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Phosphorus Removal from Textile Industrial Wastewater using Aerated High Calcium Steel Slag Filter System

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Abstract*: Phosphorus in wastewater accelerates eutrophication in water body. Textile wastewater is one of contributors to the phosphorus loading into water body which promotes the growth of algae, reducing the oxygen content and detrimental to surface water ecosystem. Myriad existing treatments for phosphorus removal have been developed but it requires a high cost treatment and maintenance. Rock filter system emerged as one of the alternative method for phosphorus removal from wastewater with steel slag as the filter media. However, application of the system in treating industrial wastewater is still unclear especially in big scale application and requires extensive study. This study is done to provide solution of phosphorus loading from textile wastewater using steel slag as filter material and to investigate the removal capacity of steel slag with high calcium and low ferum content. The steel slag was analyzed using XRF for its composition and to ensure the steel slag has high Ca content. Then, the aerated steel slag filter system was set-up on the site of textile industry for a month and analyzed according to parameter of pH, alkalinity, COD, DO, temperature and TSS. The result from this study showed that the aerated high calcium low ferum steel slag filter has a high efficiency of phosphorus removal rates varied from 35% to 67% in treating textile wastewater. It was found that aerated steel slag system was efficient in phosphorus removal by using industrial wastewater.

***Keywords* : Eutrophication, phosphorus removal, steel slag.**

I. INTRODUCTION

Phosphorus is a natural nutrient present in ecosystem which benefitting to animals, plants and humans. However, the excessive concentrations of phosphorus presents in ecosystem able to influence the water quality. Eutrophication is a phenomenon caused by overloading of phosphorus which accelerating the growth of algae by forming thick layer of algae on the surface of water body. Anthropogenic activities are one of the causes of phosphorus loading. In aquatic environments, phosphorus presents in both particulate and dissolved forms and can be operationally defined as total phosphorus, filterable reactive phosphorus, total filterable phosphorus and particulate phosphorus[1]. Total phosphorus is given as the summation of total dissolved phosphorus and particulate phosphorus. However, in these aquatic environments, phosphorus is taken up in dissolved form by primary producers almost exclusively as free orthophosphate or simply, phosphate [2]. Thus phosphate is the predominant form of phosphorus in natural waters in wastewaters.

Wastewater from domestic, industrial and agricultural activities contains high amount of chemical by-products and nutrients. Industrial wastewaters differs than other types of wastewater due to its strong characteristics and are known to be high in toxicity due to the high concentration of contaminant presents such as heavy metal, suspended solid, chemical oxygen demand and nutrient such as ammonia and phosphorus[3]. Industrial wastewaters from textile manufacturing industries, food processing industries and poultry industries are among the contributors of phosphorus loading to water environment in Malaysia[4].

In Malaysia, textiles are one of the major contributing industries towards country's economy due to high demand from consumers. However, the use of chemicals and dye during the production process makes the wastewater difficult to be treated. Often, removal of dye, suspended solid, COD and heavy metals are the main parameters in treating textile wastewater that the removal of nutrient such as phosphorus are being neglected[5]. Typical concentrations of phosphorus present in textile wastewater are 10 mg/L which are more than the allowable limit discharges stated in Environmental Quality Act 1974 (Industrial Effluent) Regulation 2009 since even 0.1 mg/L of P can accelerate the growth of algae[6]. The conventional treatments of wastewater are no longer effective since the wastewaters are high in contaminant.

Various solutions had been developed on removing phosphorus. Most common treatment for phosphorus removal are enhance biological phosphate removal (EBPR), constructed wetland (CWS), membrane and rock filters[7]. Despite all of the treatments present, the applications of the treatment seem impossible to be implemented by industry due to high cost of installation and maintenance. Therefore, an alternative of low-cost techniques are needed for removing phosphorus. Rock filter with materials with high affinities of phosphorus binding as media emerges as alternative solutions. Past studies has been made on materials such as fly ash, coconut coir pith, opoka, skin split waste and steel slag to determine its ability in removing phosphate[8][9].

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Among all of the materials, steel slag shows excellent removal of phosphorus due to high content of metal such as calcium, ferum, magnesium and aluminium to promotes phosphorus binding[10].

However, the performance of steel slag filter systems differs depending on the type of wastewater and the contaminant present. Therefore, big scale application of steel slag filter in treating industrial wastewater is difficult to implement and the optimum condition of the filter remains unclear. Extensive study is needed to determine the optimum condition for the application and its suitability in treating textile wastewater. Thus this research is conducted to further examine the removal efficiency of phosphorus using steel slag filter system in textile industrial.

