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A Perspective Model for Waste Water Treatment Plant Using STOAT Software

Md. Toufikul Haque^{1*} and M G Toufik Ahmed²

¹Nuclear Safety, Security and Safeguards Division, Bangladesh Atomic Energy Regulatory Authority, Dhaka, Bangladesh

²Department of Chemical Engineering, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh

*Correspondence: toufikulhaquepranto@gmail.com (Md. Toufikul Haque, Nuclear Safety, Security and Safeguards Division, Bangladesh Atomic Energy Regulatory Authority, Dhaka, Bangladesh).

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Abstract

Wastewater Treatment Plant (WWTP) is essential to reducing environmental contamination because it treats wastewater to meet quality requirements prior releasing it into the ecosystem. Nevertheless, not every WWTPs have operated at their best, thus regular assessments are necessary to identify issues and suggest ways to enhance the standard of WWTP treatment. Petromax Refinery Ltd., that treats wastewater generated during the oil refining process, is the subject of this research. Assessment is conducted by utilizing STOAT technology to simulate the WWTP operation scenario, conditions and processes. This technology is largely applied for predicting the results and sizing of the operation unit for wastewater treatment plant. This study aims to estimate the effectiveness and the operating parameters of biochemical oxygen demand (BOD), ammonia and total suspended solids (TSS). The treated wastewater quality was calculated using model simulation with an expected period of 48 hours and effluent quality BOD, Ammonia and TSS was found less than 20 mg/L, less than 7 mg/L and less than 10 mg/L respectively which was subsequently compared with The Environment Conservation Rules, 1997 and plant outlet parameters and found to be quite satisfactory.

Keywords: Waste water, BOD, COD, TSS, Environment conservation rules, Sedimentation tank, Bar chamber.

1. Introduction

Humans, from cavemen to city residents, have long relied on water for a variety of activities, including drinking, bathing, feeding livestock, and irrigating crops. However, due to the scarcity of this resource, the population is putting the area's only viable source of life at risk. Only 2.5% of the planet's water is freshwater, despite the fact that water covers over 71% of its surface (Shiklomanov, 1991). Today, 1.6 billion people face water scarcity due to economic reasons, and two thirds of the global population faces water scarcity for at least 1 month each year (Mekonnen and Hoekstra, 2016). Recently, scientists

discovered that among the 37 of the world's greatest aquifers, 21 have reached the point where they can no longer maintain themselves (Richey *et al.*, 2015). Already dire water shortages are about to get worse. Water shortages might affect nearly 1.8 billion people in various parts of the world by 2025, according to a new report (WWAP, 2012; Ahmad *et al.*, 2018).

It is no secret that Bangladesh, one of the world's most populous countries, suffers from widespread water pollution and shortages. The quality of water is constantly uncertain, even though 97% of the people have access to it (Hasan *et al.*, 2019). More than 230

rivers flow through Bangladesh, which is a riparian country. In spite of this, human-caused pollution has obstructed these once-clean waterways (Majumder, 2009). The risk of arsenic pollution in groundwater is likewise quite high throughout the country. During the early decade of this century, between 35 and 77 million individuals were exposed to arsenic through their daily use of water from tubewells, which provide drinking water for 97% of rural residents (Flanagan *et al.*, 2012). Water, sanitation, and hygiene-related concerns account for 8.5 percent of all deaths in Bangladesh (Hasan *et al.*, 2019). As a facility, the Wastewater Treatment Plant (WWTP) is used to remove contaminants from wastewater in order to fulfill the appropriate regulatory criteria for quality. However, obtaining effluent quality that complies with requirements is a difficult task in and of itself. Poor removal efficiency can be caused by a variety of issues faced by WWTP operators, including inadequate hydraulic and mass loading design, mechanical equipment faults, and poor operation, maintenance, and troubleshooting (Gao *et al.*, 2016). In addition, the worsening of wastewater quality as a result of population increase and land use changes must be taken into account (Bhave *et al.*, 2020; Uddin *et al.*, 2025).

In general, small and medium-sized wastewater treatment plants rely on artificial experience to regulate the technical process; however, artificial experience does not always match the needs of water treatment process improvement, and experience judgment mistake can result in a reduction in the capacity of wastewater treatment plants. Toxic contamination and economic losses can be caused by the release of a significant number of wastewaters that do not meet requirements or cannot be recycled (Gao *et al.*, 2016; Sultana *et al.*, 2024). Consequently, the use of WWTP simulation software in Bangladesh's rapid growth is critical to its success.

