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RESEARCH ARTICLE

Performance evaluation of two filter materials in intermittent sand filtration system

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ABSTRACT

The environment is a treasure that needs to be protected from point and diffuse sources of pollution. Most wastewater treatment plants cannot attain 100% efficiencies and this call for tertiary treatment process before discharging final treated wastewater into the environment. The study focused on harnessing the locally available materials, sand and granulated Palm Kernel Shell (gPKS) as filters for treatment of wastewater from constructed wetland using intermittent filtration system in the laboratory. The filter depth and hydraulic loading rate was 650 mm and 0.135 L min^{-1}, respectively. Applied wastewater was effluent from the Constructed Wetland (CW) of wastewater treatment plant University of Lagos. The filtration system was dosed intermittently 6 hourly for 12 weeks. Experimental results showed that pH of the effluent from gPKS filter medium was slightly reduced to the influent due to acidic nature of the gPKS while effluent from sand filter slightly increased. The five day biochemical oxygen demand (BOD5) removal efficiency for the gPKS and sand filters were 59.2 and 69.08% respectively, while the corresponding average Dissolve Oxygen (DO) were 2.9 ± 0.6 mg L^{-1} and 3.4 ± 0.345. The percentage removal of *E. coli* in sand and gPKS filters are 69.34% and 87.49% respectively.

Keywords: Wastewater treatment plant, granulated palm kernel shells, intermittent sand filtration, *E. coli*

1. INTRODUCTION

It was estimated that 97% of the water in the earth is stored in the sea which is not suitable for consumption due to its high salinity; the remaining 3% that is fresh water is available as ice caps, surface and ground water. The anthropogenic activities that have resulted into the usage of part of the water have also resulted into the emanation of wastewater from different areas which if discharged directly into the environment will result into pollution of such environment and receiving water body. Towards protecting the environment, a number of ways has been adopted through construction of wastewater treatment plant such as onsite wastewater treatment plant, stabilization pond, construction wetland, trickling filter, activated sludge system among others.

Towards solving the problems that may emanate from discharging expected effluent from these treatment plants that does not meet the minimum quality requirement, researchers have studied need to provide tertiary treatment. In the course of doing this, most researchers have adopted the usage of sand as material for filtration. Reference [1] adopted the usage of sand for the treatment of synthetic effluent from an onsite wastewater treatment plant. References [2], [3] and.[4] used sand as filter for phosphate removal, disinfection of secondary clarifier effluent and dissolved substances removal in wastewater treatment respectively. Due to availability, accessibility and economical reasons [5]-[8] made use of sand in their studies of infiltration because sand material is stable and cannot be subjected to any chemical degration and physical abrassion.

The highest producing Palm Oil country in Africa is Nigeria. In 2016, the country was producing 970,000 metric tonnes in a year which was estimated as 55% of the entire Africa outputs (Palm oil in African I *SPOTT.org http.//www.spott.org*). This means that the tonnage of solid waste (PKS) from this production will correspondingly be high, hence, there is need to reuse it towards best solid waste management. One of the alternatives towards the reuse of this waste material is by investigating its usage as filter medium in an

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area where sand material being used as filter medium is not available. It was reported in [9], that among the agro-based farm wastes and processing wastes in Nigeria that can serve as materials for Activated Charcoal production, PKS have the best adsorptive capacity. Through this, the stress and cost of transporting of the sand material to such wastewater treatment will be reduced while the environmental menace of the PKS solid waste shall be minimized. Therefore, this study investigates the performance evaluation of sand and gPKS as filter media.

2. MATERIALS & METHOD

This is a laboratory based experimental work to assess performance of two different filter media (PKS and sand) in the tertiary treatment of effluent from a constructed wetland of an educational institution. The sand medium was collected from Ilaje, a suburb of Lagos Mainland in Somolu Local Government Area, while the PKS was collected from Arigbajo community of Ogun State, Nigeria. The PKS was crushed and granulated to sizes relatively similar to the sampled sand filter from Ilaje of Lagos as shown in Figure 1.The hydraulic parameters of the two media were determined to confirm their relative suitability or otherwise with respect to specification recommended in [10]. The particle size distribution curves of the two media and their hydraulic parameters are presented in Figure 1 and on Table 1 respectively.

