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Phosphorus Removal Efficiencies of Recycled Concrete Aggregate Column System Filter

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ABSTRACT

is one of the key nutrients that lead to eutrophication in surface water. However, existing conventional wastewater treatment systems for removing phosphorus are expensive and complex. Recycled concrete aggregate (RCA) may be an alternative solution for phosphorus removal. It can reduce pollution and landfill disposal by converting construction waste into valuable products. This study aims to investigate the physical and chemical characteristics of RCA that influence the removal of phosphorus, as well as the percentage of phosphorus removal using RCAs of two different sizes namely, 5 mm to 10 mm and 25 mm to 30 mm. A total of five vertical laboratory-scale RCA filters were designed and five different concentrations of synthetic wastewater between 10 – 50 mg/L were prepared. The samples taken from the influent and effluent filters were tested and analysed in terms of pH, the uptake capacity of phosphorus (q) and the percentage of phosphorus removal (%). RCA was analysed using Scanning Electron Microscopy (SEM) and Energy-dispersive X-ray spectroscopy (EDX) to determine its chemical composition. The results show that RCA has a high content of aluminium, calcium and magnesium that enhances phosphorus adsorption. RCA measuring between 5 mm to 10 mm in 10 mg/L of synthetic wastewater achieved the highest phosphorus removal percentage of 99.54% at a pH 10. The highest percentage of phosphorus removal achieved was 99.54% in the initial concentration of 10 mg/L by RCA measuring between 5 mm to 10 mm while the lowest percentage of phosphorus removal was 66.25% in the initial concentration of 50 mg/L for RCAs measuring between 25 mm to 30 mm. Furthermore, RCA achieved the highest uptake capacity (q) of 3.45 mg/L in the initial wastewater concentration of 50 mg/L. In conclusion, RCA has the potential to remove phosphorus, particularly in low concentrations of synthetic wastewater and high pH conditions.

Key words : Column, Filter, Phosphorus, Recycled Concrete Aggregate, Waste Water.

1. INTRODUCTION

Excessive nutrients such as phosphorus can lead to serious problems such as eutrophication. Besides, this issue could cause water poisoning and the degradation of recreational opportunities. Therefore, wastewater treatment processes should be optimised to alleviate water pollution. The removal of phosphorus requires a secondary wastewater treatment process. Enhanced biological phosphorus removal (EBPR) and chemical precipitation are commonly practiced nowadays due to its great consistency in achieving the removal standards [1]. Yet, these conventional technologies require advanced cost, constant maintenance by experts and high energy consumption. By itself, chemical precipitation desires an abundance of chemicals and EBPR consumes a lot of energy to maintain its tank performance. Environmental pollution is a global concern because of the dangerous effects on public health and the environment. The irresponsible disposal of untreated wastewater into waters, soil and groundwater results in polluted water resources. Moreover, nutrients such as phosphorus have become culprits of concern in accelerating eutrophication. Besides, this issue could cause water poisoning and the degradation of recreational opportunities. On the other hand, rock filters (RF) have become an encouraging alternative technology for removing nutrients from wastewater. The advantages of RF due to its comparatively easy to be installed and great quantity availability as compared to the conventional method. Modifications were done on the rock filters, by replacing the filter media to develop their performances in nutrient removal. A few significant factors also need to be calculated while choosing the best filter media such as saturation time, availability at a local level, and the recyclability of filter materials. Recycled concrete aggregate (RCA) attracts more attention as the filter media due to high capability in removing phosphorus [2] since it is easily available. Also, RCA easily available at construction site, therefore recycling the waste is a better idea towards sustainability. Population growth and urbanization have accelerated consumption of concrete and construction and demolition waste generation, therefore the transformation of this product flow into something valuable nowadays is become very significant for us. In the present study, RCA was chosen as a filter media which are high Ca and can be easily obtained from old construction work which is demolition waste.