The waste water treatment facilities may get real-time data via an online real-time monitoring system. The technology offered real-time data for simulation models that can assist waste water treatment facilities identify the best optimal operating conditions. If implemented, this technology will lower the amount of energy needed to run a full load WWTP, thereby ensuring that the WWTP's discharge will meet the National Standard (Gao *et al.*, 2016). Operators of

wastewater treatment plants (WWTPs) need to know how their plants respond to changes in wastewater quality and volume. Different computer applications can now model and predict WWTP behavior. Modeling free wastewater treatment systems using STOAT (Sewage Treatment Operations and Analysis over Time) is one example. STOAT allows users to build a wastewater treatment plant, define how each unit is linked and controlled, and forecast the facility's performance over time (Minhaj *et al.*, 2020).

This study aims to estimate the effectiveness and the operating parameters of Petromax refinery Ltd. WWTP through STOAT estimated operating parameters. This study was conducted at the Petromax refinery Ltd. WWTP located in the Mongla, Bangladesh. This WWTP was chosen as the case study considering its small capacity (up to 25 m³/hr). The development of a dynamic process model for a wastewater treatment facility is demonstrated using the following case study.

2. Methodology

Selection of software

EFOR, GPS-X, STOAT, WEST, Biowin, and others are now the most popular wastewater treatment plant simulation programs. It is commonplace in wealthy nations to apply all of these methods. These modeling programs, however, are not free of charge, which may be prohibitive for certain small wastewater treatment facilities. The tiny Liaoning provincial WWTP's current challenges can only be addressed through a realistic and cost-effective computer simulation (Gao *et al.*, 2016).

A simulation software based on BOD and ammonia is available in STOAT, and it has been utilized in many nations, including the United Kingdom, Europe, the United States, and the Middle East (Stokes *et al.*, 2000). The British PLC WRc firm made the STOAT free to use in 2010 in addition to helping the industry better comprehend and use the wastewater treatment model. A free copy of the STOAT simulation software is available for download from the PLC WRc business website for any firm or person to use. Liaoning wastewater treatment facilities will be happy to hear about this development. That way, the cost of purchasing modeling software and the issue of using pirated software aren't an issue for wastewater treatment facilities (Wang *et al.*, 2019).

Case study

Petromax Refinery Ltd (PRL) is a fractionation facility of Hydrocarbon to refine and produce different grades of gasoline. The Plant is situated at the embankment of Poshur River Mongla Industrial Area, Khulna. The facility consists of Condensate Fractionation Unit (CFU), Naphtha Hydro Treating Unit (NHTU) and a Catalytic Reforming Unit (CRU) and waste water treatment unit which treats waste water coming from different unit. Petromax refinery wastewater capacity of 400 m³/day, while its design capacity is 450 m³/day.

Sampling methods

In two-point, sampling was carried out, namely before the bar screen unit where raw wastewater was collected and after the tertiary treatment process

which was chlorination unit the final sample was collected. Two sampling point (**Fig. 1**) was chosen to compare the initial waste water inlet conditions with the treated waste water effluent conditions. The purpose of this to determine the WWTP unit processing effectiveness and quality of waste water after being processed. Sample was carried out on a compound base where the sample was carried out three times each, which was acclimated to the hydraulic retention time with the interval for each sample being 4 hours. As for the parameters to be tested in this sample were BOD, TSS and Ammonia. The average value of these three parameters of the samples was shown in **Table 1**.

