Kinetic modeling of downflow hanging sponge (DHS) system treating synthetic domestic wastewater

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Background

- Domestic wastewater (DWW) is widely produced by daily tasks including bathing, cleaning one's hands, house, and car, washing clothes and kitchenware, and defecating and micturition.
- DWW has a small number of different organisms and millions of intestinal bacteria, which provide additional risks to the population.
- Hence, DWW cleansing is essential for ensuring the longevity of water bodies and aquatic life. [1].
- Selecting effective wastewater treatments is crucial, particularly in undeveloped nations with limited resources, little experience, and a lack of skilled staff [2].
- DHS technology has advanced the development of wastewater resource recovery technologies over the past 20 years, suggesting that it is now a practical solution for easing sewage issues in developing countries [3].
- Also, this reactor is easy to use, has low treatment costs, and discharges a small quantity of sludge [4].

Background

- The amount of time needed for wastewater to pass through the DHS reactor is known as the hydraulic retention time (HRT).
- Wastewater is essential to remain in the reactor to interact with the bacteria that adhere to the sponge medium.
- The efficiency of organic removal increases with the amount of time wastewater is in contact with bacteria in the reactor.
- The change in hydraulic retention times on the efficiency and stability of the DHS unit was studied. They were designed to simulate the temporary changes in the rate of domestic wastewater flow, which occurs often in actual operations.
- Environmental engineers are presently using kinetic models to help with the design and optimization of wastewater treatment systems.
- The removal of COD and nitrogen in many reactors has been studied using a variety of kinetic models. Grau second-order, Monod, Stover–Kincannon, and First-order were widely used to calculate the substrate removal rate [11]–[12].

Research Objectives and Outcomes

- **Main objective**

➢ Performance assessment and kinetic modeling of a DHS system treating synthetic domestic wastewater

➢ **Specific objectives**

1. Evaluation of the performance of the DHS system for treating synthetic domestic wastewater.
2. Moreover, experiments were done to see how HRT and F/M ratio affected the removal of carbon and ammonium.
3. Evaluating kinetic models (modified Stover-Kincannon, Monod, Grau second-order, and first-order models) for domestic wastewater treatment using the DHS system.
4. Comparison between kinetic coefficients from this study with previous studies.
5. Predicting the final effluent of COD concentration using kinetic models.

Down-flow hanging sponge reactor (Fig. 1

- Fig. 1. Configuration of the DHS unit utilized to treat SDW.

