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Improving the Performance of SBR WWTP under the Effect of Organic Shock Load using Stoat Software

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Abstract

STOAT is a computer modelling tool designed to dynamically simulate the performance of WWTP. Modelling of integrated wastewater treatment plants (WWTP) using STOAT software proved to be extremely essential because it is time- and cost-effective. Furthermore, getting the overall picture for an entire system with relatively precise results, were quick responses for various scenarios are achieved. STOAT is used without any back-breaking tasks in contrast to laboratory experiments for predicting the effect of organic shock load. In this study, a model was built for a WWTP to predict organic sock load when doubled and how it would affect the plant. The results were extremely high and not acceptable when compared to the Egyptian environmental requirements. Therefore, another model was built to predict the exact percent of organic shock load that the plant can tolerate. The resulting data from the software proved the reliability of STOAT for modelling WWTPs. Consequently, improved effluent quality, reducing cost and the risk of consent failures.

Keywords: STOAT; WWTP; Organic shock load; Modelling; Sequence batch reactor; Simulations

Abbreviations: SBR: Sequence Batch Reactor; WWTP: Wastewater Treatment Plants; BOD: Biological Oxygen Demand; COD: Chemical Oxygen Demand; TSS: Total Suspended Solids; pH: Potential Hydrogen

Introduction

There is a substantial interest for using process models in wastewater treatment plant design. The process models are used to verify that the designed process or the effluents would meet the standard guidelines. Wastewater treatment plant (WWTP) models are used for improving the treatment process to solve treatment malfunctioning for plant robust operations [1]. Sequence batch reactors (SBR) systems can eradicate growth of most of the filamentous microorganisms, by controlling the operation of SBR cycle to overcome the hydraulic and organic shock load problems [2].

Due to the advantages of computer modelling of wastewater quality systems, it became a common tool used for WWTPs in eastern and central Europe [3]. Because of the flexibility of the designs and process control that can be attained by the modern technology, SBR process uses was never limited to the sewage treatment field only. However, it has been widely used in the field of biological treatment for the industrial wastewater, were organic chemicals exist and are difficult to treat. SBR processes are broadly known to be effectively automated, moreover, SBRs is known to save more than 60% of the operating expenses needed for a conventional activated sludge process also can attain high effluent quality in a very short aeration time [4]. Recently, modelling of WWTPs became an effective tool that proved countless positive effects on the performance of WWTPs, were modelling offers noticeable advantages when analysing the performance of treatment plants together with optimization and better control of the entire plant [5].

The organic pollutants biotransformation is carried out in the aeration tanks by using the biosensors effect existing at the aeration tank and the presence of the essential amount of dissolved oxygen in the water, pollutants are converted into a safe environmentally substance [6]. Extended aeration processes of SBR are frequently more efficient when handling organic loading and flow fluctuations, since there is higher detention time for the nutrients that are digested by microbes [7]. In order to model WWTPs, many modelling software are used to enhance the plants performance such as Sewage treatment operational analysis over time (STOAT). STOAT is a computer-based program designed to simulate the performance of WWTP. The software proved to be a helpful tool when studying the performance of WWTPs [8]. In this study, we prove the substantial importance of modelling WWTPs and how it can predict and analyze the amount of sewage outflowing from the plant. This was done by testing increased amount of the organic shock load and comparing the data to the effluent data disposed at the facility

Materials and Methods

In this paper Hannoville WWTP in Alexandria, Egypt is used as a case study. SBR is the treatment process used at the Hannoville WWTP. The plant consists of three main unites; each one is not like the other neither in volume nor in dimension.

In this study, exclusively five parameters were considered at each unite in the Hannoville WWTP. These five parameters are biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), oxygen demand (DO) and potential hydrogen (pH). Each parameter has an enormous effect on improving the entire WWTP's performance. A model was built by STOAT software using activated sludge model 1 (ASM1) [9] were each unite was separately studied due to the construction variations.

Organic shock load was applied to the Hannoville WWTP predicting the acceptable shock load for the entire WWTP by doubling the influent organic load, data were compared to the Egyptian standard specifications of law 4 in 1994 for discharge in coastal environment Table 1. Three parameters were obtained which are peak load, total mass and standard deviation generated as a default from STOAT software.

