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L-Shape Steel Slag Filter Phosphorus Removal: A Perfomance Study

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Abstract: Phosphorus can often be found in domestic wastewater effluent as the existing conventional treatment system was not designed for its removal. The presence of phosphorus in the final discharge of wastewater will create an environmental problem that is eutrophication. To reduce this problem, alternative domestic wastewater treatment is needed. Therefore, this study aimed to design a lab-scale L-shape semi aerated steel slag filter designed to remove phosphorus from domestic wastewater. Steel slag has been used as a filter medium to enhance phosphorus removal due to the Ca, Al, and Mg contents as it has a high potential in adsorbing phosphorus from domestic wastewater. The lab-scale L-shaped semi aerated steel slag filter system has been set up in the MPRC laboratory, UTHM. To run the L-shape aerated steel slag filter, which combines an aerated vertical and unaerated horizontal filter, domestic wastewater was collected from UTHM Sewerage Treatment Plant influent. The effectiveness of the system in removing phosphorus was monitored for three weeks by analyzing the wastewater influent and effluent of the vertical and horizontal filter twice a week for pH, turbidity, Dissolved Oxygen (DO), and Total P. From the study, the pH value obtained was in alkaline condition, DO range from 7.52 to 7.93 mg/L due to aeration system in the vertical filter and range from 7.58 to 7.84 mg/L in the horizontal filter. The system has been able to remove turbidity effectively range from 29.73 to 3.6 NTU. The phosphorus removal efficiency in L-shape semi aerated steel slag filter range from 1.13 to 0.95. In conclusion, the L-shape semi aerated steel slag filter can remove phosphorus from domestic wastewater, and the design of the system should be improvised.

Keywords: Phosphorus Removal, Vertical Flow Filter, Horizontal Flow Filter

1. Introduction

In suburban and urban areas, an increase in the population contributes to the production of sewage. Generally, domestic wastewater is needed to treat before its discharge into water bodies due to contaminated sewage. Phosphorus and nitrogen are the main components of domestic wastewater. High

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phosphorus presence in water can cause eutrophication. The excess amount of phosphorus in the water cause growth of algal blooms, which contributed to abnormal ecosystem responses [1]. Accordingly, to reduce eutrophication, phosphorus in domestic wastewater should be controlled by removing phosphorus in the secondary treatment process. Phosphorus is the primary nutrients need to minimize in the water bodies [2]. Nonetheless, conventional phosphorus technologies nowadays are high in cost due to the chemical product. The higher the phosphorus, the higher the cost of chemicals required to treat wastewater [3]. The low-cost method in removing phosphorus is necessary to minimize cost treatment. Hence, it focuses on alternative techniques to remove phosphorus domestic wastewater in an environmentally friendly way and chemical-free to be implemented in the treatment process.

The study seeks to develop a lab-scale L-shape steel slag filter system to remove phosphorus in domestic wastewater. This research aims to design a lab-scale L – shaped steel slag filter as an alternative treatment method and study the system performance to remove phosphorus from domestic wastewater using steel slag as a filter absorbent. Steel slag is a waste product in the steel production process and has been practiced in wastewater filtration system [4]. Steel slag is becoming a promising low-cost alternative technology for removing nutrients from wastewater. The chemical composition of steel slag has the ability to remove phosphorus. Steel slag high in calcium (Ca), aluminum (Al), magnesium (Mg), and low in Ferum (Fe) content. This study to investigates the performance of phosphorus removal using a lab-scale L-shape steel slag filter system.