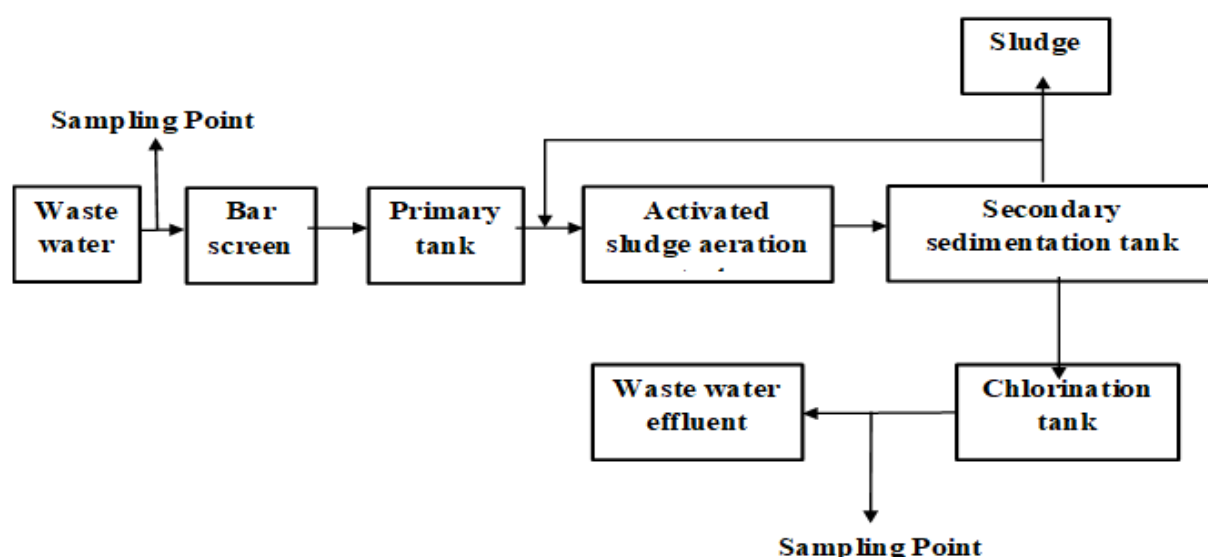


Fig. 1: Process flow diagram of Sampling Points.

Data analysis (Efficiency of removal)

The efficiency of removal was calculated for each parameter (BOD, TSS and ammonia) using the following formula,

$$\eta = \frac{C_i - C_e}{C_i} \times 100\%$$

Where η is the efficiency of removal, C_i is the wastewater inlet concentration (mg/L) and C_e is the wastewater outlet concentration (mg/L).

Modeling using STOAT software

Simulation in STOAT was conducted in order to determine which parameters have the most effects on the quality of the effluent of the wastewater produced in different unit and make long term predictions of the capability and efficiency of WWTP to treat

wastewater. The model was also used to make comparison with the mean value gathered from the wastewater discharge sampling point and to make prediction whether the wastewater treatment unit was effective or not in the long run.

3. Results and Discussion

Efficiency of Wastewater Treatment Unit

The overall efficiency of Wastewater Treatment unit of Petromax Refinery Ltd. is calculated and the quality of effluent had met the requirement and quality standards which means that it can be disposed of into water bodies. **Table 1** shows the wastewater treatment unit efficiency regarding three parameters namely BOD, TSS and ammonia.

Table 1: Efficiency of Wastewater Treatment Unit.

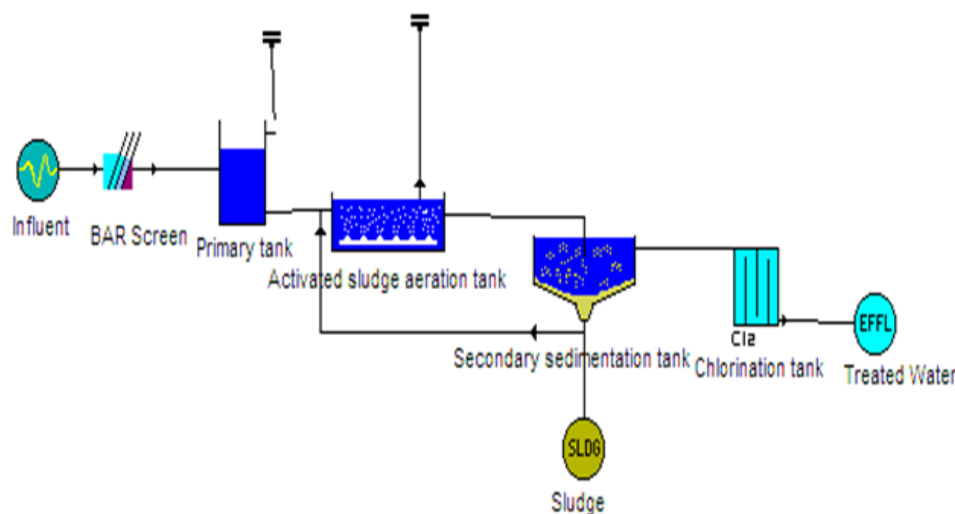
No.	Para-meter	Waste-water Inlet (mg/L)	Waste-water Outlet (mg/L)	Efficiency (%)
1	BOD	400	30	92.5
2	Ammonia	12	4	66.7
3	TSS	180	30	83.3

The overall efficiency of BOD and TSS is over 80% while the efficiency of ammonia is below 70%.