A crush concrete aggregate is one of the alternative treatments for the removal of phosphorus. It is a low-cost, alternative technology for removing nutrients from wastewater. Some of the advantages of crush concrete are its cost efficiency, high availability and relatively easy installation compared to conventional methods. According to previous studies, one of the alternative filter media for the removal of phosphorus is recycled concrete aggregate (RCA). RCA has a high capability for removing phosphorus. It is also easily available and incurs a low cost. Besides, it is a sustainable method since RCA is a recycled product from the construction site. Thus, the use of RCA is a very economical and promising solution for phosphorus removal from wastewater. Consequently, RCA was used as an alternative filter media for the removal of phosphorus in this study. This was done to reduce the uncontrolled disposal of waste at construction sites. If the situation is not controlled, it will cause problems to the environment as there will be a decrease in space in urban areas due to waste demolition. On the other hand, RCA can help to save the environment as no excavation of natural resources is needed. Less transportation as well as less land is required. Moreover, the use of RCA can also save time as it is readily available. Besides, RCA has a higher calcium content which translates to a higher ability for removing phosphorus [3]. Thus, RCA possesses high potential to be used as a filter medium for removing phosphorus. In Malaysia thus making the RCA as a medium for water treatment to reduce the waste and save the environment. Therefore, this study was carried out to investigate the removal efficiency of phosphorus using recycled concrete aggregates in different concentrations of synthetic wastewater in an unaerated filter. In this study, a total of five vertical laboratory-scale RCA filters were designed and five different concentrations of synthetic wastewater between 10 – 50 mg/L were prepared. The samples taken from the influent and effluent filters were tested and analysed in terms of pH, the uptake capacity of phosphorus (q) and the percentage of phosphorus removal (%).

2. EXPERIMENTAL

2.1 Materials

Recycled concrete aggregate (RCA) was produced from concrete cube waste at the Heavy Structure Laboratory, Universiti Tun Hussein Onn Malaysia (UTHM). Then, the concrete cube waste was crushed using crushing machines (Concrete Crusher A35399) in order to produce RCA. Next, the aggregates were sieved to obtain the desired sizes ranging between 5 mm to 30 mm (British Standard sieve BS410/1986) using a shaker (Endecotts Lombard Rd. London, model SW193BR, England). The chemical composition obtained from EDX testing was given in Figure 1. RCA samples in the range of sizes of 5 mm to 20 mm were accepted for use as adsorbents for the column study. The samples were washed up twice with tap water followed by distilled water before they were dried up in the oven for 24 hours at 105℃.

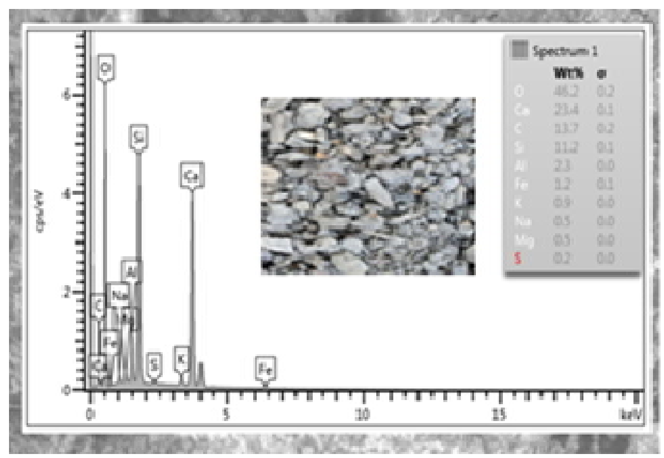

Figure 1: The chemical composition of RCA

2.2 Column Study

Lab-scale vertical RCA filters were developed to investigate the removal of phosphorus from synthetic wastewater in this study. This filter was cylindrical in shape. In this study, five filters were designed and placed at the Wastewater Engineering Laboratory, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia (UTHM). The perspex filter was designed with an inner diameter of 150 mm, a thickness of 5 mm and a total height of 420 mm. Figure 2 shows the filter design system while Figure 3 shows the schematic diagram for the arrangement of the filter. On the other hand, Figure 4 shows the layout of the lab-scale vertical aerated RCA filter system and Table 1 shows the design Parameters of the lab-scale column filter.

