewage disposal limits	-	60	40	-	-	-
WHO disposal guidelines	-	30	20	-	-	-

TSS: Total suspended solids, BOD: Biochemical oxygen demand, VSS: Volatile suspended solids, DO: Dissolved oxygen

TABLE VI
Characteristics of the Effluent Generated from Ceowwtp3 Scheme (Scenario 3)

Parameters	Flow (m≥/h)	TSS (mg/l)	BOD (mg/l)	VSS (mg/l)	Non VSS (mg/l)	DO (mg/l)
Mean	68.46	5.47	24.30	1.18	4.29	1.89
Standard deviation	28.45	3.16	18.92	0.60	2.61	0.38
Total mass (kg)	-	20.15	80.65	4.20	15.92	6.25
Peak load (g/s)	-	0.40	1.43	0.09	0.32	0.06
Iraqi sewage disposal limits	-	60	40	-	-	-
WHO disposal guidelines	-	30	20	-	-	-

TSS: Total suspended solids, BOD: Biochemical oxygen demand, VSS: Volatile suspended solids, DO: Dissolved oxygen

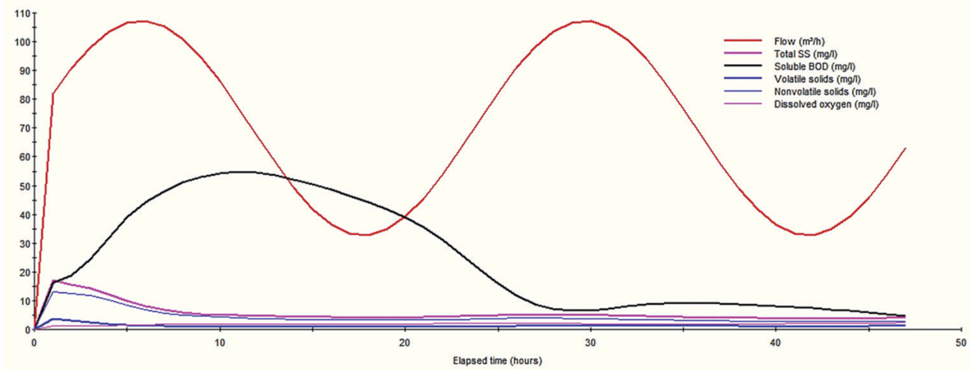


Fig. 7. Effluent profile from COEWWTP 3 scheme (Scenario 3) as simulated by sewage treatment operation analysis over time along 48 h run time.

The results presented in Table VI show that the treatment efficiency made by the scheme COEWWT3 is satisfactory for both TSS and BOD mean values. The removal percentage of TSS and BOD was 93.2 and 68%, respectively. Comparing with the previous schemes, these results lead to only consider the last scenario of COEWWTP3 for further modification and renovation for the existed and abandoned WWTP of COEWWTP.

IV. Conclusion

In this work, a dynamic simulator like STOAT that has been widely validated in many previous studies was chosen to optimize the design possibilities of modification and renovation of an abandoned WWTP COEWWTP located at Erbil, Iraq. First, the existing scheme COEWWTP was simulated using STOAT software. Simulated effluent data were obtained with this scheme disclose that the current plant configuration has failed to assure accepted effluent levels regarding the TSS and BOD allowable limits according to Iraqi and the WHO guidelines. Two alternative design schemes have been then proposed by applying STOAT simulation software to improve effluent quality: COEWWTP2 and COEWWTP3. The design of COEWWTP2 scheme involves a trickling filter with a secondary sedimentation basin showed that this approach is unsuitable due to high TSS level in the effluent. However, the second design approach COEWWTP3, in which the activated sludge aeration basin conjugated with the secondary sedimentation basin, is more convenient and achieved reasonable results. The final scheme looks to be a technically feasible scheme with respect to TSS and BOD profile in the plant effluent. This scheme might be able to give considerable treatment efficiency compared to that in the existing COEWWTP or the proposed COEWWTP2. This study thus leads to taking into consideration the dynamic simulators potentials in optimizing and development of the WWTP design approaches, especially in the Kurdistan region of Iraq.

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