Environmental Health Engineering and Management Journal 2022, 9(3), 213-221
http://ehemj.com
doi 10.34172/EHEM.2022.22
Environmental Health Engineering and Management Journal
Original Article
Open Access Publish Free

Performance improvement of textile wastewater treatment plant design by STOAT model simulation

Desalegn Abdissa Akuma[1*], **Ketema Beyecha Hundie**[2], **Tafere Aga Bullo**[2]

[1]Environmental Engineering, Jimma Technology Institute, Jimma University, Jimma, Ethiopia
[2]Process Engineering, Jimma Technology Institute, Jimma University, Jimma, Ethiopia

Abstract

Background: To control pollution, wastewater treatment from textile plays an important role in treating wastewater to meet quality standards before it is discharged into the environment. Without properly treated wastewater from the textile industry, it contains organic and inorganic pollutants that cause environmental problems such as water pollution, loss of marine life, and soil and air pollution. The aim of this study was to design and simulate a textile sewage treatment plant.

Methods: This study was conducted by simulating the process and operation of a wastewater treatment plant using STOAT software. In addition, STOAT's graphical and static data analysis models are efficient in removing multi-component pollutants from the textile industry.

Results: Some pollutant parameters prior to the design model are suspended solids (SS) (260 mg/L), DS (3600 mg/L), ammonia (65 mg/L), biochemical oxygen demand (BOD) (430 mg/L), nitrate (35 mg/L), and dissolved Oxygen (DO) (12 mg/L). The wastewater of the simulation result of the sewage treatment plant model contained SS (3.3 mg/L), ammonia (25 mg/L), BOD (4 mg/L), nitrate (61.3 mg/L), and the removal percentage of total suspended solids (TSS), BOD, and Ammonia was 99.75, 99.1, 61.33 mg/L, respectively. Through the treatment process, Ammonia was oxidized and nitrification was processed rather than denitrification.

Conclusion: Using the stoat modeling software, wastewater treatment plant design is very effective in removing contaminants from textile wastewater by selecting specific parameters.

Keywords: Wastewater, Sewage, Environmental pollution, Nitrification, Water pollution

Citation: Akuma DA, Hundie KB, Bullo TA. Performance improvement of textile wastewater treatment plant design by STOAT model simulation. Environmental Health Engineering and Management Journal 2022; 9(3): 213-221. doi: 10.34172/EHEM.2022.22.

Article History:
Received: 10 August 2021
Accepted: 29 December 2021
ePublished: 14 August 2022

***Correspondence to:**
Desalegn Abdissa Akuma,
Email: abdissa694@gmail.com,
desalegn.abdissa@ju.edu.et

Introduction

Wastewater treatment is a broad term that refers to a process, operation, or combination of processes and operations that can reduce the unpleasant nature of waste carrying water and reduce its danger and resilience to humans (1). Wastewater from various manufacturing stages of the textile industry has high pH values, temperatures, detergents, oils, suspended and dissolved solids, dispersants, leveling agents, degradable and non-biodegradable substances, dyes, biochemical oxygen demand (BOD), chemical oxygen demand (COD), contains nitrogen and sulfites as NH_4^+, $(SO_3)^{2-}$, sulfate $(SO4)^{2-}$, phenol, lead (Pb^{2+}), cadmium, Hexavalent chromium (Cr^{6+}), copper (Cu^{2+}), Nickel (Ni^{2+}), zinc (Zn^{2+}), and Free or residue chloride (2). Such contaminated sewage can cause environmental problems if not properly treated before it is released into the environment.

The estimated daily release of sewage from the Ayka Addis textile industry, which contains approximately 1200 m^3/day of high concentrations of reactive dyes used in the Ethiopian industry, poses major environmental problems (3). Pollution from domestic and industrial activities is a major threat to Ethiopia's surface and groundwater quality, according to the EEPA report in 2016 (4). Most of the country's industry is reported to dump sewage into nearby waters and open up land without any treatment (5). However, the survival of ecosystems depends on their ability to manage waste in an environmentally sound way (6). This can only be achieved by establishing and implementing appropriate standards and guidelines to ensure that the environment is not destroyed (6).

Textile wastewater released for industry must be treated before it can be reused or disposed for several reasons. These reasons include: i) Non-biodegradability of organic dye present in wastewater, ii) High COD, BOD, and total dissolved solids content (TDS) of wastewater (7). The purpose of using sewage treatment operation and analysis over time (STOAT) simulations is to identify the parameters that have the greatest impact on changes in the quality of the wastewater produced and to make long-term predictions of the ability of sewage treatment plants to purify wastewater (1). However, achieving the quality of effluent that is following regulations is also challenging. Various problems faced by wastewater treatment plant operators, such as (i) improper design of hydraulics and heavy loads, (ii) mechanical equipment problems, (iii) inadequate operation, maintenance, and troubleshooting, may cause poor removal efficiency. In addition, the deterioration of wastewater quality due to population growth and changes in land use must be taken into account. Some EPA guidelines for the textile wastewater discharge into the environments are shown in Table 1.

The parameters that highly changed by performance of the wastewater treatment plant STOAT model simulation designs are COD, BOD, dissolved oxygen (DO), total suspended solids (TSS), and potential hydrogen (pH) (10,11). The investigated effluent parameters are flow rate, soluble BOD, TSS, particulate BOD, volatile suspended solids (VSS), DO, and non-VSS, after a retention time of 48 hours (12).