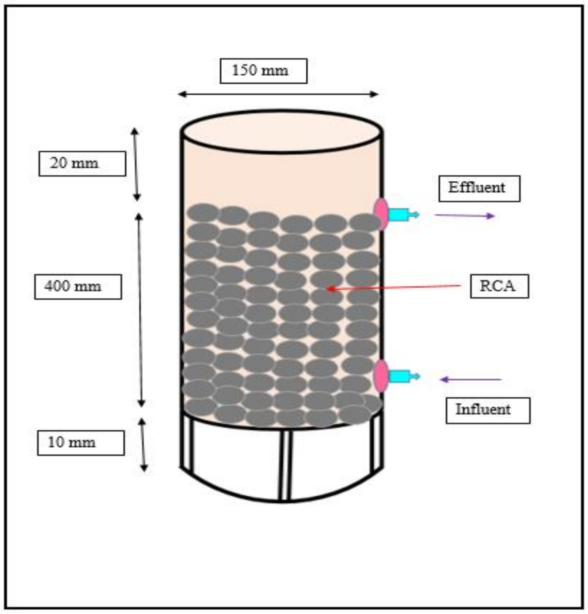

Figure 2: Dimension of the lab-scale column filter

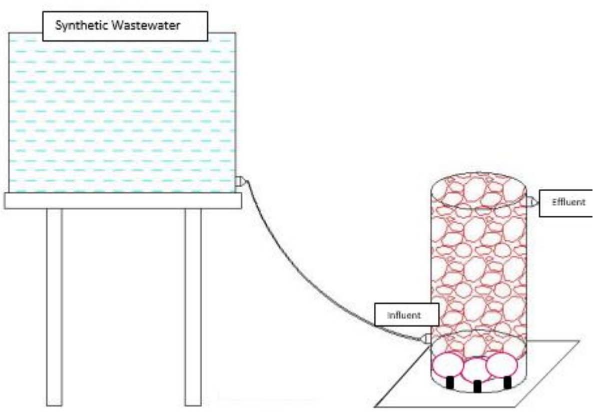

Figure 3: The schematic diagram for filter arrangement

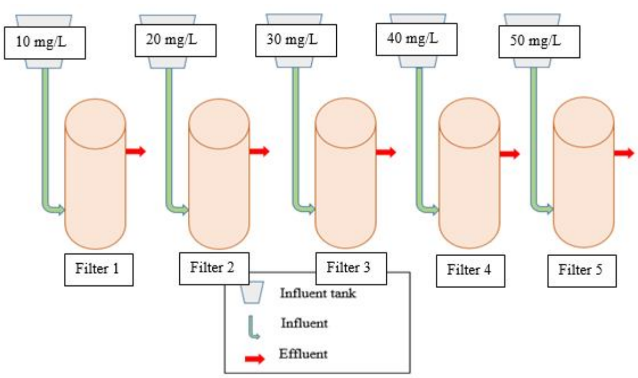

Figure 4: The layout of the lab-scale vertical unaerated recycled concrete aggregate filter system

Table 1: Design Parameters of the lab-scale column filter

Parameter	Unit	Value
Height	m	0.42
Diameter	m	0.15
Depth of RCA	m	0.30
Hydraulic Loading Rate	$m^3/m^3.d$	0.60
Volume of RCA	m^3	0.007
Flow Rate	ml/min	2.9
Time taken for overflow	Hours	7.6

3. RESULTS AND DISCUSSION

3.1 Percentage Removal of Phosphorus due to pH

pH value refers to the concentration of the hydrogen ions contained in a solution [4]. Figure 5 shows the percentage graph of phosphorus removal versus pH reading. From the graph, the percentages of phosphorus removal at a pH of 10, 9, 8, 7 and 6 are 99.54%, 76.92%, 74.94%, 69.91% and 67.60% respectively. It was shown that the higher the pH, the greater the efficiency of phosphorus removal. This is similar to the findings by Ahmad *et al*. [5] where the percentage of phosphorus removal is 98% at a pH of 9 in an unaerated system filter. This is true for unaerated systems which allow precipitates to form. Mohan *et al.* [6] stated that the higher the pH value, the higher the calcium content. Thus, the higher the calcium content, the higher the ability of the material to remove phosphorus.