Results and Discussion

Criteria and specifications

The validation of STOAT software was done by building a model for the first unite "ABJ" and influent inputs used for the model was from monthly experimental data at the Hannoville WWTP that were collected for a year [11].

Firstly, the Hannoville WWTP was studied before applying organic shock load, then the organic shock load was doubled to predict the plant performance under such circumstances. The resulting data was too high when compared to the Egyptian environmental requirements (shown in Table 1). Thus, various influent organic shock load was simulated using STOAT until a satisfactory shock load was reached.

Table 1: Criteria and specifications for certain substances when discharged into the marine environment according to the Egyptian environmental requirements [10].

Item	Maximum Limits of Criteria and Specifications (mg/l -Unless Otherwise Indicated)
Temperature	10 ºC > average Temperature of receiving body
pH	6-9
COD (Chemical Oxygen Demand)	100
BOD (Biological Oxygen Demand)	60
TSS (Total Suspended Solids)	60

According to the Egyptian specifications of law No. 48 of 1982 regarding the protection of the Nile river and its administrative regulations, the substance discharged from the Hannoville WWTP shall never exceed the effluent level, indicated in Table 1, for each parameter, predicted in this study. Impotently, the environmental impact on sewage effluent disposal depends on the treatment level and flow rate [12].

STOAT software results for evaluating the performance of Hannoville WWTP under organic shock load

Table 2: Design parameters of the biological treatment technology at the Hannoville wastewater treatment plant [11].

		ABJ Units	Biogest Units	Extension
Average Influents Flow Rate (m^3/day)		10,000	10,000	30,000
Number of SBR unites		2	5	4
Dimensions	V(m^3)	4,167	2,420	8,333
	A(m^2)	970	484	1,852
	Depth(m)	4.3	5	4.5
Cycle period(min)	Total	360	570	480
	Fill	90	140	120
	Aeration	135	220	180
	Settle	60	90	90
	Decant	60	90	60
	Wastage	15	30	30
Decant flow rate (m^3/cycle)		1,200	750	
Wastage sludge flow rate (m^3/cycle)		50	25	100

Wastewater treatment values was taken by STOAT software to observe the performance of the entire plant under organic shock load which is classified into 3 main unites: First unite (ABJ), second unite (Biogest) and third unite (ABJ-extension), also, studying the Parameters used for the performance evaluation which was TSS, BOD, COD, DO and pH for each unite.

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A model was built for the entire WWTP were each unite was applied with double the organic shock load that it usually accepts, the results exceeded the Egyptian environmental requirements. Consequently, more simulations were made till each unite reached the acceptable organic shock load. All data were compared when applying shock load and before applying any shock load to the plant. Design parameters, used as an input for STOAT software, of the Hannoville WWTP are shown in Table 2.

Since the results when doubling the organic shock load were too high when compared to the Egyptian environmental requirements, then another model was built showing the effluent data obtained when acceptable organic shock load was reached were it was 30% higher than before applying the organic load.

All effluent data for ABJ unite before applying organic shock load, after applying 2x and 1.3x organic shock load using STOAT software (as shown in Figure 1).

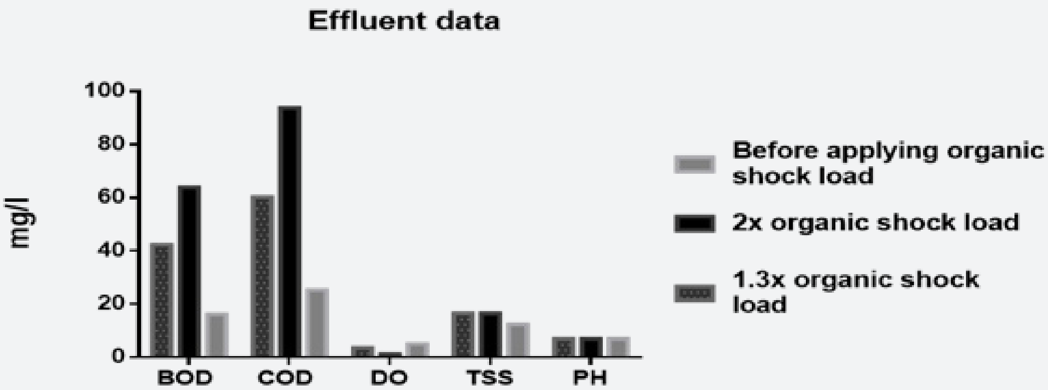

Figure 1: shows effluent data for ABJ unite before applying organic shock load, after applying 2x and 1.3x organic shock load using STOAT software.