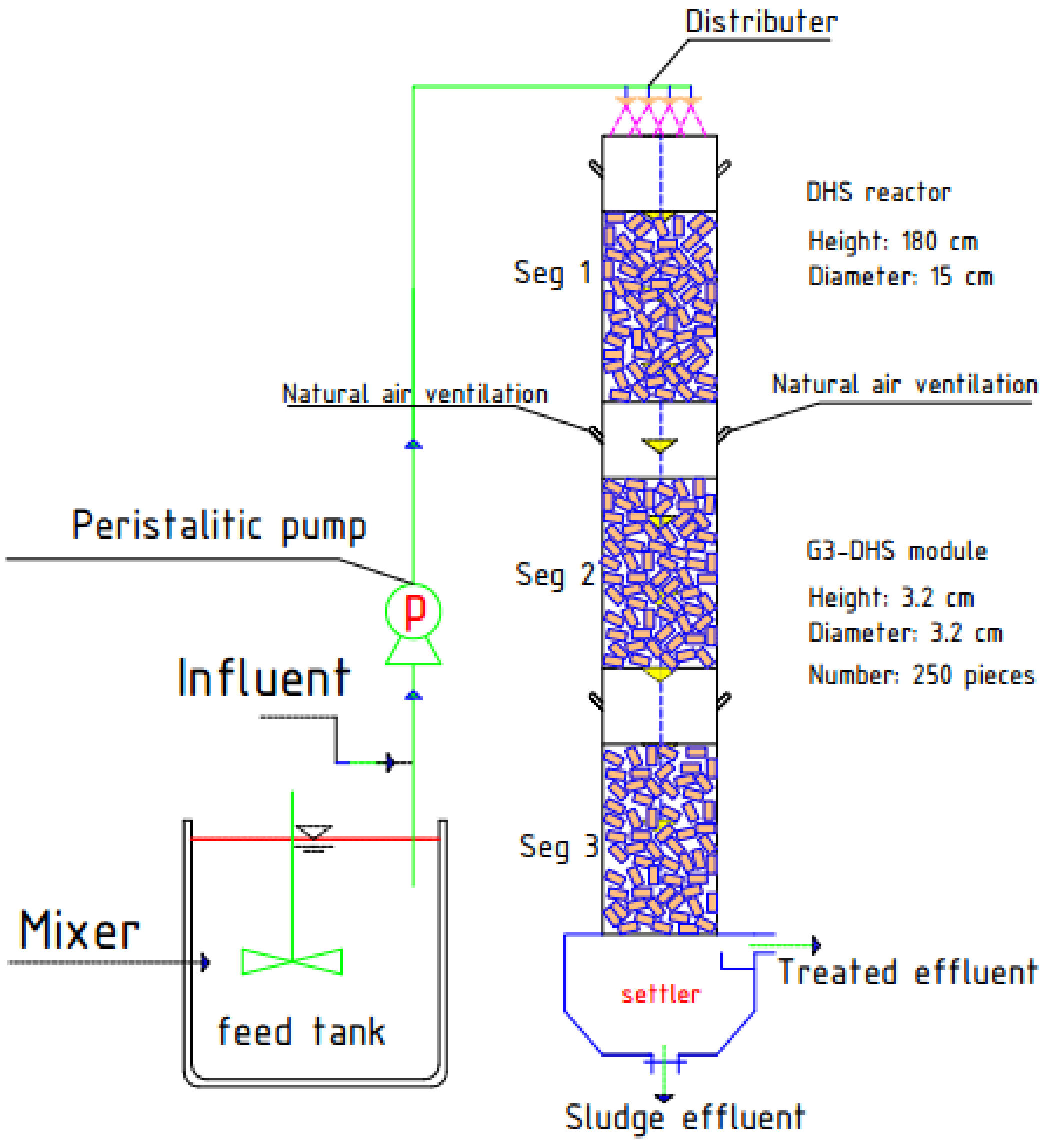


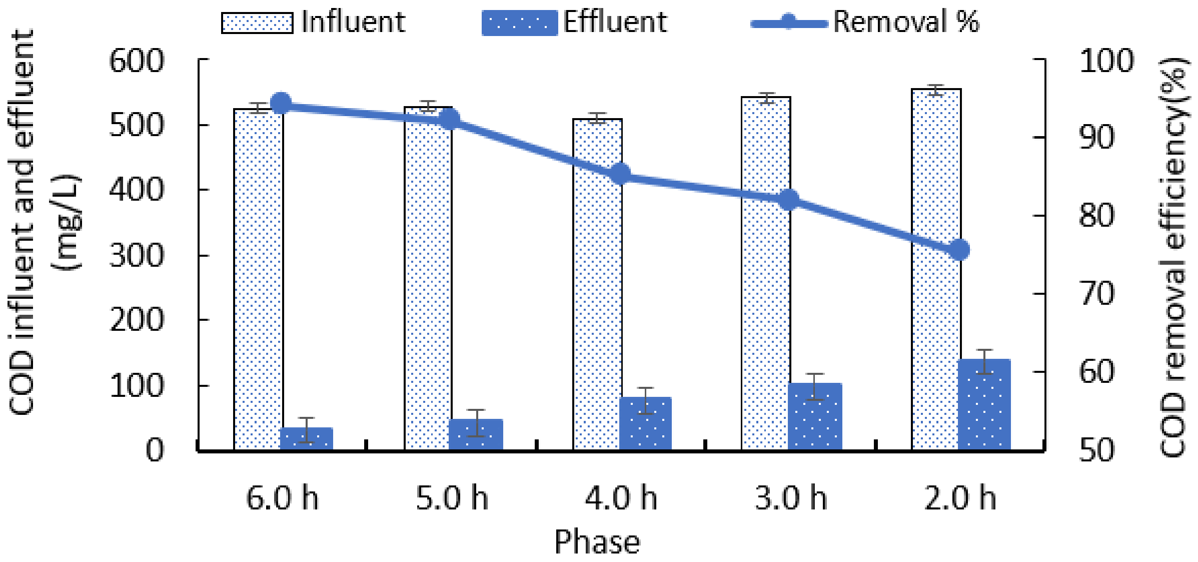
Table 1. Wastewater characteristics and Operational conditions.