2. Materials and Methods

2.1 L-Shape Semi Aerated Steel Slag Filter system

A lab-scale L-shape semi aerated steel slag filter has been designed and constructed at Micropollutant Research Center (MPRC) laboratory, FKAAB, UTHM. The schematic diagram L-shape semi aerated steel slag filter is shown in Figure 1. The filter system used to remove phosphorus from domestic wastewater using steel slag used as filter absorbent in this system. Steel slag was supplied by Antara Steel Mills Pasir Gudang, Johor. As preparation, steel slag was washed several times with tap water to remove dirt and dried in the oven at 105ºC for 24 hours. A sample of domestic wastewater was sourced locally from Universiti Tun Hussein Onn Malaysia (UTHM) sewerage treatment plant. Untreated domestic wastewater was pumped using peristalic pumps into vertical flow filter and horizontal flow filter using. A vertical flow filter was installed with airflow meters and aerated by Air compressor, as described in Figure 1. The required HLR controlled the system, and the air flow rate meter is 0.06 m^3/day and 1.0 L/min, respectively. The influent and effluent for L-shape semi aerated steel slag filter were collected twice a week for laboratory analysis on parameters include pH, turbidity, dissolve oxygen (DO), and phosphorus-based on Standard Methods for water and water examinations [10].

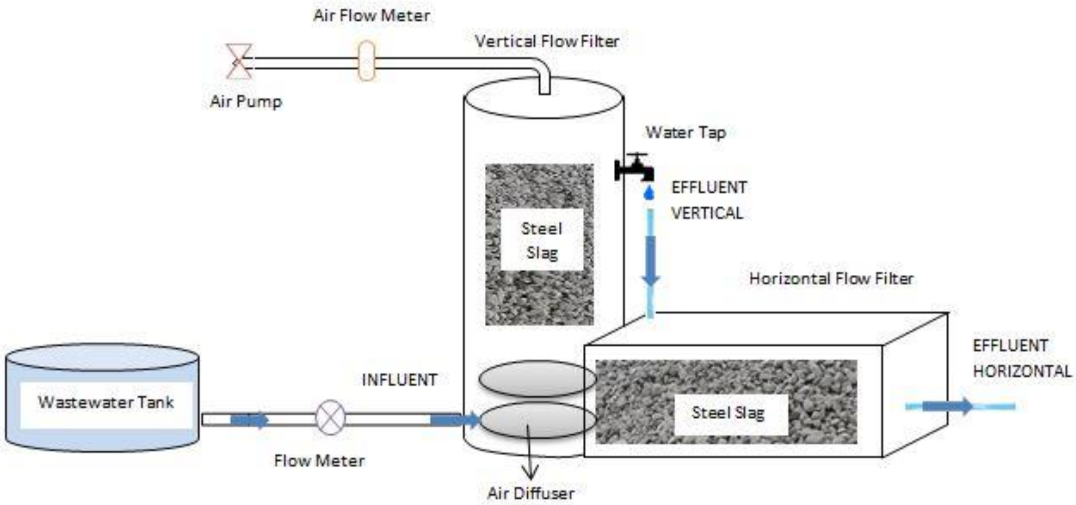

Figure 1: L-shape semi aerated steel slag filter schematic diagram [5]

3. Results and Discussion

3.1 The performance of L-shape Semi Aerated Steel Slag Filter

The quality of wastewater quality monitoring of L-shape semi aerated steel slag filter system in three weeks at Micropollutant Research Center (MPRC) laboratory, FKAAB, UTHM. The domestic wastewater influent and effluent were collected twice a week for laboratory analyses during the monitoring performance system. The study compared phosphorus removal effectiveness using L-shape steel slag filter systems. The removal phosphorus performance, influent, and effluent concentration for the parameter for systems are presented in Table 1. Based on data obtained, the system has the potential to remove phosphorus from domestic wastewater. The discussion regarding the reading sample is presented in the sub-sections.

Table 1: Summary of wastewater quality for L shape steel slag filter system

Parameters	Sampling Points		
	Influent Conc. (Mean ± s.d.)	Effluent Vertical Conc. (Mean ± s.d.)	Effluent Horizontal Conc. (Mean ± s.d.)
pH	7.215 ± 0.244	7.738 ± 0.054	8.928 ± 0.334
Turbidity	23.245 ± 4.334	4.525 ± 1.088	3.020 ± 0.198
DO	4.508 ± 0.252	7.730 ± 0.181	7.710 ± 0.114
Orthophosphate	1.125 ± 0.171	1.105 ± 0.071	0.953 ± 0.212

Note: All units are mg/L expect pH and turbidity (NTU), s.d. = Standard Deviation

3.2 Chemical Composition of Steel Slag

Steel slag filter is widely used in domestic wastewater due to low cost, low maintenance, and efficiency of phosphorus removal [6]. The potential of steel slag in removing phosphorus from domestic wastewater is due to its chemical composition. Chemical composition in steel slag, which indicates the highest percentage of chemical composition is limestone (CaO) followed by silica (SiO) and then magnesium oxide [7]. The composition of chemicals in steel slag was determined using XRF analysis.