The sand medium has the effective size (d_{10}) of 0.28, coefficient of uniformity (C_u) of 2.85 and pore diameter (d_{15}) of 0.39. The d_{10}, C_u and d_{15} values respectively for gPKS are 0.34, 2.94 and 0.39. The values are all within the recommended values by [10] and shows that the materials can serve as filter media for intermittent sand filtration.

The experiment was setup in the Granulometric Laboratory of the Hydraulic Research Unit of University of Lagos, using two columns of Perspex material of 100 mm diameter and thickness of 5 mm. The columns were sealed at the bottom with 10 mm thick flat Perspex plate and filled with underdrain material of 7.5 cm and each of the columns was filled with separate filter medium (sand or gPKS) of 650 mm depth. The choice of 650 mm was based on [1], where it was reported that a depth of 500 mm and little above it will perform effectively in the removal of the organic load of wastewater through intermittent sand filtration. Also, in an earlier research, Prasad [11] reported removal of organic load 2 ft (0.6 m) depth.

Wastewater samples used for the study were collected from the effluent of the constructed wetland of the Wastewater Treatment Plant of University of Lagos, Nigeria using sterile container. The sewage quality of the university wastewater fluctuated during the operation period detailed whether the university was in session or not.

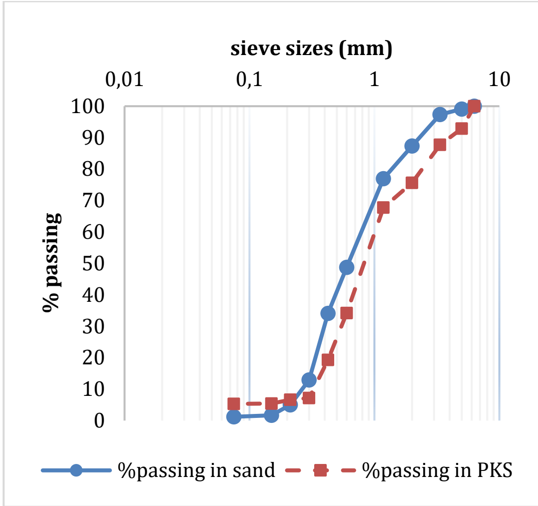

Fig 1. Particles size distribution curves of Ilaje sand and Arigbajo granulated palm kernel shell

Table 1. Granulometric properties of filter media

Property	Sand	PKS
D_{10}(mm)	0.28	0.34
D_{15} (mm)	0.31	0.39
D_{30} (mm)	0.40	0.55
D_{60} (mm)	0.80	1.00
C_u	2.85	2.94

The columns were first saturated by pumping water into it followed by draining prior performing the test. Effluent from the wetland that serves as influent to the SSF was collected and served as the influent for the laboratory intermittent sand filtration set up as shown in Figure 2. The sample was applied to the filter from the top through the use of peristaltic pump. The pump operation was for 15 minutes duration for each batch at the hydraulic loading rate of 0.135 L min^{-1}. The batching of the columns was 4 times a day as shown on Figure 3 for 90 days and was performed concurrently. Samplings of treated wastewater from columns were done once weekly for laboratory analysis. The parameters tested for were BOD, DO and *Escherichia coli* (*E. coli*) and were analyzed using standard methods of measurement [12].

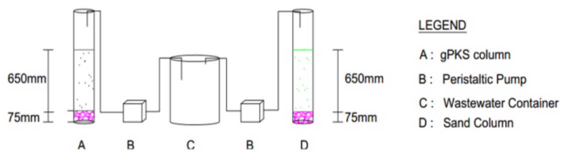

Fig 2. Filtration setup

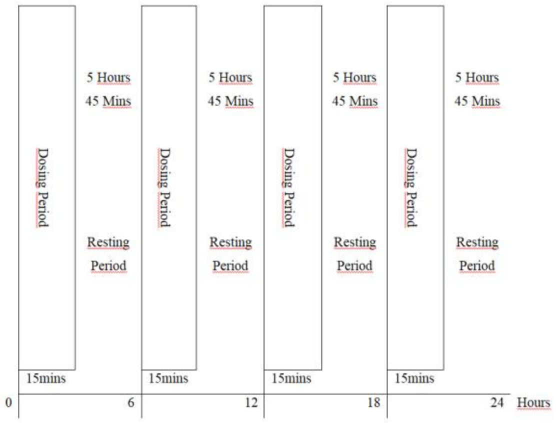

Fig 3. The dosing pattern of the columns

3. RESULTS & DISCUSSION

The average pH of the influents was 7.0 while that of effluents from the sand and gPKS filters were 7.1 and 6.7 respectively. The slight increase in pH in the sand filter column was due to biological activity and gas exchange as reported by Kim et al. [13] on one hand but that of slight decrease of the gPKS effluent may be due to the effect of traces of palm oil from the gPKS which contains higher proportion of saturated fatty acids[14] -[15], this could be responsible for the lower pH value of the effluent from the gPKS filter medium. Generally, the system pH values indicate that the system operated optimally for biological activities.