Capacity Variation

The inlet flow of wastewater had a huge fluctuation due to the fact that the plant had different production rates and deviation in factory activities. For this the

wastewater inlet flow fluctuated between 450 m³/day to 300 m³/day. Moreover, the wastewater quality also fluctuated. In this study the mean value is considered to determine the effluent wastewater quality using STOAT.

**Fig. 2:** Wastewater treatment model using STOAT.

Model selection

The model was prepared through STOAT (Fig. 2 and the units were adjusted comparing to the field). The main units used in the model were Bar screen, Primary tank, Activated sludge aeration tank,

Secondary sedimentation tank and Chlorination tank. The bar spacing in the bar chamber was considered 0.01 m, the volume of Primary tank was taken 100 m³, the volume of Activated sludge unit was taken 500 m³.

Table 2: Wastewater inlet flow Model in STOAT.

No	Parameter	Value	Source
1.	Flow	25 m ³ /hr	Sampling
2.	BOD	400 mg/L	Sampling
3.	Dissolve Oxygen	1 mg/L	Default of STOAT
4.	Ammonia	12 mg/L	Sampling
5.	TSS	180 mg/L	Sampling
6.	pH	6.5	Sampling

The Secondary sedimentation tank surface area was taken 25 m² while the depth of the tank was taken 5 m, number of vertical layer was taken 10 and depth of the feed was taken 4 m and finally the chlorination unit volume was taken 100 m³ where the chloride dosage

was considered 1 mg/L. Model was done using the advance model and the inlet flow of wastewater was considered the mean flow of wastewater 25 m³/hr and the average wastewater temperature was considered 28°C. The other parameters were shown in Table 2.

Table 3: Wastewater Outlet Flow Model in STOAT.

No.	Parameter	Value	Source
1	BOD	Less than 20 mg/L	STOAT
2	Ammonia	Less than 7 mg/L	STOAT
3	TSS	Less than 10 mg/L	STOAT

The default STOAT data was used for MLSS, Viable Autotroph, and Viable Heterotroph values due to the fact that there was no data regarding these matters. Using STOAT simulation of estimated time 48 hours

the treated wastewater quality was formulated (**Table 3**) which was later compared with The Environment Conservation Rules, 1997 (**Table 4**) (Standard, 1997).

Table 4: Wastewater Outlet Flow Comparison.

No.	Parameter	Sample of WWTP unit	STOAT Model	Standard Limit
1	BOD	30 mg/L	Less than 20 mg/L	50 mg/L
3	Ammonia	3 mg/L	Less than 7 mg/L	5 mg/L
3	TSS	30 mg/L	Less than 10 mg/L	150 mg/L

Using STOAT trends were generated for wastewater effluent for different parameters such as BOD, TSS and Ammonia with respect to elapsed time 48 hours. **Fig. 3** illustrates the combined STOAT simulation

trends of flow rate, total suspended solids (TSS), total biological oxygen demand (BOD) and ammonia concentration over 48 hours simulation period.

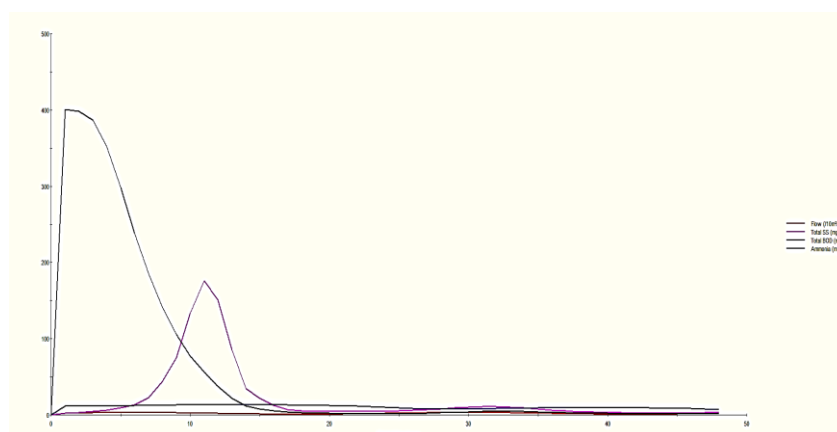
**Fig. 3:** STOAT simulation trend for Flow (/10m³/h), Total SS (mg/l), Total BOD (mg/l), Ammonia (mg/l).