Nasir [7] also obtained the optimum pH value for the effective removal of phosphorus. 80% of phosphorus was removed using steel slag at a pH of 9.40. This is because steel slag also has higher calcium content and alkalinity. It shows that an alkaline condition allows precipitation which can influence the removal of phosphorus. Next, the effective removal of phosphorus by using opoka as a filter occurred at a pH of 12.60. The removal of phosphorus using sand was also effective between a pH of 7.8-9.5. In sand, phosphorus is bound to the medium due to adsorption and precipitation reactions with calcium, aluminium and iron. According to Yihuan and Andrew [8], an alkaline pH could also help cement release more Ca^{2+} ions into the solution to react with hydrogen phosphate, causing the precipitation of $Ca_3(PO_4)_2$. The increase in P removal above pH 9 could be due to a similar mechanism due to the formation of OH enriched complexes precipitating calcium phosphate. At pH levels greater than 6, the reactions are a combination of physical adsorption to iron and aluminium oxides and precipitation as sparingly soluble calcium phosphates [9].

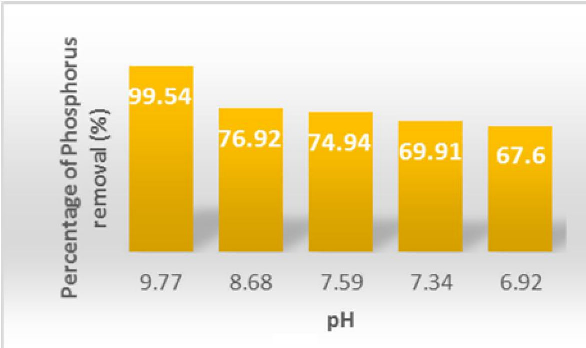

Figure 5: Percentage of phosphorus removal versus pH reading

3.2 Percentage of phosphorus removal efficiency

This section discusses the data and analysis on the percentage of phosphorus removal by RCA. Figure 6 shows the percentage graph of phosphorus removal using RCA of different sizes (5-10 mm and 25-30 mm) in five different concentrations of synthetic wastewater. For RCAs measuring between 5-10 mm, the percentages of phosphorus removal were 99.54%, 76.92%, 74.94%, 69.91% and 67.60% for the initial concentrations of 10 mg/L, 20 mg/L, 30 mg/L, 40 mg/L and 50 mg/L, respectively. Next, for RCAs measuring 25-30 mm, the percentages of phosphorus removal were 94.49%, 68.95%, 67.89%, 66.42% and 66.25% for the initial concentrations of 10 mg/L, 20 mg/L, 30 mg/L, 40 mg/L and 50 mg/L, respectively.

The highest percentage of phosphorus removal achieved was 99.54% in the initial concentration of 10 mg/L by RCAs measuring between 5 mm to 10 mm while the lowest percentage of phosphorus removal was 66.25% in the initial concentration of 50 mg/L for RCAs measuring between 25 mm to 30 mm. It can be seen that the percentage of phosphorus removal decreases as the concentration of synthetic wastewater increases. From the graph, the percentage of phosphorus removal decreases as the initial concentration of synthetic wastewater increases. It was similar due to the outcomes by Wood and Atamney [10] where 80-90% of initial phosphorus was absorbed by Laterite in concentrations of 10-25 mg/L while 60% of initial phosphorus was absorbed when higher concentrations were applied. According to Yihuan and Andrew [8], the adsorption capacity increases linearly for the initial concentrations between 5 to 30 mg/L, but the percentage of phosphorus removed reached its maximum at the initial concentration of 15 mg/L. This suggests that the removal of phosphorus is not suitable at higher initial concentrations.