This study was done because few textile industries have sewage treatment plants and some plants in developing countries are not functioning at all. The aim of this study was to evaluate the disposal efficiency, dealing with the simulation operating parameters, and design sewage treatment plants in the Ayka Addis textile industry, which releases the multi-components pollutants beyond the EPA limit concentrations. STOAT has evaluated the operating parameters of the main effects of pollutant removal in primary sedimentation, aeration, and clarification tanks. The simulation model depends on the concentration of pollutants released by the industry and the EPA of the treatment applications. This wastewater treatment plant was selected as a case study due to its huge capacity (up to 1200 m^3/day) and its essential role in the Ayka Addis textile industry. Minhaj and Adhiraga Pratama conducted a study in 2020 in Indonesia entitled “Modeling performance of industrial park wastewater treatment plant by STOAT software (1). Hassan and Mostafa conducted a study in 2019 in Egypt entitled “Improving the performance of SBR WWTP under the effect of organic shock load using STOAT software”.

Table 1. Some EPA guidelines for the textile wastewater discharge into the environments (8, 9)

Item	Maximum limits of textile effluent value
Temperature	10°C< Average temperature of the recipient
pH	6–9
BOD	50–100 mg/L
COD	150–200 mg/L
TSD	80–110 mg/L
TSS	40–60 mg/L
Suspended solids	40–80 mg/L

BOD, biochemical oxygen demand; COD, chemical oxygen demand; TSS, Total dissolved solids; TSD, Total dissolved solids.

Methods

The raw sewage was collected from a textile industry called the Ayka Addis Textile and Investment Group in Addis Ababa, Ethiopia. Samples were collected directly at the exit of the static screen. STOAT is one of the sewage treatment plants modeling software used primarily to predict the performance of sewage and is ideal for simulating wastewater treatment plants, which took three days to complete the simulation.

Data analysis

STOAT has been developed in 1989 as a PC-based software package that integrates a dynamic model of the wastewater treatment process as a series of research projects (13). The top priority was to investigate the feasibility of dynamic modeling of the entire sewage treatment plant by simulating individual sub-processes. The dynamic modeling of wastewater treatment plant processes is to establish better planning and operational procedures and gain significant cost effective. The inflow data obtained through measurement results and sample tests are analyzed by WRc STOAT version 4.3. The units used for simulation and sensitivity analysis remain the same, but the discharge values, load parameters, operation, and process parameters are changed. The wastewater inflow data used in BOD modeling are adjusted from the state of on-site drainage from both emission values, BOD and volatile solids values. The runoff value itself is determined from the average wastewater runoff measurement of the textile wastewater treatment plant, but the BOD and volatile solid values are obtained from inspections of wastewater samples taken during the survey.

Therefore, a simulation process is needed to validate the model to ensure that the conditions and effluent generated by the STOAT model match the on-site conditions and effluent. The inflow data used in STOAT modeling are the data obtained through measurement results and sample tests. The units used for simulation analysis remain the same, but the discharge values, load parameters, operation, and process parameters are changed. STOAT operates at a flow rate of 1000 m^3/h. As shown in Table 2, the required parameters are COD, BOD, ammonia nitrogen (NH_3-N), total nitrogen (TN), total phosphorus (TP), and TSS, which varies between 127 and 360, 93 and 219, 11 and 47, 21 and 58, 2.64 and 6.24, 114, and 227 mg/L, respectively (14).

Sampling protocols and reagent uses

Sampling was performed at three points: Before the bar screen plant where the wastewater was untreated, after

Table 2. STOAT parameters of influent into ditch

Parameter	Units	Max	Min	Average	References
Flow	m^3/h	1000	1000	1000	
TSS	mg/L	227	114	173	
pH		7	7	7	
Temperature	°C	15	15	15	
COD	mg/L	364	127	256	(14)
BOD	mg/L	219	93	158	
TN	mgN/L	58	21	42	
NH_3	mgN/L	47	11	31	
TP	mg/L	6.24	2.46	3.98	

BOD, biochemical oxygen demand; COD, chemical oxygen demand; TSS, Total dissolved solids; TN, total nitrogen; TP, total phosphorus

the primary treatment plant, after the pretreatment with extremely high parameter removal efficiency, and after the secondary treatment. It was treated at the receiving water before the treatment plant or wastewater was discharged. The sampled raw sewage was analyzed and characterized by a turbid meter, muffle furnace, electronic weighing balance, and evaporation tray. Chloride and bicarbonate, NO_2, CN, sulfide, Br, I, chlorite, and chlorate were used to measure nitrates in weight ratios of NO_3–N> 10 and> 5. Standard 0.02 N sulfuric acid containing boric acid indicator solution was used for ammonia measurement. Data inflows were established for modeling using plant inflow data collected from wastewater. Suspended solids data were reported as VSS and total solids, and BOD data were reported as soluble and total BOD. Ammonia data was supplied as soluble NH_4-N and could be entered directly into the model feed. TKN was total nitrogen used in combination with ammonia-soluble data to provide the organic nitrogen status required for the model. Simulation dimensions of plant processing for the primary tank (volume 700 m^3, area 250 m^2), for the aeration area (volume 630 m^3), and for the secondary sedimentation tank(volume 350 m^3, depth 4 m) were determined.

Primary tank

The simulations were used to determine the primary settlement tanks expect the removal of BOD particles from wastewater, settleable VSS, and non-volatile configurable solids. Simulation data analysis was performed at three locations: Before the bar screen plant where the wastewater is untreated, after the primary treatment plant, which is the point after the pretreatment with extremely high parameter separation efficiency, and after the secondary treatment. It was treated at the receiving water before the treatment plant or wastewater was discharged.