Fig. 4 represents the simulated variation of influent flow rate with elapsed time and the flow pattern flows a cyclic fluctuation indicating varying hydraulic

loading conditions throughout the operation period that can significantly influence model performance and efficiency.

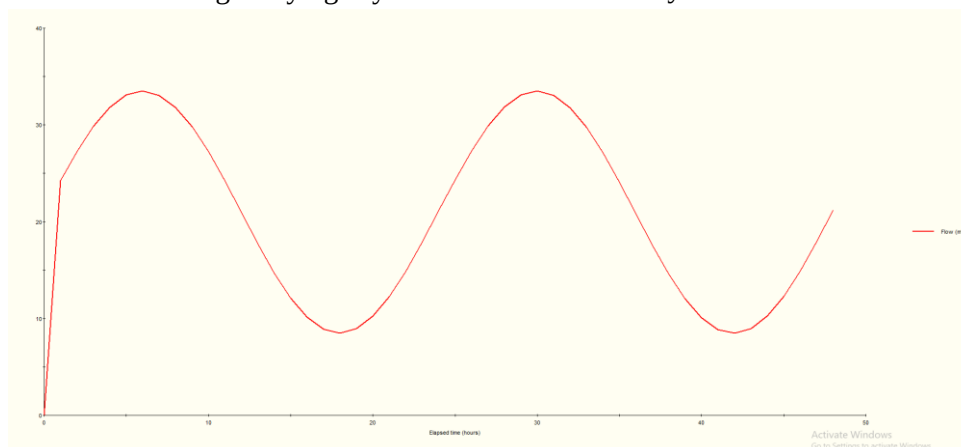
**Fig. 4:** STOAT simulation trend for Flow (m³/h).

Fig. 5 shows the simulated trend of TSS over time which shows sharp peak during the initial phase followed by a gradual decline, indicating sedi-

mentation and solids removal within the treatment process.

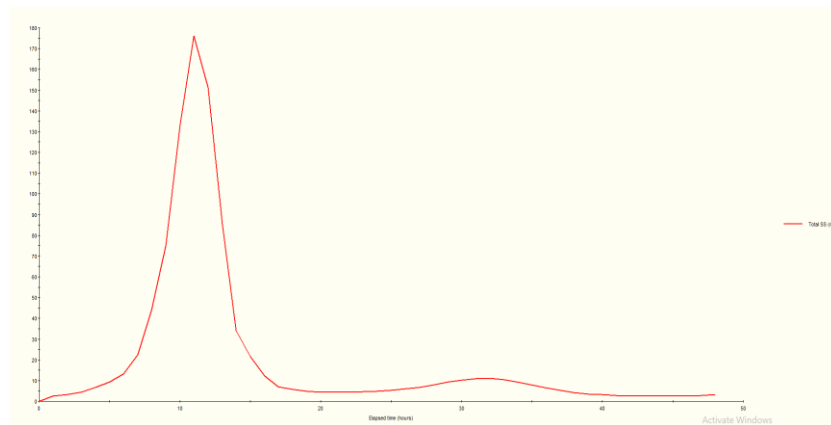


Fig. 5: STOAT simulation trend for Total SS (mg/l).

Fig. 6 illustrates the simulated trend of total BOD concentration over time. The initial BOD concentration is high, and then gradually and rapidly decreases. The decreasing trend shows the efficiency

of biological treatment methods for degradation of biodegradable organic matter from wastewater stream.