The existence of other components such as aluminum oxide and iron oxide in steel slag is due to the blast furnace of steel slag making.

Table 2: Chemical composition of steel slag (Ahmad et al., 2020)

Element	Concentration (%)
CaO	49.50
SiO2	18.00
C	0.10
MgO	4.32
SO3	2.58
Al2O3	2.23
Fe2O3	1.64
MnO	0.38
TiO2	0.22

3.4 Effect Value of pH

The pattern of the pH value of samples is presented in Figure 2 below. The pH of influent in the L-shape semi aerated steel slag system shows a stable pattern. However, the pH value increases on the second sample, where it reaches the value of 7.55 and back to its stable value on the third and fourth samples with 7.02 and 7.05, respectively. As for the effluent vertical pH value, all four samples show a stable value from 7.81, 7.68, 7.72, and 7.74. The pH value for effluent horizontal shows the highest value on the third sample with 9.41, while others are 8.84, 8.64, and 8.82 respectively for sample 1, sample 2, and sample 4. The system is produced in alkaline conditions. The system can also fulfill the permissible limit of Standard B under Environmental Quality (Sewage) Regulations 2009.

The increasing concentration pH value in L shape semi aerated steel slag filter system due to concentration of metal oxides in steel slag composition. Calcium oxide element in steel slag contributes to increases of value pH. As studied by [8], Copper smelter slag was used as absorbent phosphorus, and the efficiency of adsorption increases with the value of pH and temperature.