Parameter	COD	NH_3	PH	TSS	Conductivity
Unit	mg/L	mg/L		mg/L	(µS)
Value	531.62±93.6	66.22±3.47	7.12±0.82	102.26±13.12	1316.18±40

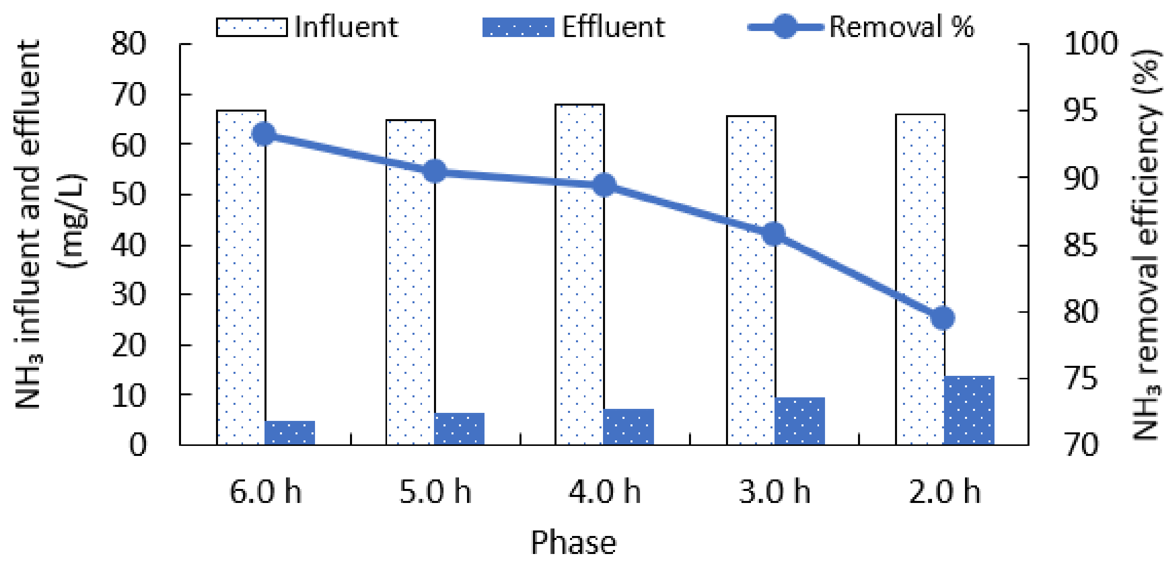
Parameters	(Unit)	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
HRT	(h)	6.0	5.0	4.0	3.0	2.0
Flow rate (Q)	(L/d)	20.4	24.5	30.6	40.8	61.2
HLR	($m^3/d/m^2$)	1.15	1.39	1.73	2.31	3.46
SRT	(d)	151.96	86.74	70.33	60.91	52.03
F/M ratio	(Kg COD/kg VS d)	0.12	0.14	0.15	0.20	0.28
temperature	º C			25-32		

Results and discussion

Figure 2. Effect of changing HRT on DHS performance for (a) COD removal (b) NH3 removal; (c) TSS removal.