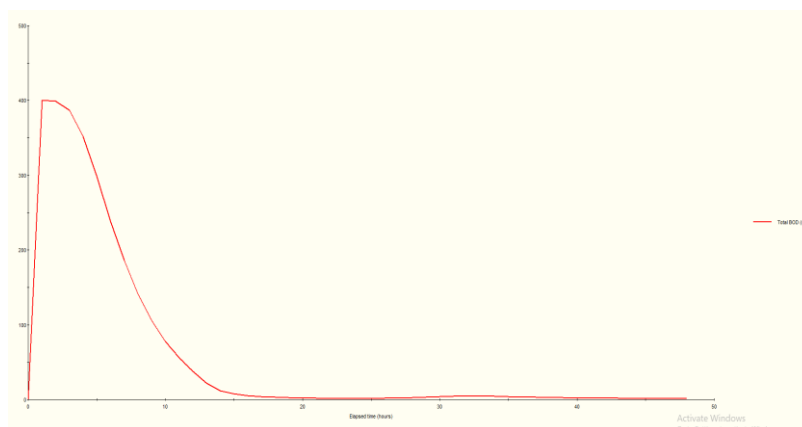


Fig. 6: STOAT simulation trend for Total BOD (mg/l).

Fig. 7 shows the trend of ammonia concentration in the treatment period simulated by the STOAT. The

ammonia concentration initially increases slightly and then decreases gradually with time.

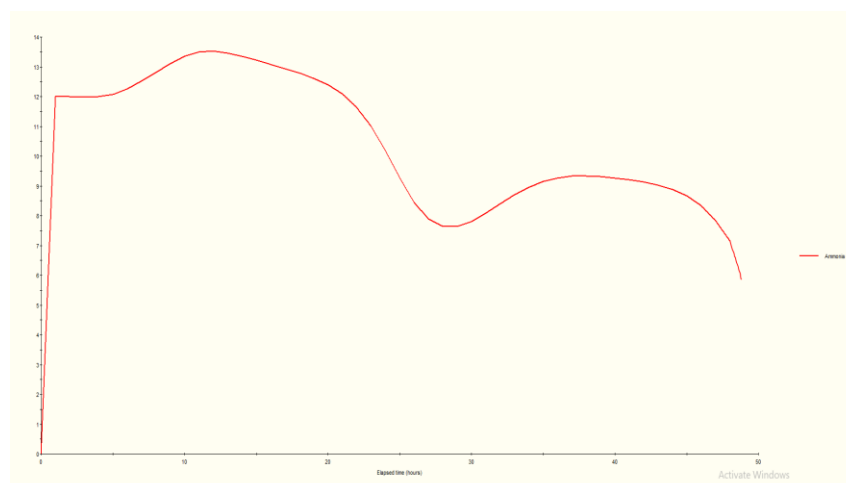


Fig. 7: STOAT simulation trend for Ammonia (mg/l).

In **Fig. 8**, the total BOD concentration in the secondary sedimentation tank is shown in the STOAT simulation profile in three dimensions as a function of elapsed time with eight operating stages. The initial BOD concentration is very high at the beginning of

the operation, and as time elapsed and stages increased the concentration of BOD decreases significantly. The decreasing concentration trend suggests the removal of biodegradable organic matter by the biological treatment processes is effective.

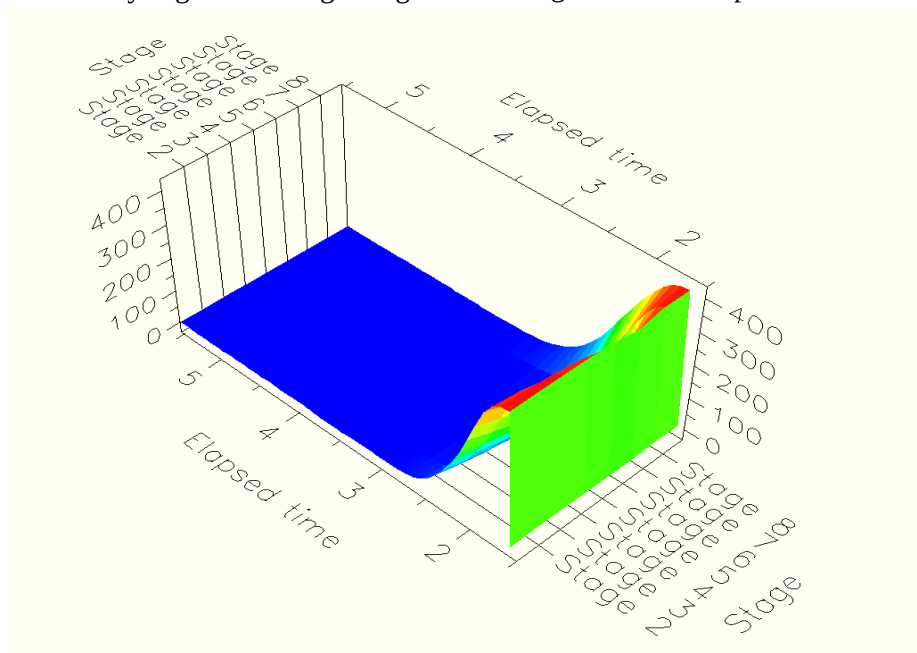


Fig. 8: STOAT simulation trend for Total BOD (mg/l) in Secondary sedimentation tank in 8 stages.