BOD effluent values before any organic shock load was applied ranged between 16.03mg/l & 16.05mg/l were after doubling the load it ranged between 59.56mg/l & 70.88mg/l, since the effluent data after 2x shock load was too high and not acceptable when compared to the Egyptian environmental requirements (as shown in Table 1). Thus, simulations were made for the unite till the acceptable effluent data was predicted with 1.3x organic shock load. The effluent data ranged from 40.11mg/l to 43.98mg/l which is adequate to the Egyptian environmental requirements (as shown in Table 1). Mean values were 63.93mg/l for 2x shock load while after decreasing the load to 1.3x it became 42.33 mg/l. Additionally, total mass was 1345.137kg for 2x shock load while it decreased to 1004.904kg in case of 1.3x shock load. The peak load was 1.88g/s and for 1.3x load it became 1.02g/s. The percentages of removal for BOD proved higher efficiency when organic shock load was applied with 1.3x (shown in Figure 2).

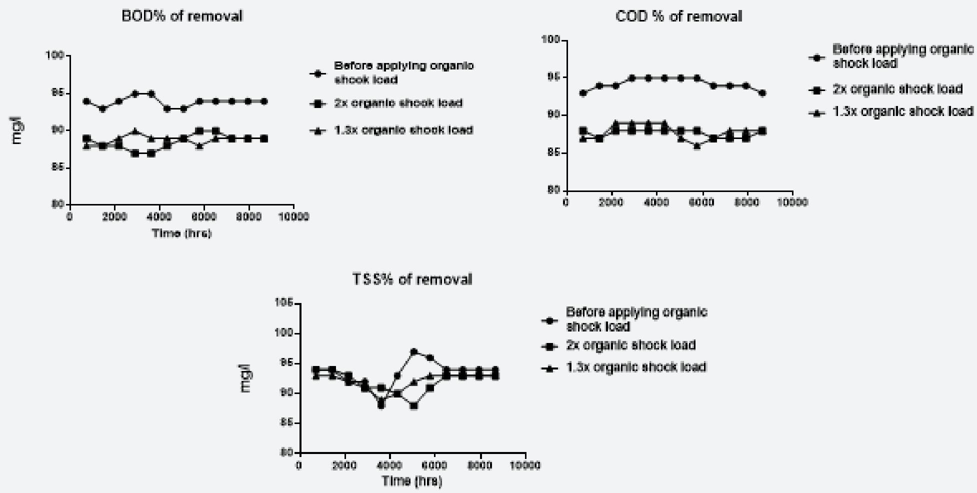

Figure 2: Shows BOD, COD and TSS removal percentages for first unite (ABJ) before applying organic shock load, after applying 2x and 1.3x organic shock load using STOAT software.

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COD effluent values before any shock load was applied in a range between 23.09mg/l to 26.68mg/l were after the shock load was doubled, it ranged from 92.01mg/l to 97.35mg/l, and after applying 1.3x shock load it became 58.45mg/l to 61.78mg/l. Mean values for COD in case of 2x load was 93.86mg/l and turned out to be 60.17mg/l under 1.3x organic load. Compared to the Egyptian environmental requirements (shown in Table 1) it was convenient. Meanwhile, total mass was 2154.48kg for 2x shock load and after decreasing the load to 1.3x it became 2053.551kg. peak load was 2.01g/s and after 1.3x shock load was 1.57g/s. also COD removal percentages were acceptable when compared to the Egyptian environmental requirements in case of applying 1.3 organic shock load to the ABJ unite shown in Figure 2.