Activated sludge plant

Simulation data analysis was done at three different points: The wastewater treatment inlet, the pretreatment plant outlet, and the wastewater outlet before it were discharged into the body of water. The simulation parameters that were checked during the removal of this sampling are SS, BOD, and NH_4-Nby microbial activity in an activated sludge tank and used to assess the capacity of an activated sludge treatment plant (15).

Aeration tank

The rate of oxygen transfer at each aeration stage was determined by the amount of oxygen transferred by the surface aeration device (16). In the aeration tank, the first stage operates at a high rate of oxygen transfer and the oxygen is direct injects by pressure through the line of oxygen inlet. The concentration of saturated oxygen was limited to 40 mg/L (where the global oxygen saturated concentration of 30 mg/L is required for the mixed liquor in stages 4 and 3, where only the oxygen is absorbed in the space head) (17). In stage 1, surface aerator was typically turned off at the high oxygen transfer rate achieved in stage 1 when the gas was turning into a liquid. For stage 2, it was assumed that the oxygen concentration in the space head will be higher than in stages 3 and 4, giving an oxygen saturation concentration of 40 mg/L in the mixed liquor. The model predicted that much of the BOD would be consumed in the first stage, resulting in a predicted DO concentration of 0.5 mg/L or less. This is similar to what was measured at stage A of the aeration tank during the intensive survey.

Results

Characteristics of textile wastewater effluent

The wastewater sample collected had a bad odor and an alkaline bluish tinge because the pH was measured to be 8.9. This indicates that wastewater has high alkalinity and high light absorbance. Such wastewater can be discharged into the environment without treatment and can damage animals and plants. High alkalinity is a measure of the strength of wastewater from the dyeing process. Table 3 shows the physicochemical properties of raw

Table 3. Physicochemical properties of raw wastewater collected from the textile sewage

Parameters measured	Unit	Value
pH		8.9
Turbidity	NTU	80
Total solid	mg/L	3600
Total suspended solid	mg/L	1200
Total dissolved solid	mg/L	1800
Total volatile solid	mg/L	600
Soluble biochemical oxygen demand	mg/L	250
Particulate oxygen demand	mg/L	180
Ammonia	mg/L	65
Nitrate	mg/L	35
Dissolved oxygen	mg/L	12

textile wastewater collected from the Ayka Addis textile industry. Inflow and outflow wastewater is continuously collected, and wastewater characteristics are standard for COD, ammonia, nitrate, total suspended solid, total dissolved solid, and suspended solids (SS), etc. It was analyzed according to the method represented by Wang et al (18).

This means that the wastewater is highly polluted and requires further treatment. These high levels exceed the EEPA permissible wastewater values for discharge to water bodies, so that high concentrations of pollutants in textile wastewater have a significant impact on the environment.

Sampling was performed at three points to determine the efficiency of separation for each processing unit and the entire processing plant. In Figure 1, the numbers 1 to 8 represent the stream number of the treatment center entrance and external operations. As shown in Figure 1, the standard model sampling of wastewater treatment was done at three different points: The primary sedimentation or wastewater treatment inlet (connected with streams 1, 2, and 3), the pretreatment plant outlet or clarifier, aeration (connected with streams 2, 4, 5, and 7), and the wastewater outlet before it was discharged into the body of water or sludge sedimentation section (connected with stream 5, 6, 7 and 8).The parameters checked during this sampling are ammonia, nitrate, BOD, COD, and TSS.

Removal efficiency

After determining the value of each parameter at each sampling point, the allowance efficiency value was calculated by the processing unit. The removal efficiency of the entire sewage treatment plant was calculated according to Eq. (1):

$$E = \frac{C_i - C_f}{C_i} \times 100 \qquad (1)$$

Where, E is the removal efficiency, C_i is the inflow concentration (mg/L), and C_f is the outflow concentration (mg/L).

The flow rate of wastewater taken from continuous release of Ayka Addis textile industry with high concentration SS, BOD, and Ammonia, and lower nitrates are shown in Table 4, theoretically data survey, and lab tests. This wastewater directs inters to primary tank or stage 1 shown in Figure 1.

TSS, total BOD, and soluble BOD were constant with the flow rate, and the only changes were related to dynamic stream flows.

The wastewater flows through stream 2 from the primary treatment tank declines the concentration of TSS from 1761.21 to 300 mg/L on average. The total BOD increases from 420 to 660 mg/L on average, indicating that favourable conditions happen in the primary sedimentation tank for microbial development.

The soluble BOD, TSS, total BOD were the minimum and nitrate contents increase by decreasing ammonia values at the effluent stream shown in Table 5. The total BOD, TDS, and total suspended solid all most all were removed by practical treatment modeling simulation as shown in Figure 1. The removal of these pollutant components were emphasized through activated sludge process and sedimentation, primary tank or in the first stage the high denser of SS and partial of the settle able BOD were removed. At secondary sedimentation tank or stages one to eight also the process of separation, which most suspended solid and particulate BOD removed as sludge. There were no removal processes in the aeration section; it was only the system of microbial development by the suspension growth process. Most of the dissolved and suspended organic materials were consumed by microorganisms in the aeration tank system by partial recycling sludge process. The treatment plant model simulation efficiencies were 99% for BOD removal and 99.8% TSS at effluent, which is the efficiency and highest efficiency relative to preview articles (1). At the outlet model stream, the ammonia concentration decreases while nitrate concentration increases and the overall treatment model sows the nitrification process. The outlet-treated water is recommended to use for agricultural purposes and nitrate contents uses as fertilizer. Nitrification is a biological process by which aerobic bacteria oxidize ammonium to nitrate. Nitrifying bacteria oxidize ammonium ions (NH^{4+}) to nitrite (NO^{2-}), and then, oxidize nitrite to nitrate (NO^{3-}) (19).