The BOD_5 of the wastewater and effluent from the filters are shown on Table 2. The average BOD_5 value of wastewater was 33.3 mg L^{-1} with the maximum BOD_5 of 90.4 mg L^{-1} measured in week 2 and the minimum of 4.2 mg L^{-1} measured in week 11. The value for week 11 was due to non-availability of the students in the hall of residence during the period. Though average value of 33.3 mg L^{-1} may be slightly higher than the minimum standard required by WHO [16], that may not necessarily need to be polished, the occurrence of higher values in weeks 2, 3, 6, 7 and 8 make it desirable and validate the essence of polishing the effluent from the constructed wetland before being discharged as corroborated by Longe and Ogundipe [17].

From Figure 4, it was shown that the sand filter gave an average of 69.08% removal efficiency of the organic load, BOD_5, while the gPKS filter recorded 59.2% removal. The average value recorded in sand filter was close to the 72.5 % recorded by Prasad et al. [11] that uses sand and soil in the treatment of domestic wastewater. The value recorded for gPKS was lower to that of sand; this may be due to larger d10 value of gPKS (0.34 mm) compared to that of sand (0.28 mm) which affects the porosity of the media and directly affect the detention of the wastewater in the filter and consequently organic matter removal. Generally, the performance of gPKS in organic load removal throughout the treatment period was relatively close to that of the sand as filter. Expectedly, the usage of raw gPKS without charring it could have also been a factor that contributed to the low BOD_5 and decrease in pH recorded. Further work need to be done to ascertained this.

Table 2. Result of BOD_5

Weeks	Wastewater	Effluent from Sand	Effluent from PKS
1	67.6	25.6	30.6
2	90.4	24.5	25.2
3	56.8	22.4	21.4
4	23	22.2	21.6
5	13.4	8.6	12
6	59.4	40.6	23
7	39.2	29.4	28.4
8	62.2	23	28.4
9	11	6.8	7.4
10	8	5.6	12.2
11	4.2	3.4	2.8
12	25.8	22.4	12.2
Average	33.34	19.49	18.76
Maximum	90.4	40.6	30.6
Minimum	4.2	2.8	2.8

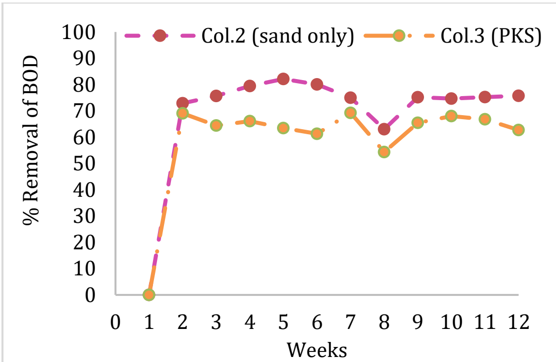

Fig 4. Percentage removal of BOD in sand and gPKS columns

The level of dissolved oxygen present in water is directly proportional to the quality of that water. That is, dissolved oxygen increases with increase in water quality and vice-versa. Bulley and Husdon [18] reported that most systems that are designed for the aerobic treatment of municipal waste recommend the dissolved oxygen concentration be maintained in the range of 0.5 – 2 mg L^{-1} this was supported by Awoyemi et al. [19]that reported a DO of 0.6 mg L^{-1} of a domestic wastewater. The level of DO in wastewater depicts the degree of contamination of the wastewater by organic matter. On examination, average DO value after 12 weeks of experiment was 2.48 ±0.56 from the wastewater and shows that the effluent from constructed wetland is relatively treated as shown on Table 3. The average DO recorded for the sand and gPKS columns respectively are 3.4 ± 0.345 and 2.9 ± 0.6 mg L^{-1}. This confirmed the reason why the organic load removal from the PKS filter material was averagely low compared to that of the sand filter because enhancement of dissolved oxygen in the sewage after treatment may be due to minimization of organic pollution load in the wastewater during treatment [11]. Though, the DO from the two filters is less than the recommended value of 4.0 mg L^{-1} before discharging to the environment, the table shows a consistency increase in DO values from week 8 to week 12, if this experiment is extended beyond 12 weeks duration, it is expected that the DO values would have reached the minimum standard expected of 4.0 mg DO L^{-1} because more slime would have developed around the filter that will aid the removal of organic matter and consequently increase the DO in the effluent.