II. METHODOLOGY

The filter was installed at textile wastewater treatment plant from chosen textile industry located in Batu Pahat for a month. The high calcium low ferum steel slag was obtained from Pasir Gudang, Johor. The steel slag was characterized using X- ray fluorescent (XRF) to determine the composition the steel slag. The sample of steel slag was prepared by crushing the steel slag using Fritsch ball mill grinder model Pulverisette 6, Germany and tested using Supreme 8000, Oxford instrument. Before testing, the sample was sieved with 63 micrometer sieve to obtained fine powder sample. The XRF results obtained was shown in Table 1. The steel slags are confirmed to have high Calcium oxide content to promote removal of phosphorus.

Table – I: Chemical composition of steel slag

Compound	Percentage (%)
CaO	30.217
MgO	11.173
SO_3	0.975
Al_2O_3	7.897
Fe_2O_3	12.963
Mn_2O_3	1.687
TiO_2	0.289
Na_2O	0.955
P_20_5	0.075
Cl	0.079
K_2O	0.383
Cr_2O_3	0.376
ZnO	0.636

The steel slags in range of sized 9.5 mm to 25 mm were accepted for use in the filter[11]. A cylindrical filter with dimensions of with 400 mm high and diameter 150 mm was set up as illustrated in figure 1 and the schematic diagram of the filter system was visualized in Figure 2. The tube was connected at the bottom of the filter to supply aeration for the filter with airflow of 0.25 m^3/L. The sample collected was analyzed based on the parameter of temperature, pH, dissolved oxygen, alkalinity, total suspended solid, total phosphorus and chemical oxygen demand for the duration of 4 weeks.

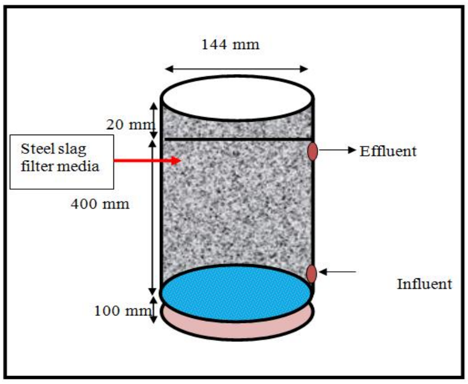

Fig. 1. Filter dimension

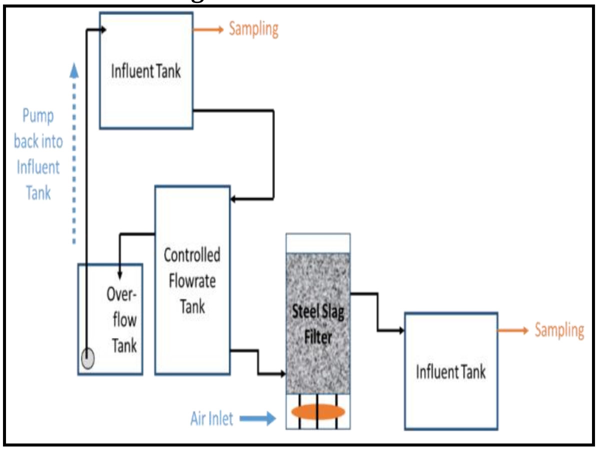

Fig. 2. Schematic diagram of the filter system.

III. RESULTS AND DISCUSSION

The main objective of this system is understands the factors that affect the removal of orthophosphate using steel slag as filter media by analyzing the removal efficiency of orthophosphate. Besides, the determination of phosphorus removal mechanisms also can be done. The parameter of pH and alkalinity was analyzed as it was the affecting parameter of phosphate removal. Other parameter such as COD and TSS was also done to monitor the standard filter performance.

Removals of phosphorus are closely related to the pH of the water. The removals of phosphorus are likely to occur in high pH wastewater when the Ca rich steel slag was used as the filter media[12]. Figure 3 shows the experimental results for the pH of the textile wastewater. The pH value of influent are higher than effluent. This shows that the steel slag lowers the pH value of the wastewater but still in the alkaline ranges to able the removal of phosphorus. The pH of the influent shows decreasing pattern which from 11 to 8.5. The pH for effluent shows similar pattern with influent as its decreasing from 9.5 to 8.2.