The wastewater treatment plant model simulation results in high-efficiency removal of total solids and BOD. There was a regular pollutant constituent with dynamic outflows

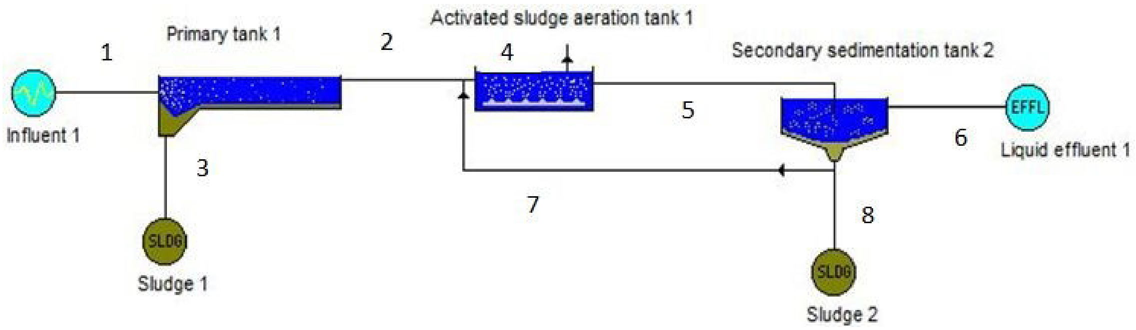

Figure 1. Model design simulation of wastewater treatment plant basic components.

Table 4. Summary characteristics of wastewater inlet of the model for wastewater treatment plant

	Flow (m^3/h)	Total SS (mg/L)	Total BOD (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Soluble BOD (mg/L)
Mean	48.92	1761.21	420.73	63.6	34.25	244.61
Standard deviation	19.15	689.26	164.66	24.89	13.4	95.73
Total mass (kg)		4756.08	1136.17	171.75	92.48	660.57
Peak load (g/s)		55.93	13.36	2.02	1.09	7.77

Table 5. Sludge effluent flow properties of wastewater after treatment plant models at stream 6

	Flow (m^3/h)	Total SS (mg/L)	Total BOD (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Soluble BOD (mg/L)
Mean	42.66	3.3	3.72	25.33	61.33	2.98
Standard deviation	18.03	1.14	0.96	23.05	34.55	1.13
Total mass (kg)		6.736	7.94	58.916	118.955	6.439
Peak load (g/s)		0.08	0.09	1.173	1.646	0.089

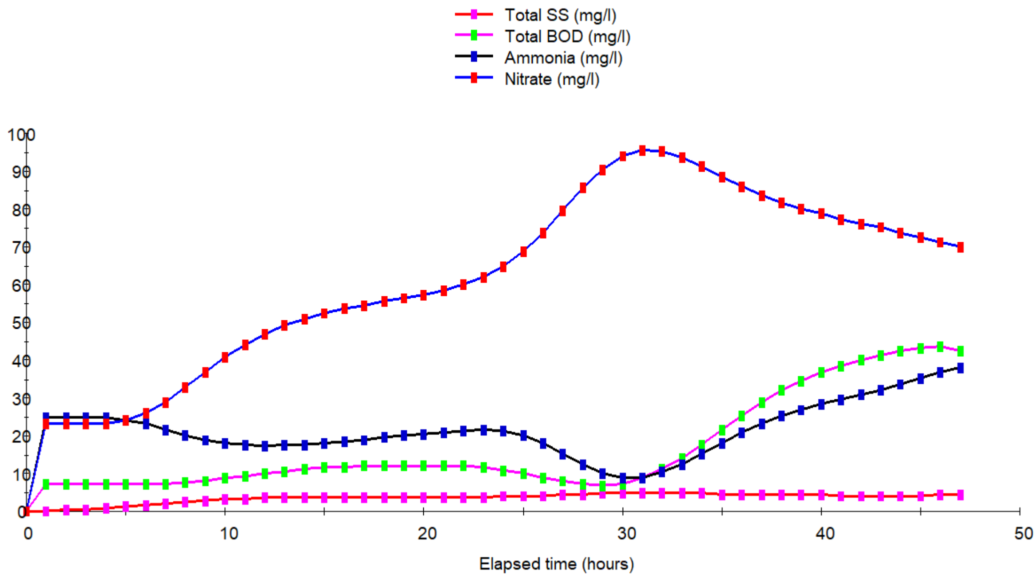

Figure 2. Wastewater dynamic flows from plant treatment simulation to environment.