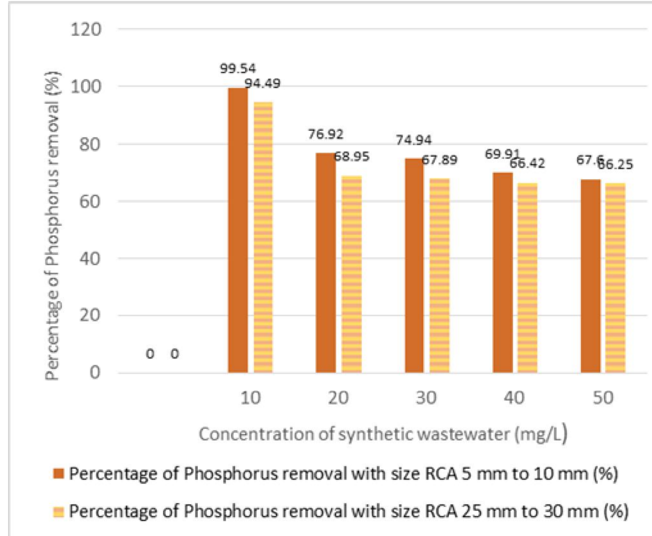

Figure 6: Percentage of Phosphorus removal with different size of RCA versus different concentration of synthetic wastewater

3.2 The correlation between the uptake capacity of RCA of different sizes versus the initial concentration of synthetic wastewater

Figure 7 shows the linear correlation between the uptake capacity coefficients of RCA of different sizes versus the initial concentrations of synthetic wastewater. The linear correlation coefficient measures the strength and the direction of a linear relationship between two variables.

From the graph, the R^2 between the uptake capacities of phosphorus is near 1.00 namely, 0.9916 for RCAs measuring between 5 mm to 10 mm and 0.9929 for RCAs measuring between 25 mm to 30 mm. Thus, the correlation coefficient for the uptake capacity of RCA of different sizes have a strong positive linear correlation as R^2 is close to +1. It clearly shows that the relationship between the uptake capacities and RCA of different sizes is a positive linear correlation relationship. In contrast, Maung, [10] found that the R^2 between the uptake capacities of P using limestone was about 0.7865 for limestones measuring between 10 mm to 20 mm and 0.8654 for limestones measuring between 20 mm to 30 mm.

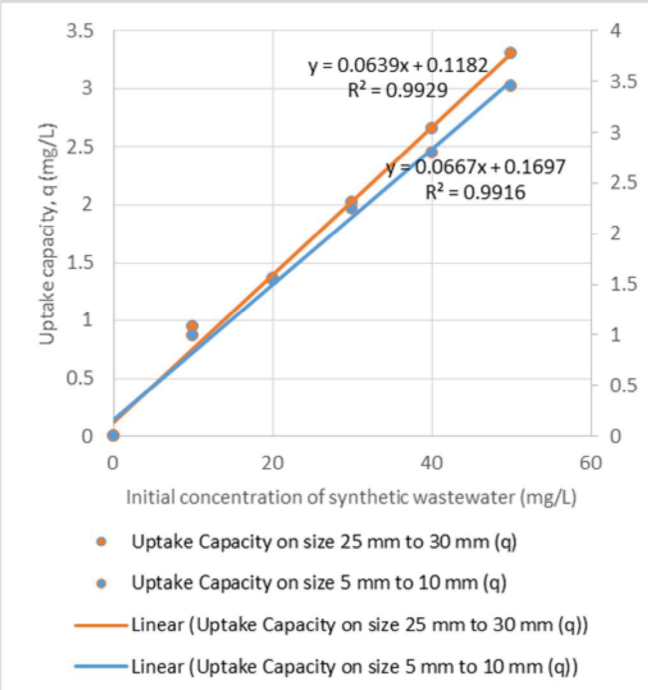

Figure 7: The correlation between the uptake capacity of RCA of different sizes versus the initial concentration of synthetic wastewater

5. CONCLUSION

A removal percentage of 99.54% of phosphorus was achieved in an initial wastewater concentration of 10 mg/L using RCAs measuring between 5-10 mm. The lower initial concentration affected the absorption of phosphorus as the phosphorus uptake achieved equilibrium. Moreover, the highest pH reading resulted in the highest phosphorus removal efficiency. 99.54% of phosphorus was removed at a pH of 9.77. Thus, as a conclusion for this study, RCA has the potential to be used as a filter medium for phosphorus removal in synthetic wastewater. This finding could benefit the environment by reducing the discharge of phosphorus from wastewater to water bodies, which could further lead to eutrophication. Other than this, the use of RCA as a filter medium seems to be a promising contribution towards the sustainability of the construction industry. By using RCA, production waste at construction sites, pollution, landfill space and the cost of concrete disposal can also be reduced.

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