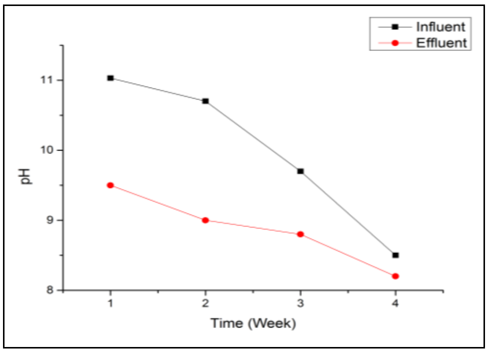

Fig. 3. pH of the system

Based on alkalinity results on figure 4, the alkalinity of wastewater after being treated by this steel slag system shows an increasing throughout the experiment. The high alkalinity value of effluent was at week 4 which is 440 mg/L of $CaCO_3$ and the lowest plotted at the first week which was 365 mg/L of $CaCO_3$. High alkalinity provides more hydroxide ion for ionic exchange for the binding of phosphorus onto the steel slag surface to promotes removal through adsorption. This alkalinity is above the allowable discharge standard from 100 mg/L to 200 mg/L and cannot be discharged directly to the river without any treatment being done.

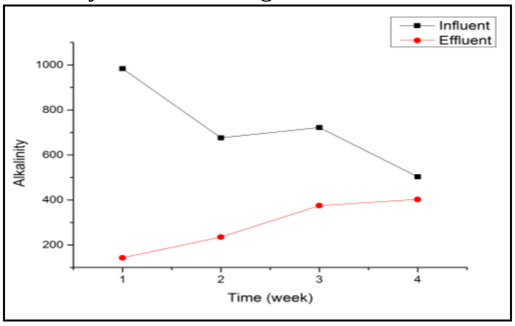

Fig. 4. Alkalinity of the aerated system

Temperature of influent and effluent of the aerated system was visualized in Figure 5. The result obtained shows influent have higher range of temperature compared to effluent. The temperature of the effluent decreased from 30.1ºC to 24.9ºC. Temperature plays an important role in phosphorus removal process as most microorganisms depend on the temperature for the physicochemical processes, absorption and precipitation[13]. Generally, the process of absorption is categorized as a process aid in the term in which the reaction energy released in the form of heat. The level of phosphorus absorption is increased when the temperature decreases.

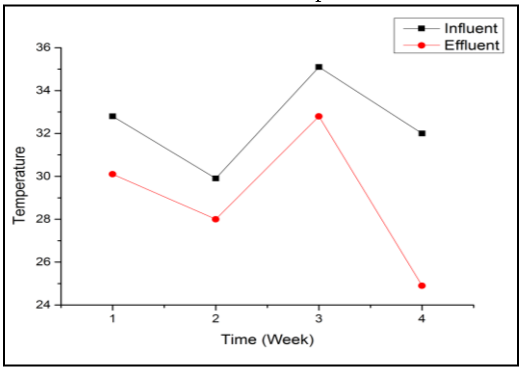

Fig. 5. Temperature of the aerated system

Figure 6 tabulated below explained on the dissolved oxygen content of influent and effluent for aerated steel slag filter. Aeration provides aerobic condition for the Ca to be adsorbed to the binding site of the slag and phosphorus will precipitated together with Fe. Results from laboratory testing showed that the dissolved oxygen for influent is 3.12 – 1.8 mg/L. Value of DO for effluent sample is in the range 0.12-0.42 mg/L. The effluent have lower DO compared to influent even though the aeration is applied. This provides early understanding that removal of phosphorus through precipitation with Fe less likely to occur.

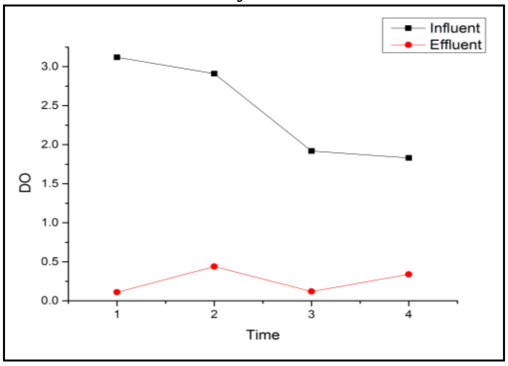

Fig. 6. Dissolve oxygen of the aerated system

Moving on, the value of COD is shown in Figure 7 for influent sample was in the range of 537 mg/L – 663 mg/L. While the value of COD for effluent sample in the range 365 mg/L – 440 mg/L. This indicates that the steel slag filter system was able to remove COD even though it is not highly efficient. The low in dissolve oxygen making the removal of COD is not effective. It can be understood that the COD value of wastewater from the factory exceed the allowable limit from the Malaysia Standard which stated that the allowable of discharge industrial wastewater for standard B is 200 mg/L. Thus, the application of pre-treatment is suggested to remove the COD first before focusing on phosphorus. From the observation, the steel slag system removing COD with the value between 32% to 39%.