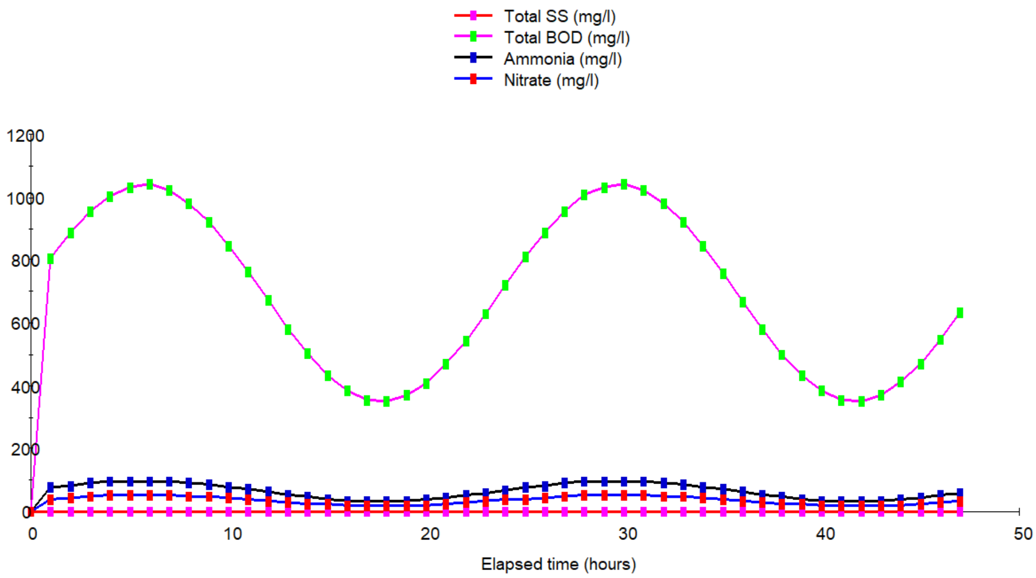

Figure 3. Continuously dynamic flow of wastewater to the treatment plants with pollutant properties.

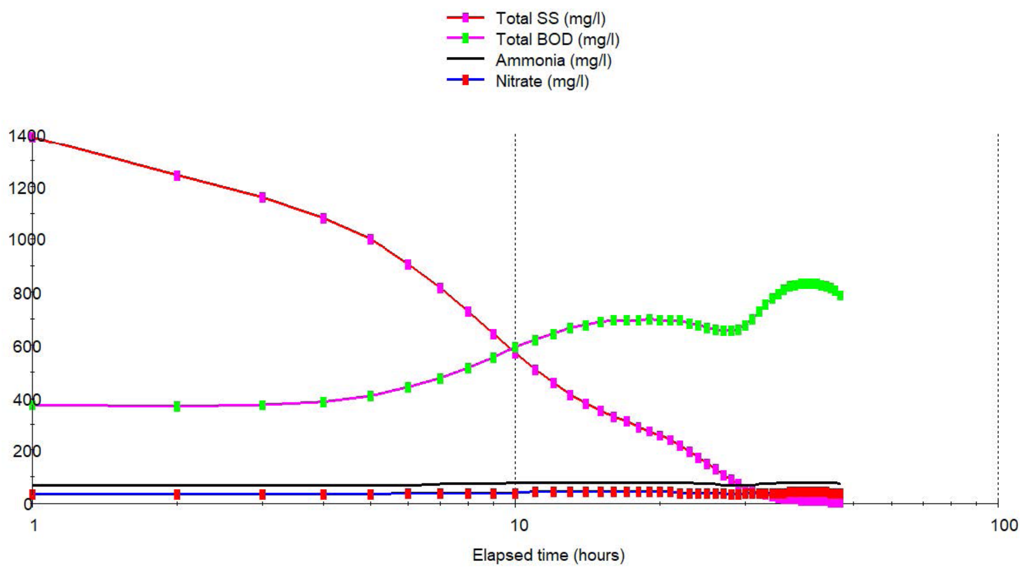

Figure 4. The dynamic flow of wastewater from primary treatment section at stream 2.

Table 6. The outlet Sludge 1 flow and its properties

	Flow (m^3/h)	Total SS (mg/L)	Total BOD (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Soluble BOD (mg/L)
Mean	1.37	51406.25	4526.49	63.6	34.25	244.61
Standard deviation	0.89	7577.72	861.16	24.89	13.4	95.73
Total mass (kg)		3453.74	313.40	5.18	2.79	19.93
Peak load (g/s)		39.50	4.86	0.07	0.04	0.28

and the nitrate was risen up exponentially with elapsed time and the maximum at the end of elapsed time while Ammonia rapidly declines with elapsed time shown in Figure 2.

The outlet Sludge 1 flow and its properties are shown in Table 6.

There are insufficient changes of pollutants concentration at inlet stream, and TSS are the highest pollutant concentration shown in Figure 3. The decline of total suspended solid at stream 2 results in the settling efficiency by primary settlement tank and microbial consumptions in suspended solids and the total BOD increases from 420 to 660 mg/L on average, indicating that favorable conditions happen in the primary sedimentation tank for microbial development as shown in Figure 4.

There were high SS and BOD concentrations with little flow rates of sludge and there were no more biological reactions in this stage, the only denser materials settled down and collected the sludge at stream 3 are shown in Figure 1. Also, there were no more changes of ammonia and nitrate generation with elapsed time shown in Figure 5 for the case of absence of biological reaction there. And there were no more nitrification and denitrifications in stream 3.

The flow rate of the sludge was insignificant to indicate on graph due to small value while the graph used high scale values for measuring TSS and BOD in-stream as shown in Figure 5. The amount of BOD and Ammonia in this stream was similar to the influent stream and was constant with elapsed time, indicating that no microbial activities at less detention time in the primary settlement tank.

The outflow properties of sludge at stream 8 are shown in Table 7.

The TSS and BOD were the major sludge constituents in stream 8 as shown in Figure 1. The highly rising concentration of TSS and BOD results from conditions, the first was microbial developments and aeration processes in the activated sludge aeration tank, and the second was liquor thickening at the bottom of the secondary sedimentation tank.

The highest TSS and nitrate recovery in this little dynamic sludge flow rate with elapsed time is shown in Figure 6. The maximum total suspended solid in sludge was 6000 mg/L, which was specified or limited in the sludge zone.