Fig. 9 demonstrates the STOAT simulated three-dimensional distribution of ammonia concentration in the secondary sedimentation tank over eight treatment stages with elapsed time. The ammonia

concentration exhibits moderate fluctuations during the initial stages followed by a gradual reduction as the treatment progresses and relatively stable ammonia profile observed in the later stages.

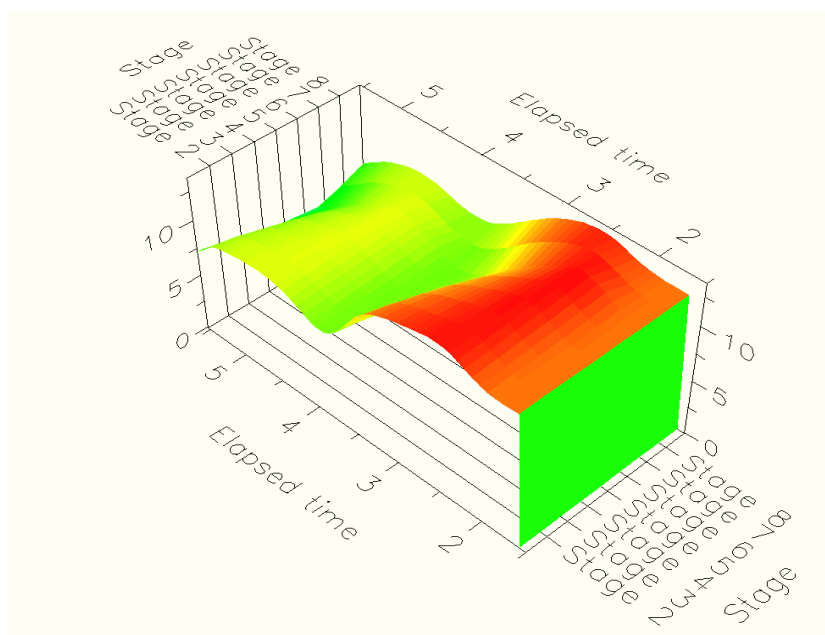


Fig. 9: STOAT simulation trend for Ammonia (mg/l) in Secondary sedimentation tank in 8 stages.

4. Conclusion

The performance of the wastewater treatment unit of Petromax Refinery Ltd. is assessed in this study.

STOAT simulation modeling and compared results to measured outlet data and regulatory standards. The comparison shows that the existing WWTP per-

formance is generally satisfactory with all the key parameters (biochemical oxygen demand, ammonia and total suspended solids) remaining within the limits prescribed by Environmental Conservation Rules (1997). STOAT model shows better treatment especially for removal of BOD and TSS. The simulated concentrations of BOD and TSS in the effluent are 20 and 10 mg/l respectively which are lower than the measured values at the plant outlet (30 mg/l for both parameters) and the regulatory limits. This suggests that optimized operational conditions can improve the treatment performance significantly. The plant outlet value for ammonia is below the standard limit (5 mg/l) but the ammonia model prediction (less than 7 mg/l) indicates there may be some variability under simulated conditions, removal of ammonia may require more careful operational control to consistently meet more stringent targets. In general, the STOAT-based simulation model has great potential as a decision support tool for performance and process optimization of wastewater treatment systems. The findings suggest that regular monitoring and evaluation in terms of models is needed for stable compliance and to find opportunities for operational improvement.

5. Author Contributions

M.T.H.: contributed to the conceptualization of the study, methodology development; M.G.T.A.: STOAT model design, overall review of the manuscript, data interpretation, literature review, manuscript writing, editing, validation of the model structure, technical review and revising of the manuscript and corresponding author responsibilities.

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7. Conflicts of Interest

The authors declare that there is no conflict of interest to publish it.

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