a



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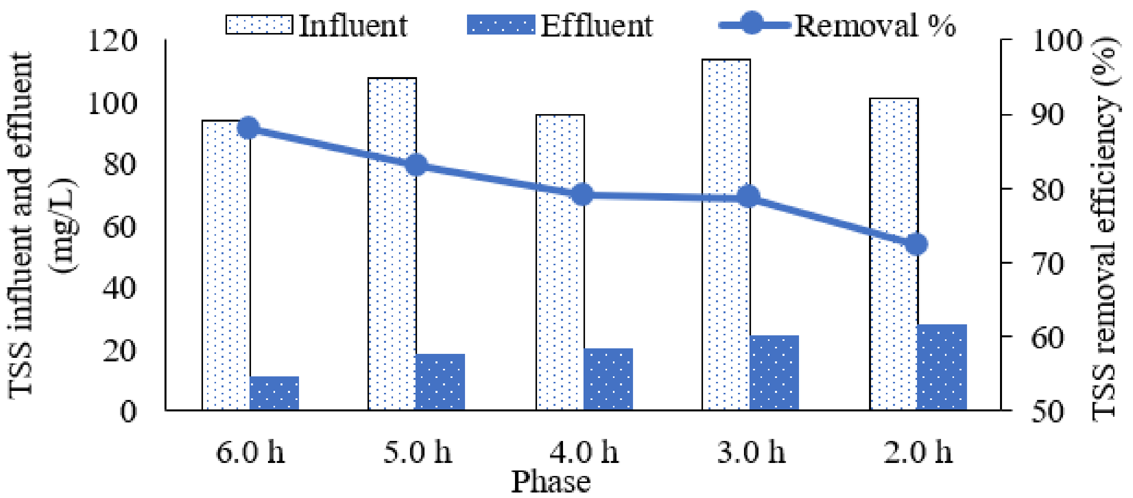


c

Kinetic Models for COD Removal

$$S_e = \frac{0.085(1 + 0.0025 \times \text{SRT})}{(0.0339)\text{SRT} - 1}$$