DO effluent data ranged from 3.26mg/l to 6.42mg/l before any shock load was applied and after applying 2x shock load it ranged from 0.97mg/l to 1.22mg/l, which was higher. After decreasing the load to 1.3x it ranged from 2.16mg/l to 4.98mg/l. The increase in oxygen demand is very beneficial.

TSS effluent data before applying any shock load was from 9.48 to 19.08mg/l and after applying 2x shock load ranged from 15.11 to 18.32mg/l, the change is insignificant, however, convenient. After applying 1.3x shock load data ranged from 15.03 to 17.87mg/l. The effluent TSS values was slightly changed and acceptable in all cases when compared to Egyptian environmental requirements (as shown in Table 1). TSS removal percentages were almost the same in all the previous discussed cases applied to the ABJ plant and all were acceptable (as shown in Figure 1).

pH values were almost identical in all cases and acceptable when compared to Egyptian environmental requirements Table 1.

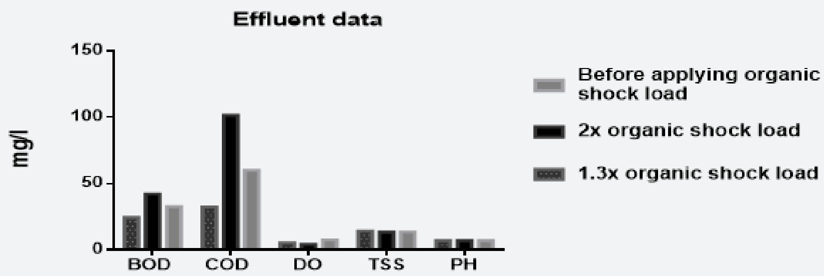

Figure 3: shows effluent data for Biogest unite before applying organic shock load, after applying 2x and 1.3x organic shock load using STOAT software.

The effluent data resulting from the BIOGEST unite before applying organic shock load, after applying 2x and 1.3x organic shock load using STOAT software (As shown in Figure 3).

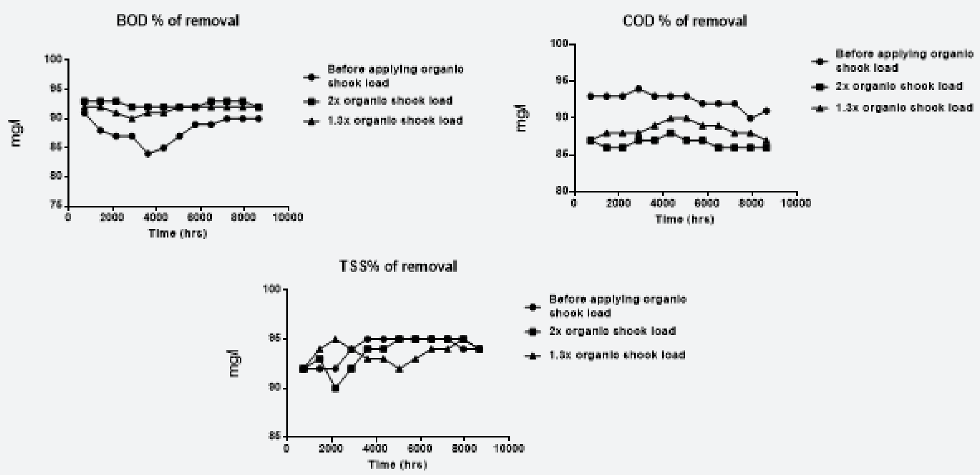

Figure 4: Shows BOD, COD and TSS removal percentages for first unite (Biogest unite) before applying organic shock load and after applying 2x and 1.3x organic shock load using STOAT software.

BOD effluent values before any organic shock load was applied it ranged between 23.08mg/l & 25.71mg/l were after doubling the load it ranged between 40.08mg/l & 44.85mg/l. Those effluent results were high as in the ABJ unite. After 1.3x shock load was applied, effluent values ranged from 31.78mg/l to 33.56mg/l which are acceptable when compared to the Egyptian

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environmental requirements (as shown in Table 1). Mean values were 42.21 mg/l for 2x shock load, while after decreasing the load to 1.3x it became 32.59mg/l. Additionally, total mass was 8060.29 kg for 2x shock load while it decreased to 1418.66kg in case of 1.3x shock load, which is acceptable. Peak load was 10.261g/s, nevertheless, for 1.3x load it became 2.98g/s. Removal percentages (as shown in Figure 4) were acceptable in case of 1.3x organic shock load.