Wastewater treatment simulation overall and stream mass balance

Having the conservations of mass, every component of pollutants in wastewater was balanced using automatic stream balance shown in Table 8. The overall balance shows the treatment efficiencies or removal efficiencies while the stream balances show or determine the operations and conversions.

As shown in Table 8, the material balances indicate 2.4 kg ammonia, 8.4 kg nitrate, and 624.48 kg suspended

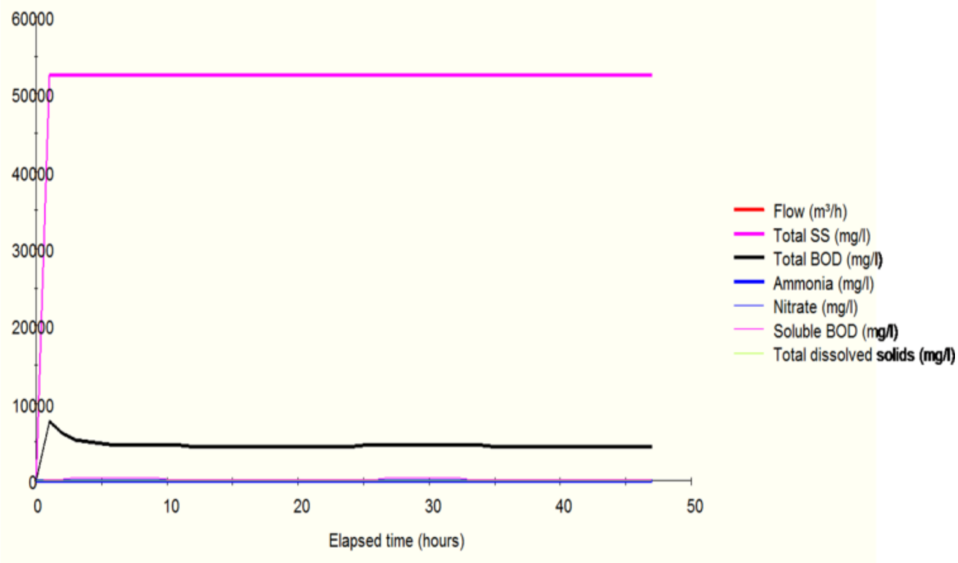

Figure 5. Sludge flow properties through the stream 3 with elapsed time.

Table 7. Outflow properties of sludge at stream 8

	Flow (m³/h)	Total SS (mg/L)	Total BOD (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Soluble BOD (mg/L)
Mean	4.9	5095.02	1123.29	20.24	68.56	2.61
Standard deviation	0.72	876.97	196.40	24.5	36.98	1.29
Total mass (kg)		1222.81	269.59	4.86	16.45	0.63
Peak load (g/s)		8.08	1.87	0.09	0.14	0.01

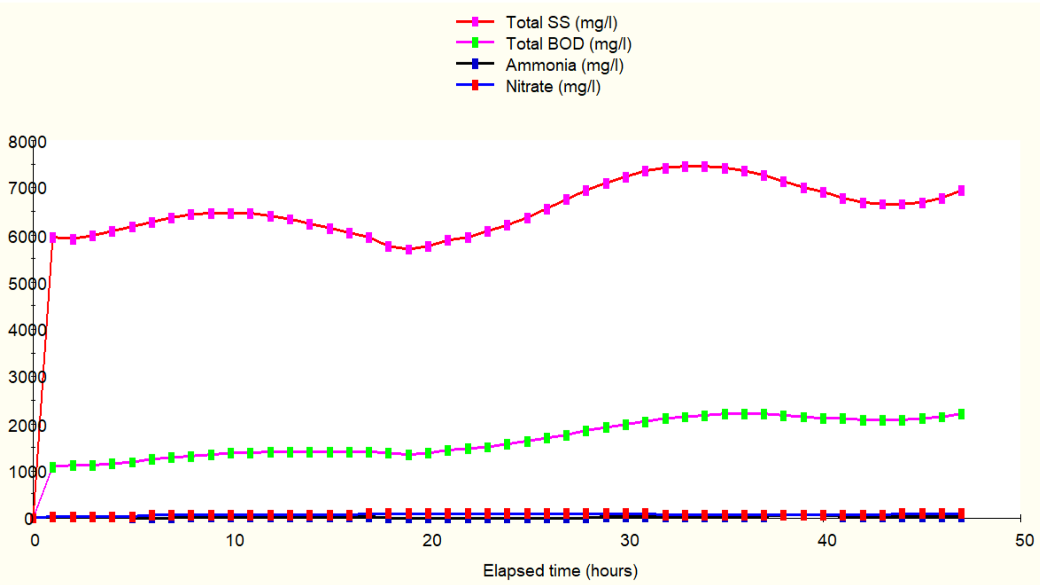

Figure 6. Sludge flow properties in stream 8 with elapsed time.

solids per day were generated through stream 8. Even the major component of sludge released from plant simulation design was organic SS, which is easily converted to plant organic nutritional contents. These sludge components are necessary for plant nutritional values; ammonia was converted into the nitrate by the nitrification reaction process.

$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 2H^+ + H_2O$

$2NO_2^- + O_2 \rightarrow 2NO_3^-$

The NO_3^- ion forms are the highest nutritional plans, which freely flow through soil and plant organs (20). It also represents an important economic inefficiency, because producers apply excessive amounts of fertilizer to compensate for the leaching (21).