Monod model

Y = 0.1337 g VSS/g COD and k_d =0.0025 1/d, μ_{max} 0.036 1/d and K_S and 0.085 g COD/L

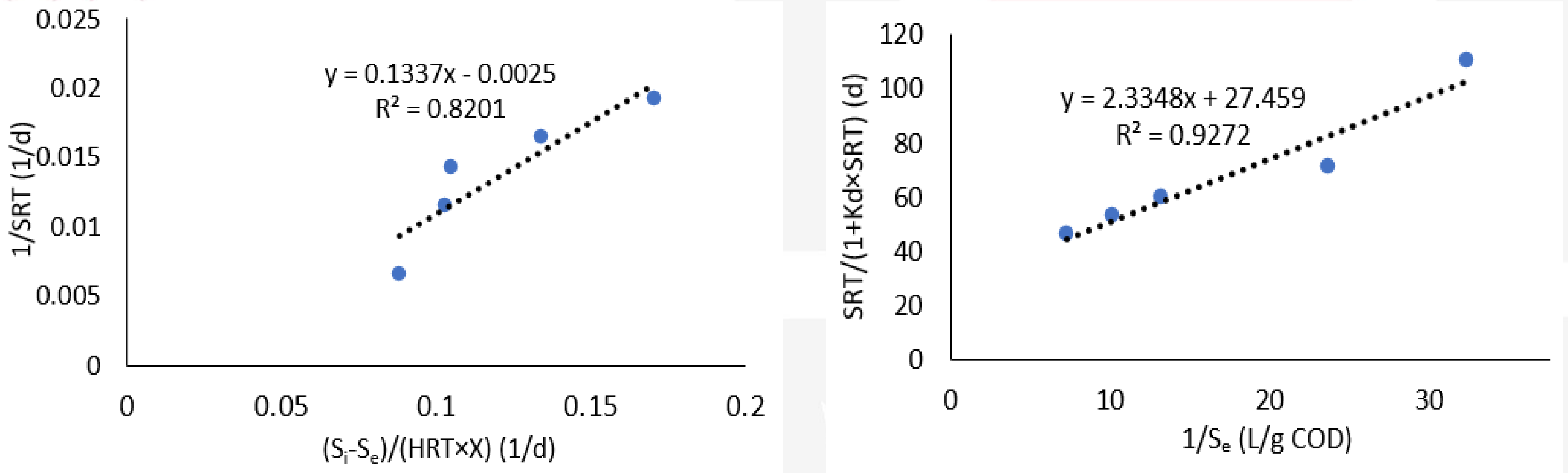
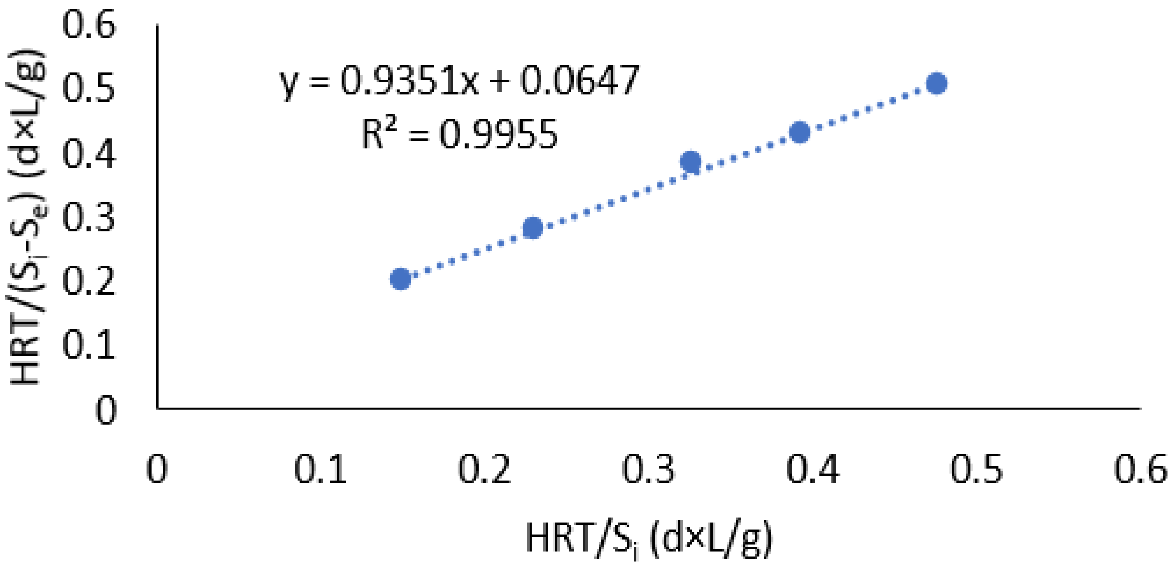