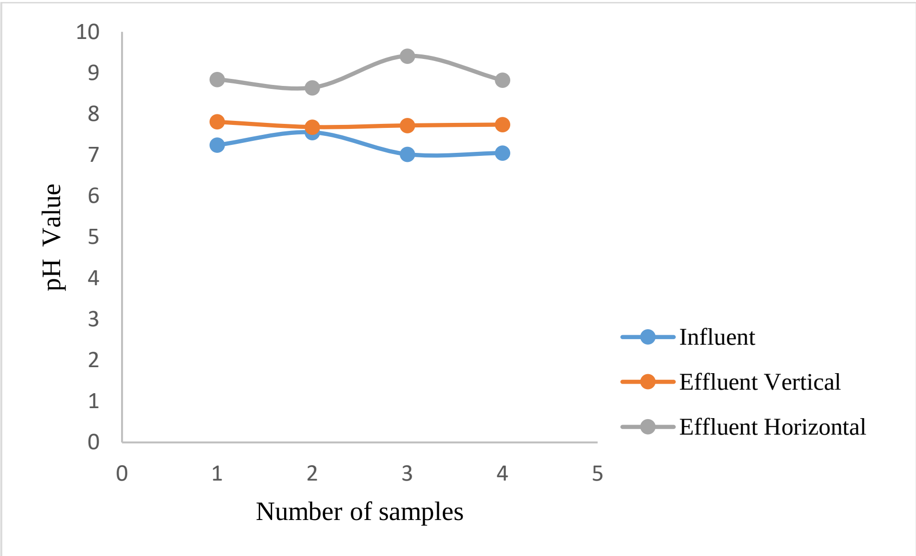

Figure 2: Value pH concentration of L shape semi aerated steel slag systems

3.5 Effect of Turbidity

The turbidity effect for phosphorus removal using L-shape semi aerated steel slag is shown below in Figure 3. The turbidity effect of influent for samples 1, 2, and 3 are 20.66, 21.2, and 21.39, while for sample 4, the turbidity value increases drastically to 29.73 NTU. As for effluent vertical, the turbidity effect for sample 1 is 4.67 NTU. The value increases to 5.77 NTU for the second sample and drops to 4.01 NTU for the third sample. 6.01 NTU was recorded for the fourth sample, which increases. For effluent horizontal, turbidity value is 4.12, 4.50, 2.05 and 4.64 NTU for each sample. The turbidity trends are decreasing from high turbidity at influent to the low turbidity at effluent horizontal in the systems. The low turbidity was produced in the system and showed efficiently reduced turbidity from domestic wastewater. Low turbidity due to aeration process and the presence of steel slag in the system, which is biodegradation. Oxygen was supplied in an aerated system and provided surface area in media to an attached microbe. As for turbidity, the systems can produce effluent quality within the permissible limit of Standard B, which is below 5 NTU.

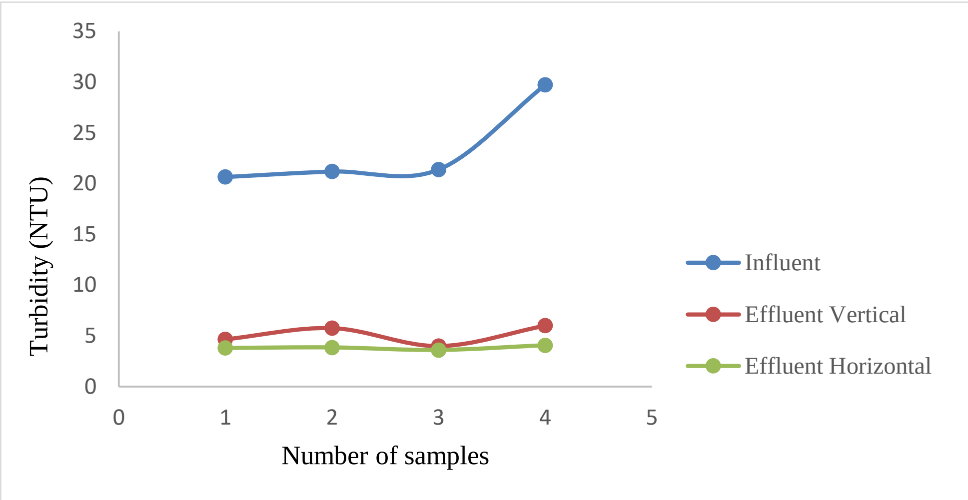

Figure 3: Turbidity concentration of L shape semi aerated steel slag systems

3.6 Effect of Dissolved Oxygen

The quantity of dissolved oxygen is determined for all samples of influent, effluent vertical and effluent horizontal in the systems. DO for influent is 4.4 mg/L for sample 1 and increase to 4.56 mg/L for sample 2. The value increase to 4.83 mg/L for third sample and drop to 4.24 mg/L for sample 4. As for effluent vertical and horizontal, both show quite similar pattern in range 7.52 ± 7.93 mg/L. In term of filter performance, the L-shape semi aerated steel slag filter showed efficiency performance in vertical flow filter and horizontal flow filter due to aeration and reaeration conditions occur in filter system. The systems produced effluent quality within the permissible limit of Standard B which is below than 8 mg/L.