COD effluent values before any shock load was within 30.17mg/l to 33.82mg/l were after the shock load was doubled it became from 100.37mg/l to 102.76mg/l. As previously shown at the first unite, effluent values were not acceptable. After applying 1.3x shock load it became 58.34mg/l to 60.78mg/l. Mean values for COD in case of 2x load was 101.35mg/l and turned out to be 59.83mg/l under 1.3x organic load which is within the acceptable limit. Total mass was 8060.29kg for 2x shock load and after decreasing the load to 1.3x it became 3808.62kg. Furthermore, peak load was 10.26g/s and after 1.3x shock load was 4.95g/s. As shown in Figure 4, percentages of removal were acceptable when 1.3x organic shock load was applied.

DO effluent data ranged from 4.05mg/l to 6.83mg/l before any shock load was applied and after applying 2x shock load it was within the range 3.14mg/l to 4.88mg/l, Meanwhile, when decreasing the load to 1.3x it ranged from 6.84mg/l to 8.09mg/l. The results are convenient in case of 1.3x organic shock load.

TSS effluent data before applying any shock load was from 12.58 to 15.78mg/l and after applying 2x shock load it ranged from 12.11 to 14.74mg/l. After applying 1.3x shock load data ranged from 12.34 to 14.34mg/l. the effluent. TSS values was slightly changed and acceptable in all cases when compared to Egyptian environmental requirements (as shown in Table 1). Removal percentage (shown in Figure 4) of TSS did not differ significantly in all cases.

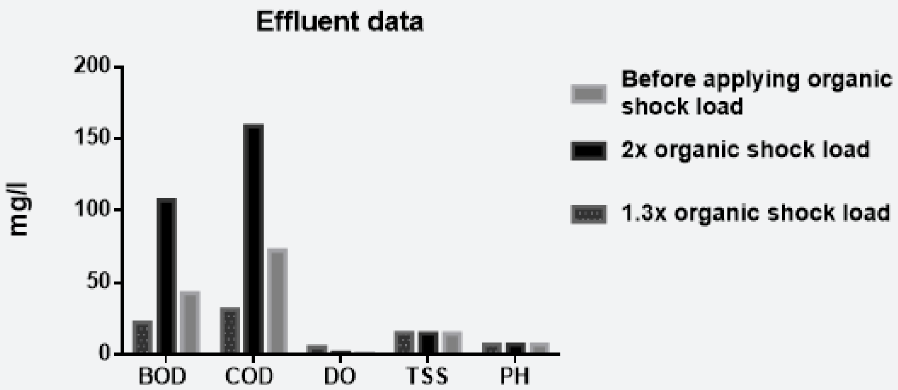

Figure 5: shows effluent data for ABJ extension unite before applying organic shock load, after applying 2x and 1.3x organic shock load using STOAT software.