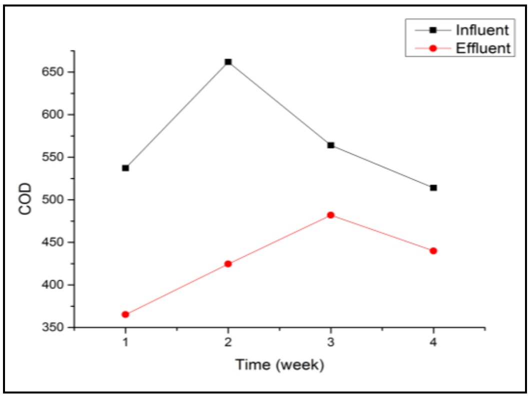

Fig. 7– Chemical oxygen demand of the aerated system

Based on suspended solid results on Figure 8, the suspended solid of wastewater after being treated by the systems was decreasing throughout the experiment. The high suspended solid value of influent was at week 1 which is 336 mg/l and the lowest plotted at the fourth week which was 233 mg/l. While for effluent, the highest reading is 92 mg/l and the lowest is 71 mg/l. According to Malaysian Standard, the allowable limit of discharge for industrial wastewater standard B for suspended solid is 100 mg/L. Based on the result, the steel slag filter system are able to reduce the suspended solid within the allowable limit.

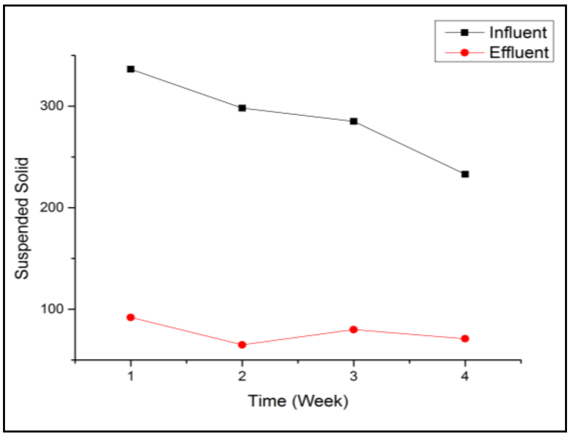

Fig. 8– Total suspended solid of the aerated system

The removal efficiency of phosphorus is visualized in Figure 9. The system has shown a potential in removing orthophosphate. The removal efficiency were range from 35% - 67% which in medium range. The high in pH and alkalinity provides suitable condition for phosphorus removal in alkaline condition when Ca rich slag was used. Furthermore, high in COD disturbs the phosphorus removal as it provides competition with the phosphorus ion to adsorb onto the slag surfaces. The low of DO also affect the removal since its unable to lower the COD value. Nonetheless, the steel slag still able to remove the phosphorus from textile wastewater.

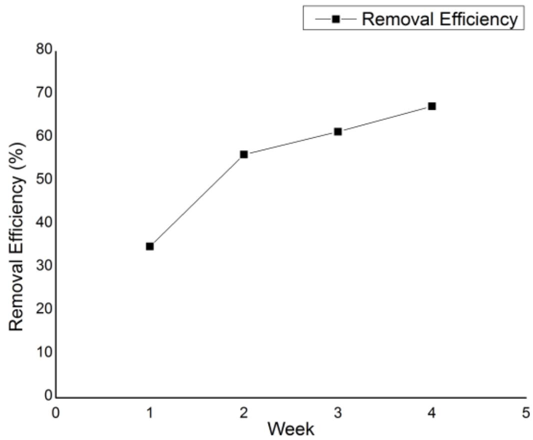

Fig9:

IV. CONCLUSION

Steel slag with high calcium and low ferum has shown potential to be applied in industrial wastewater for removing phosphorus. In this study, orthophosphate shows medium efficiency of removal which in the range of 35 % to 67 %. Other parameters which are DO, COD, total suspended solid showed removal by the aerated steel slag filter. Other parameter such as temperature, pH and alkalinity were monitored to obtain an optimum condition of the filter. The aerated steel slag filter system has a great potential as new green technology. The uses of steel slag also encourage waste utilization effort making it a cost effective method.

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