Figure 3. Determine the kinetic constants using a linear plot of the Monod model: (**a**) k_d and Y; (**b**) μ_{max} and K_s.

Modified Stover-Kincannon model

$$S_e = S_i - \frac{15.46 S_i}{14.45 + \frac{S_i}{HRT}}$$

(K_B) = 14.45 g/L/d and U_{max} are 15.46



Grau second-order model

$$S_e = S_i \left(1 - \frac{HRT}{0.037 + 0.922HRT}\right)$$

a = 0.037 and b = 0.922

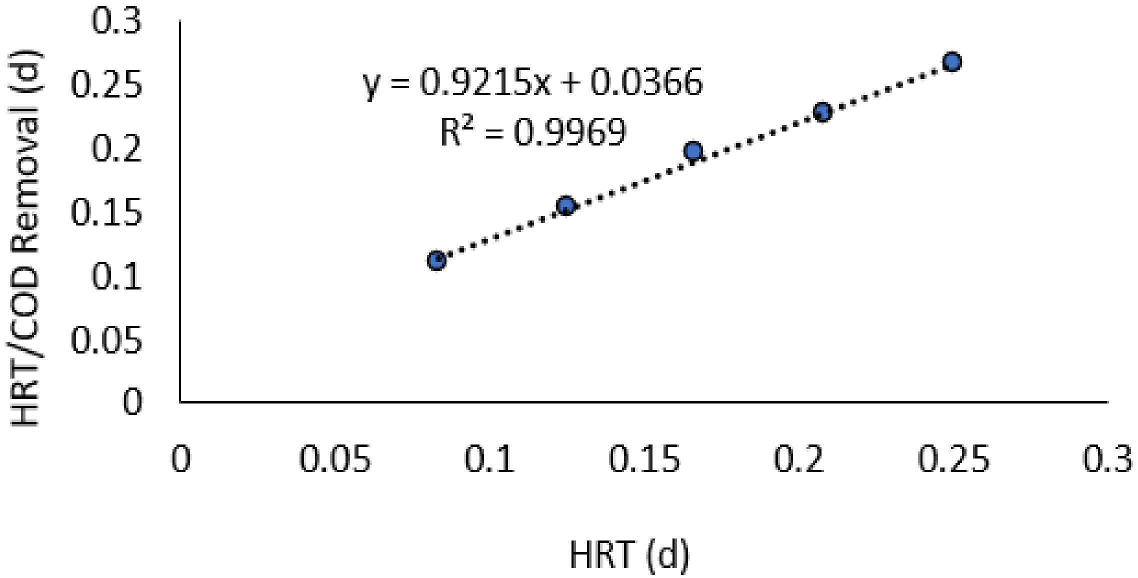
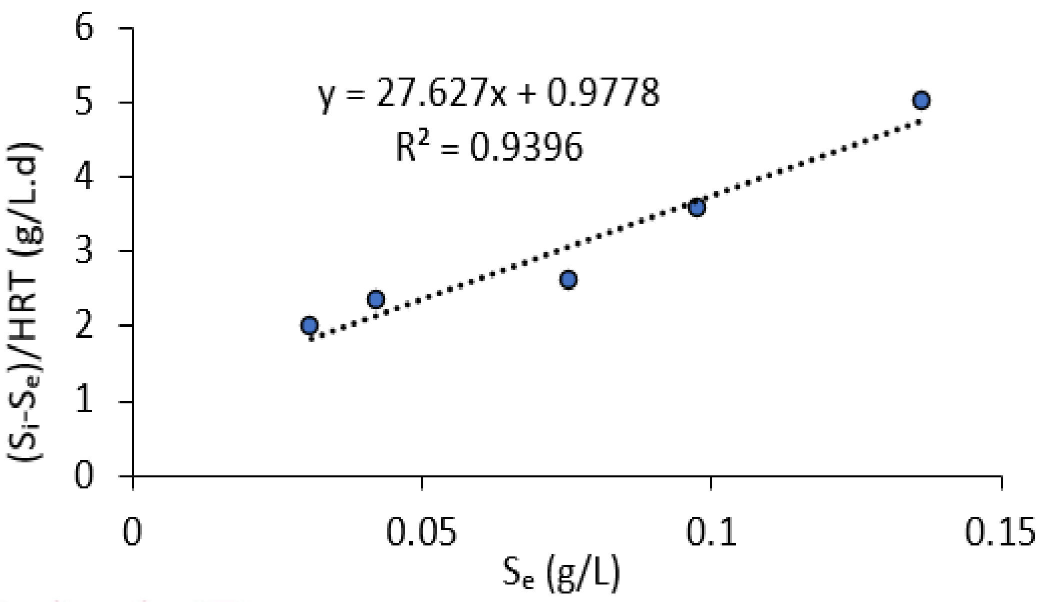


Figure 4,5. Determine the kinetic constants of (**4**) K_B and U_{max} using the modified Stover-Kincannon model; (**5**) a and b using a Grau second-order model.