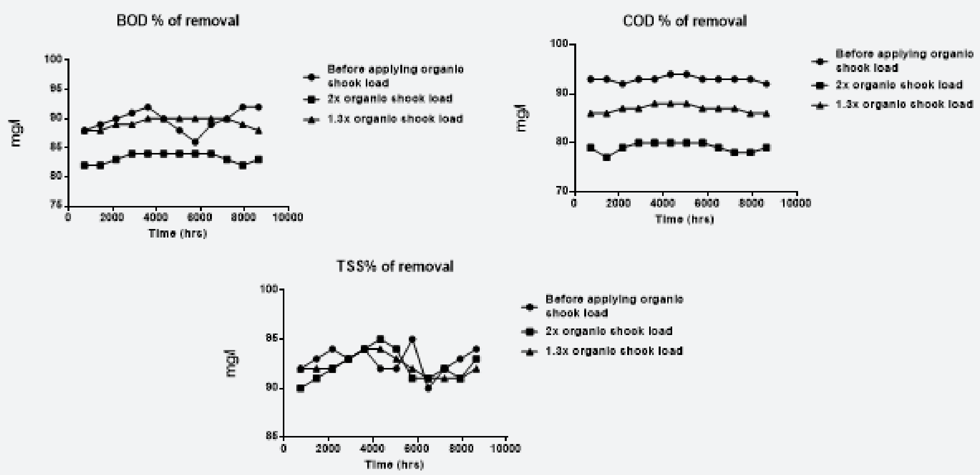

Figure 6: Shows BOD, COD and TSS removal percentages for first unite (ABJ extension unite) before applying organic shock load, after applying 2x and 1.3x organic shock load using STOAT software.

At the ABJ extension unite, all effluent data are shown (Figure 5) before applying organic shock load, after applying 2x and 1.3x organic shock load using STOAT software. BOD effluent values before any organic shock load was applied

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ranging between 20.69mg/l & 24.2mg/l. On the other hand, after doubling the load, the effluent ranged between 103.49mg/l & 110.79mg/l. Further simulations were done till the acceptable range was reached. After 1.3x shock load was applied, effluent values ranged from 41.29mg/l to 43.9mg/l which are acceptable to the Egyptian environmental requirements (as shown in Table 1). Mean values were 107.28mg/l for 2x shock load while after decreasing the load to 1.3x it became 42.73mg/l, additionally, total mass was 21991.6kg for 2x shock load while it decreased to 12310.7kg in case of 1.3x shock load. Peak load was 28.64g/s and for 1.3x load it became 20.41g/s. BOD removal percentages were acceptable in case of 1.3x organic shock load (shown in Figure 6).

COD effluent values were between 30.04mg/l to 32.76mg/l before any shock load was applied. In addition, when the shock load was doubled, it ranged from 154.28mg/l to 162.31mg/l, while, after applying 1.3x shock load it became 71.43mg/l to 73.81mg/l. These results were found to be in the acceptable range when compared to the Egyptian environmental requirements (shown in Table 1). Mean values for COD in case of 2x load was 158.72mg/l and turned out to be 72.44mg/l under 1.3x organic load. Total mass was 35179.2kg for 2x shock load and after decreasing the load to 1.3x it became 2324.5kg. Peak load was 31.97g/s and after 1.3x shock load it became 23.97 g/s. Removal percentages for COD (shown in Figure 6) was acceptable in case of applying 1.3x organic shock load.

DO effluent data ranged from 4.19mg/l to 6.73mg/l before any shock load was applied and after applying 2x shock load it ranged from 1.12mg/l to 1.9mg/l. However, when decreasing the load to 1.3x it ranged from 0.02mg/l to 1.11mg/l. As a result, the increase in oxygen demand is not significant, but acceptable, due to the good extended aeration system.

TSS effluent data before applying any shock load was from 13.12 to 16.65mg/l and after applying 2x shock load it was from 13.15 to 15.91mg/l. Subsequently, applying 1.3x shock load data ranged from 13.61 to 15.91mg/l, which is insignificant. Percentages of TSS removal were almost the same in all three cases (shown in Figure 6) and the results were all satisfactory according to the Egyptian environmental requirements.

Conclusion

STOAT software proved to be an advantageous tool when studying the performance of wastewater treatment plants. The significant impact shown by STOAT software in the field of wastewater treatment, facilitated the evaluation of Hannoville WWTPs and improving its performance.

In the presented study, WWTP was tested if it was adequate to receive 200% of the organic shock load that it typically receives. The effluent results exceeded the normal loading ranges when compared to the Egyptian environmental requirements. Consequently, further simulations were done till the acceptable organic load which was 130% of the typical organic loading. This case study shows the efficiency of modelling programs in the field of WWTP and how much it can solve problems that may occur in the long-term future for the entire SBR plant. The modelling will improve effluent quality, reduce cost and the risk of consent failures. This study elucidated the significant effect of modelling on the wastewater treatment environment and how it can predict such vital outcome in the long-term future with the least efforts and almost no cost.

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