Table 8. Overall mass balance on the treatment simulation design

Parameter	Stream 1	Stream 2	Stream 3	Stream 5	Stream 6	Stream 7	Stream 8
Av. flow (m^3/h)	49.96	48.56	1.4	128.56	43.56	80	5
Av. Temp (deg. C)	15	15	15	15	15	15	15
Av. BOD (mg/L)	483.83	377.85	4764	763.58	3.88	1147.19	1147.19
Av. COD (mg/L)	483.83	377.85	4764	763.58	3.88	1147.19	1147.19
Av. SS (mg/L)	2025.34	595.07	52500	3409.11	3.29	5203.43	5203.43
Av. NH_3 (mg/L)	73.14	73.48	78.78	8.44	28.77	20.67	20.67
Av. NO_3 (mg/L)	39.38	39.57	42.42	89.63	58.1	70.02	70.02
Av. TN (mg/L)	112.52	113.05	121.21	98.07	86.87	90.69	90.69
Av. BOD (kg/h)	24.17	18.35	6.67	98.17	0.17	91.78	5.74
Av. COD (kg/h)	24.17	18.35	6.67	98.17	0.17	91.78	5.74
Av. SS (kg/h)	101.19	28.9	73.48	438.29	0.14	416.27	26.02
Av. NH_3 (kg/h)	3.65	3.57	0.11	1.09	1.25	1.65	0.1
Av. NO_3 (kg/h)	1.97	1.92	0.06	11.52	2.53	5.6	0.35
Av. TN (kg/h)	5.62	5.49	0.17	12.61	3.78	7.26	0.45

Discussion

There are insufficient changes of pollutants concentration at inlet stream, and TSS are the highest pollutant concentration shown in Figure 3. The decline of total suspended solid at stream 2 results in the settling efficiency by primary settlement tank and microbial consumptions in suspended solids and the total BOD increases from 420 to 660 mg/L on average, indicating that favorable conditions happen in the primary sedimentation tank for microbial development as shown in Figure 4. There was a regular pollutant constituent with dynamic outflows and the nitrate was risen up exponentially with elapsed time and reach the maximum level at the end of elapsed time while ammonia rapidly declined with elapsed time as shown in Figure 2. TSS at effluent is the effective and the most efficient in the removal relative to preview articles (22). There were high SS and BOD concentrations with little flow rates of sludge and there were no more biological reactions in the primary settlement tank, the only denser materials settled down and collected the sludge at stream 3 as shown in Figure 1. Also, there were no more changes of Ammonia and nitrate generation with elapsed time shown in Figure 5 for the case of absence of biological reaction there, and there were no more nitrification and denitrifications in stream 3.

At secondary sedimentation tank, microbials were not functional to consume pollutants because of they loaded by TSS and BOD. Also, the amount of ammonia reduces from 65 to 20 mg/L while nitrate increases from 35 to 69 mg/L in outlet sludge as shown in Table 6. This sludge waste is recommended for fertilizer concern of nitrates rather than Ammonia concern fertilizers (23). The maximum total suspended solid in the sludge was 6000 mg/L, which was specified or limited in the sludge zone as shown in Figure 6. Table 9 shows that the overall removal efficiency of the textile wastewater treatment plant exceeds 99% and that the quality of the wastewater meets established quality standards. In other words, wastewater from the textile wastewater treatment plant meets the requirements and can be safely disposed of in the water body. Comparing this removal efficiency results with those of similar studies, it has better improved the removal efficiency of the textile industry (the tolerable efficiency of the new BOD is 99.1% from 90% and the TSS parameter of 99.75% from 96.12%) (1).

The pollutant parameters measured in the raw wastewater listed in Table 3 were completely removed by plant-designed model simulations at outlet stream 6. The wastewater treatment plant design simulation model was efficient for the selected pollutant parameter.

Conclusion

The aim of this study was to evaluate the removal efficiency and operating parameters of the textile wastewater treatment plant. The STOAT modeling of this study is very efficient in removing contaminants from textile wastewater by selecting specific parameters. The result of this sewage treatment plant is simulation model of wastewater and sludge recovery units. The effluent water to the environment pollutant containing was very lower pollutant parameter than the recommended EPA limits. The sludge recovery from the treatment plant simulation model was higher in nitrate than ammonia, which shows that Nitrification bacteria were major factionalized rather than denitrification bacteria in the

Table 9. Summary of parameter comparison of wastewater treatment plant (WWTP) model simulation efficiency

Parameter	Before (mg/L)	After (mg/L)	Efficiency (%)	EPA limits (mg/L)	References
TSS	1200	3	99.75	50	(1)
BOD	430	4	99.1	70	

BOD, biochemical oxygen demand; TSS, Total dissolved solids.

treatment unit operations. The recovered sludge was harmless to the environment and it was recommended for the agricultural area as fertilizer. Based on the water samples, BOD, TSS, and COD removal efficiencies were 99.1%, 99.75%, and 99%, respectively, and have met the effluent standards. When compared these removal efficiency results with those of similar studies, it has better improved the removal efficiency of the textile industry (the tolerable efficiency of the new BOD is 99.1% from 90% and the TSS parameter of 99.75% from 96.12%). Overall, STOAT software is a convenient and reliable tool for predicting and optimizing removal efficiency.

Acknowledgments

The study was conducted at Environmental Engineering Laboratory, Jimma Technology Institute, Jimma University. The authors would like to express their gratitude to all participants, directly or indirectly, in this research.

Ethical issues

The authors hereby certify that all data collected during the study are as stated in the manuscript, and no data from the study have been or will be published separately elsewhere.

Competing interests

The authors declare that there is no competing interests.

Authors' contributions

All authors have an equal share in the suggestion of the problem, design of experiments, data collection, model design simulation, and article approval.