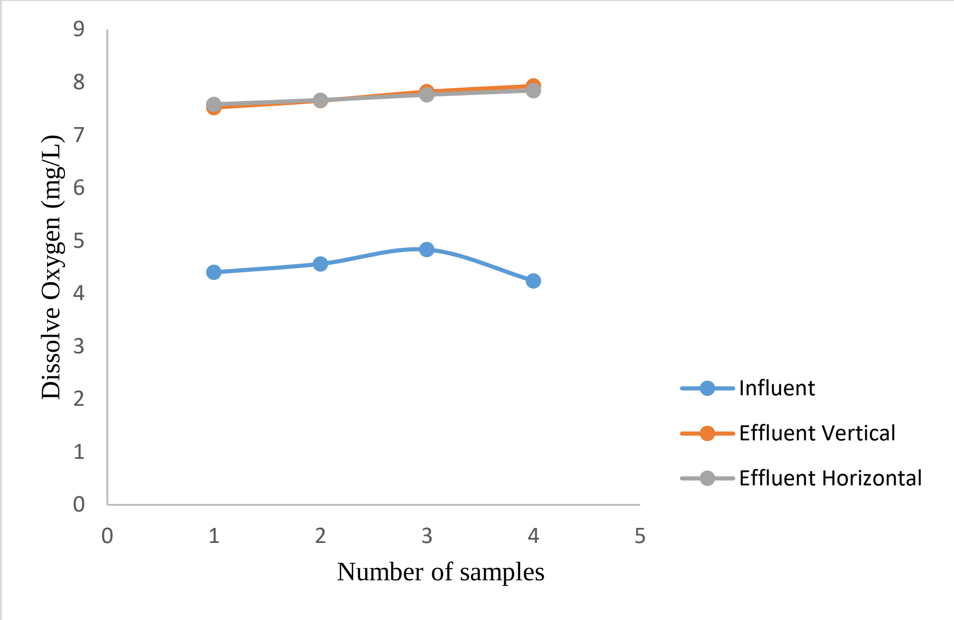

Figure 4: Dissolve oxygen for L shape semi aerated steel slag systems

3.7 Effect of Orthophosphate

Orthophosphate represents the phosphorus in the systems. Figure 5 below shows the pattern of orthophosphate effect value for influent, effluent vertical, and horizontal flow filter. Influent samples show a decreasing pattern value from 1.22, 1.26, 1.14, and 0.88 mg/L. As for effluent vertical, the orthophosphate value is 1.16 mg/L for sample 1 and decreases to 1.13 mg/L for sample 2. The value keeps dropping to 1.0 mg/L for sample 3 and rises to 1.13 mg/L for the fourth sample. The orthophosphate value for effluent horizontal is 1.13 mg/L for sample 1, followed by sample 2 with the value of 1.12 mg/L and a drop to 0.69 mg/L for sample 3. For sample 4, the value increases to 0.87 mg/L. From the result, it shows in systems performed well in removing phosphorus. Horizontal flow filter shows better removal of phosphorus compared to vertical flow filter. Both flow filters showed the reduction of phosphorus in the systems. The reduction of phosphorus due to precipitation and adsorption. [9] proved that adsorption and precipitation occur due to the presence of steelmaking slag, which confirms Ca – P precipitates at the surface steel slag after adsorption. Releasing calcium from steel slag was produces high pH and resulting Ca-P precipitates [9].