Table 3. DO Improvement in the filters

Week	Influent	Effluent (Sand)	Effluent (PKS)
1	3.6	3	3
2	2.3	2.9	1.5
3	1.7	3.3	3.7
4	2.8	4.1	3.8
5	3.1	3.5	3.2
6	2.8	3.4	3
7	1.7	3.3	2.8
8	2.5	2.9	2.7
9	2	3.1	2.9
10	2.7	3.6	3.1
11	2.4	3.4	2.3
12	2.2	3.6	2.9
Ave.	2.48	3.34	2.91
STDV	0.56	0.34	0.60

The *Escherichia coli* in the wastewater were within 65 and 90 cfu 100 mL^{-1}, these values shows that the constructed wetland of the university has greatly removed the E. coli from the wastewater. Figure 4 shows the trend of *E. coli* removal in the sand and gPKS columns. From the figure, the number of *E. coli* in the wastewater ranged between 63 and 89 cfu 100 mL^{-1} that of the effluent from sand was between 10 and 35; while gPKS effluent has values that ranged 0 and 30.

The gPKS column performed better than the sand column is *E. coli* removal, which may portends that the gPKS, though have higher d_{10} but has more adsorption characteristic to *E. coli* which made the removal better than the sand filter. Generally, the removal of the *E. coli* by the sand and gPKS filters was efficient enough and requires only little chlorination for reuse of the treated water or discharging into the environment where necessary. Also it is expected that increasing the duration of the experiment could have eliminate the total removal of the *E.coli*.

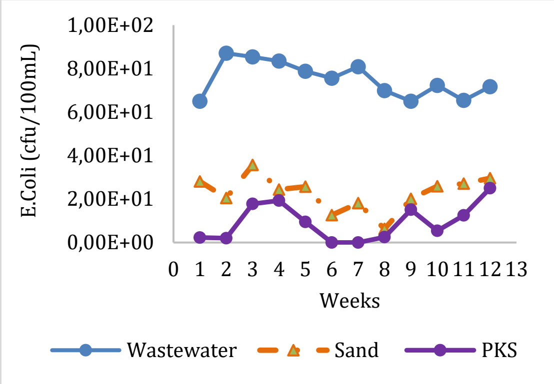

Fig 5. Percentage of *E. coli* removal in the filter

4. CONCLUSION & RECOMMENDATION

The tertiary treatment of effluent from the constructed wetland of University of Lagos, Nigeria was done through Intermittent Sand Filtration using sand and gPKS as different filter medium to ascertain the level of performance of the filters and their suitability as filter material. The pH of the effluent from the sand filter slightly increased from 7.0 to 7.1 while that of the gPKS filter was slightly reduced to 6.7 due to the traces of fatty acid that may be present around the gPKS surface. The DO of the gPKS effluent is 2.9 ± 0.6 mg L^{-1} and it's lower than that of sand filter effluent that if 3.4 ± 0.345 mg L^{-1}. This directly was related to removal of organic matter from the wastewater with the removal of 59.2% and 69.08% BOD_5 efficiency for gPKS and sand media respectively. The removal of *E. coli* was 69.34% in sand filter and 87.49% in PKS filter. The effluent from the filter has between 0 and 30 cfu 100 mL^{-1}, this is greater than the recommended value of Nigeria Standard for Water Quality (2007). This can be removed through little chlorination during the early part of the experiment, As the experiment progresses beyond the 12 weeks, there is possibility of the microorganisms to be removed completely. The renovated water from this system can be re-used in an area where scarcity of water prevails.

It is recommended that further work should be done to look at the use of charring PKS for the study and a long period of time for the experiment to assess the degree of improvement of the quality of the effluent properties.

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