References

1. Minhaj PGO, Adhiraga Pratama M, Adityosulindro S, Hartono DM. Modeling performance of industrial park wastewater treatment plant by STOAT software. E3S Web Conf. 2020;211:02018. doi: 10.1051/e3sconf/202021102018.
2. Tamilchelvan P, Muralimohan N. A case study on "assessment of groundwater quality in and around NAmakkal district in Tamil Nadu". Int Res J Multidiscip Tech. 2019;1(6):662-7. doi: 10.34256/irjmtcon94.
3. Musa J. Assessment of Occupational Injury and Associated Factors Among Workers of Ayka Addis Textile Factory in Sebeta, Oromia Region, Ethiopia: Institutional-Based Cross Sectional Survey [dissertation]. Addis Ababa, Ethiopia: Addis Ababa University; 2019.
4. da Silva Arrigo J, Balen E, Júnior UL, da Silva Mota J, Iwamoto RD, Barison A, et al. Anti-nociceptive, anti-hyperalgesic and anti-arthritic activity of amides and extract obtained from *Piper amalago* in rodents. J Ethnopharmacol. 2016;179:101-9. doi: 10.1016/j.jep.2015.12.046.
5. Yohannes H, Elias E. Contamination of rivers and water reservoirs in and around Addis Ababa city and actions to combat it. Environ Pollut Climate Change. 2017;1(2):116. doi: 10.4172/2753-458x.1000116.
6. Geng Y, Côté R. Diversity in industrial ecosystems. Int J Sustain Dev World Ecol. 2007;14(4):329-35. doi: 10.1080/13504500709469733.
7. Ogunlaja OO, Aemere O. Evaluating the efficiency of a textile wastewater treatment plant located in Oshodi, Lagos. Afr J Pure Appl Chem. 2009;3(9):189-96.
8. Tomei MC, Soria Pascual J, Mosca Angelucci D. Analysing performance of real textile wastewater bio-decolourization under different reaction environments. J Clean Prod. 2016;129:468-77. doi: 10.1016/j.jclepro.2016.04.028.
9. Tüfekci N, Sivri N, Toroz İ. Pollutants of textile industry wastewater and assessment of its discharge limits by water quality standards. Turk J Fish Aquat Sci. 2007;7(2):97-103.
10. Hassan HH, Mostafa ME. Improving the performance of SBR WWTP under the effect of organic shock load using STOAT software. Int J Environ Sci Nat Resour. 2019;20(2):68-74. doi: 10.19080/ijesnr.2019.20.556035.
11. Hassan HH, Ragheb AM. Modelling of an SBR WWTP to enhance the performance under hydraulic shock load using STOAT software. J Civil Eng Archit. 2019;13:704-14. doi: 10.17265/1934-7359/2019.11.005.
12. Issa HM. Optimization of wastewater treatment plant design using process dynamic simulation: a case study from Kurdistan, Iraq. ARO (Koya). 2019;7(1):59-66. doi: 10.14500/aro.10488.
13. Wang W, Shi C, Yang J, Zeng M, Dai Z, Zhang Z, editors. Modelling performance of oxidation ditch in wastewater treatment plant by STOAT software. IOP Conference Series: Earth and Environmental Science; 2019;300(3):doi:10.1088/1755-1315/300/3/032065.
14. Wang W, Shi C, Yang J, Zeng M, Dai Z, Zhang Z. Modelling performance of oxidation ditch in wastewater treatment plant by STOAT software. IOP Conf Ser Earth Environ Sci. 2019;300(3):032065. doi: 10.1088/1755-1315/300/3/032065.
15. Makinia J, Zaborowska E. Mathematical Modelling and Computer Simulation of Activated Sludge Systems. London: IWA Publishing; 2020. doi: 10.2166/9781780401683.
16. Pittoors E, Guo Y, Van Hulle SW. Modeling dissolved oxygen concentration for optimizing aeration systems and reducing oxygen consumption in activated sludge processes: a review. Chem Eng Commun. 2014;201(8):983-1002. doi: 10.1080/00986445.2014.883974.
17. Uby L. Next steps in clean water oxygen transfer testing - a critical review of current standards. Water Res. 2019;157:415-34. doi: 10.1016/j.watres.2019.03.063.
18. Wang X, Ratnaweera H, Holm JA, Olsbu V. Statistical monitoring and dynamic simulation of a wastewater treatment plant: a combined approach to achieve model predictive control. J Environ Manage. 2017;193:1-7. doi: 10.1016/j.jenvman.2017.01.079.
19. Nsenga Kumwimba M, Meng F. Roles of ammonia-oxidizing bacteria in improving metabolism and cometabolism of trace organic chemicals in biological wastewater treatment processes: a review. Sci Total Environ. 2019;659:419-41. doi: 10.1016/j.scitotenv.2018.12.236.
20. Wuana RA, Okieimen FE. Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation. ISRN Ecol. 2011;2011:402647. doi: 10.5402/2011/402647.
21. Singh B, Schulze DG. Soil minerals and plant nutrition. Nature Education Knowledge. 2015;6(1):1-10.
22. Wunderlin P, Mohn J, Joss A, Emmenegger L, Siegrist H. Mechanisms of N2O production in biological wastewater treatment under nitrifying and denitrifying conditions. Water Res. 2012;46(4):1027-37. doi: 10.1016/j.watres.2011.11.080.
23. Sebilo M, Mayer B, Nicolardot B, Pinay G, Mariotti A. Long-term fate of nitrate fertilizer in agricultural soils. Proc Natl Acad Sci U S A. 2013;110(45):18185-9. doi: 10.1073/pnas.1305372110.