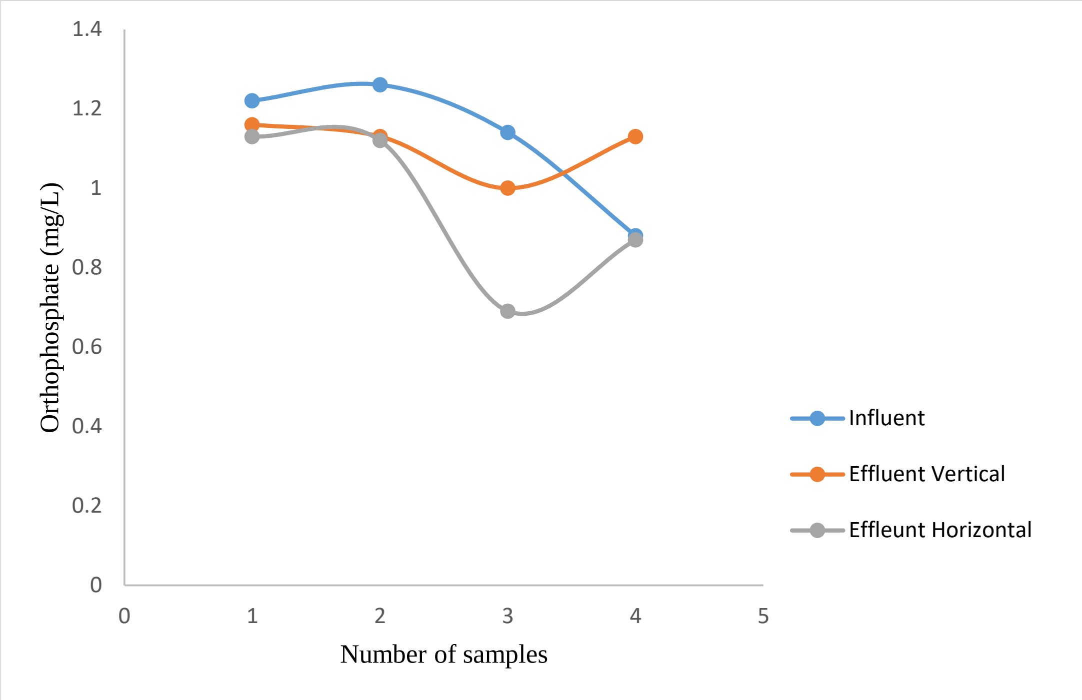

Figure 5: The orthophosphate for L semi aerated steel slag systems

4. Conclusion

In conclusion, L-shape semi aerated steel slag filter systems can be used as an alternative method to remove phosphorus from domestic wastewater with low-cost and eco-friendly. Performance phosphorus removal in horizontal flow filter (unaerated systems) better than vertical flow filter (aerated systems). The systems can produce good quality for parameters selected within the permissible limit of standard B Malaysian Environmental Quality (sewage) Regulations 2009.

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References

[1] Qin, B. Q., Gao, G., Zhu, G. W., Zhang, Y. L., Song, Y. Z., Tang, X. M., Xu, H., & Deng, J. M. (2013). Lake eutrophication and its ecosystem response. Chinese Science Bulletin, 58(9), 961–970

[2] Zhang, J., Tang, L., Tang, W., Zhong, Y., Luo, K., Duan, M., Xing, W., & Liang, J. (2020). Removal and recovery of phosphorus from low-strength waste waters by flow-electrode capacitive deionization. Separation and Purification Technology, 237(September 2019), 116322.

[3] Ojoawo, S. O., Udayakumar, G., & Naik, P. (2015). Phytoremediation of Phosphorus and Nitrogen with Canna x generalis Reeds in Domestic Wastewater through NMAMIT Constructed Wetland. *Aquatic Procedia*, *4*(Icwrcoe), 349–356.

[4] Barca, C., Meyer, D., Liira, M., Drissen, P., Comeau, Y., Andrès, Y., & Chazarenc, F. (2014). Steel slag filters to upgrade phosphorus removal in small wastewater treatment plants: Removal mechanisms and performance. Ecological Engineering, 68, 214–222.

[5] Norazizan Ramli (2021). L-shape semi aerated steel slag filter for phosphorus removal from domestic wastewater. Universiti Tun Hussein Onn Malaysia: Thesis

[6] Claveau-Mallet, D., Boutet, É., & Comeau, Y. (2018). Steel slag filter design criteria for phosphorus removal from wastewater in decentralized applications. Water Research, 143, 28–37. https://doi.org/10.1016/j.watres.2018.06.032

[7] Li, J., Wu, B., Zhou, T., & Chai, X. (2018). Preferential removal of phosphorus using modified steel slag and cement combination for its implications in engineering applications. Environmental Technology and Innovation, 10(August 2017), 264–274. https://doi.org/10.1016/j.eti.2018.02.007

[8] Letshwenyo, M. W. and Sima, T. V. (2020) ‘Phosphorus removal from secondary wastewater effluent using copper smelter slag’, Heliyon. Elsevier Ltd, 6(6), pe04134.

[9] Vu, M. T., Nguyen, L. N., Hasan Johir, M. A., Ngo, H. H., Skidmore, C., Fontana, A., Galway, B., Bustamante, H., & Nghiem, L. D. (2020). Phosphorus removal from aqueous solution by steel making slag – Mechanisms and performance optimisation. Journal of Cleaner Production, xxxx, 124753. https://doi.org/10.1016/j.jclepro.2020.124753

[10] APHA, AWWA and WEF (2017) ‘3120 B. Iductively Coupled Plasma (ICP) Method’, Standard Methods for the Examination of Water and Wastewater, American Public Health Association, pp. 1–5