First-order substrate removal model

$$S_e = \frac{S_i}{1 + 27.627HRT}$$

k_1= 27.627 1/d



Relation between measured values and predicted values from the four models

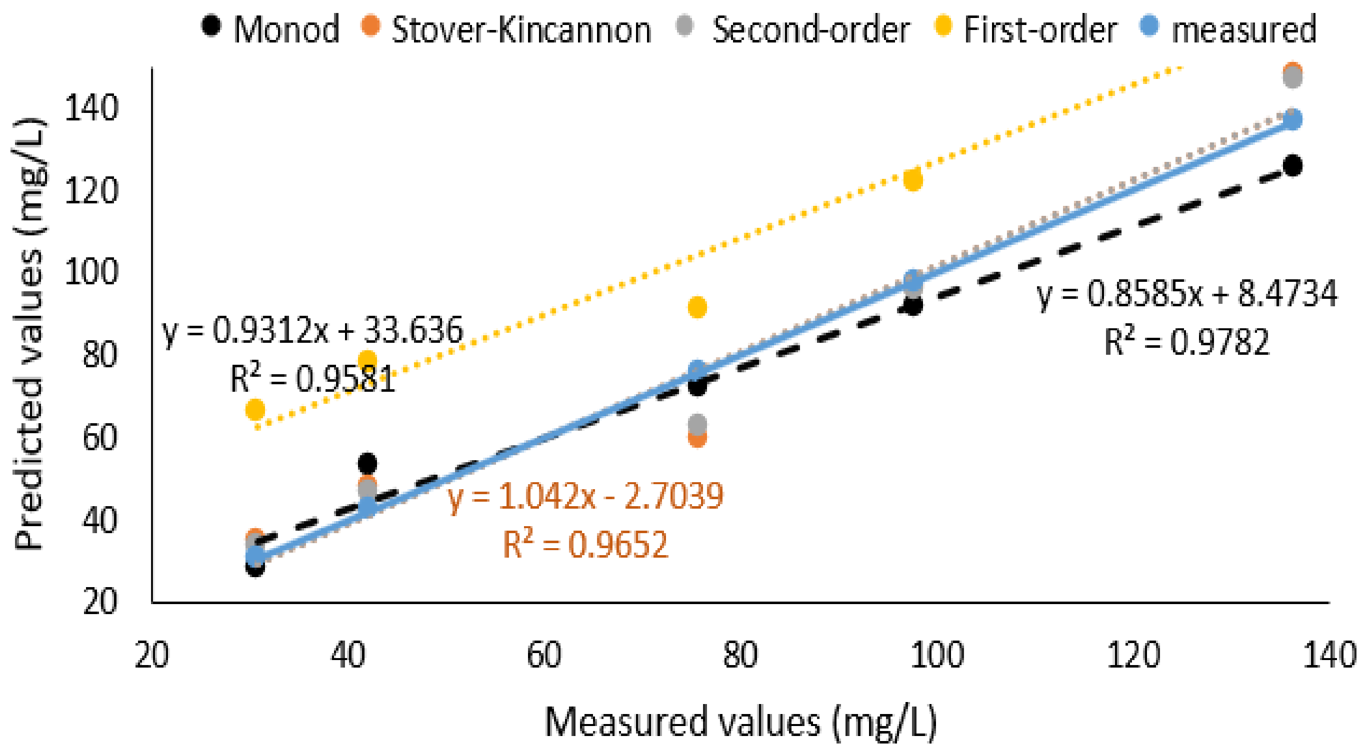


Figure 6,7. (6) COD removal plot by First-order model; (7) Linear correlation between predicted values and measured values.

Conclusion

- The results of this work demonstrate that SDW can be effectively treated by a DHS system at various HRTs ranging from 6.0 to 2.0 h. COD, NH_3, and TSS removal efficiencies decreased from 94.12±5.21 to 75.34±3.64, 93.18±3.19 to 79.46±2.81, and 88.07±4.72 to 72.4±4.17% with decreasing HRT from 6.0 to 2.0 h.
- This show that the DHS system was able to produce effluent compliant with the Egyptian wastewater discharge standards (COD < 80, andNH_3< 4 mg/L) at HRTs ≥4 compared to 2.0 h for TSS effluent (TSS < 40).
- For estimating the performance of a lab-scale DHS system along with substantial kinetic coefficients, modified Stover-Kincannon, and Grau second-order kinetic models were discovered to be more appropriate than the other applicable models, with correlation values of 0.99.
- The microbial kinetics of the DHS system was likewise found to be adequately expressed by a Monod-type kinetic model with a correlation coefficient of 0.9272.
- Despite having a strong first-order correlation coefficient (0.9396), it was not acceptable for predicting how well the DHS system would perform.
- If the SDW was treated under equivalent loading conditions and wastewater characteristics, the outcomes of the kinetic studies calculated from the lab-scale DHS system could be utilized to predict the performance of full-scale DHS systems

Thank You

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