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EFFECTIVENESS OF BURNT OIL PALM SHELL FILTER MEDIA FOR THE REMOVAL OF PHYSICAL CONTAMINANTS IN WATER TREATMENT PROCESS

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ABSTRACT

Drinking water contamination is one of the most important environmental concerns requiring worldwide attention. It is now universally agreed that by providing the community with safe water, the plague of water-borne diseases can be prevented. The increasing global concern on the environment, the utilization of agricultural waste transformed into wealth material for value-added products should be given priority. Thus, this study is using granular bed filtration as a vigorous, simple and economical method to prevent the physical parameter contamination, by discovering an alternative filter media from local source; namely the burnt oil palm shell (BOPS). Granular media filter with mix media classes which is dual-media filtration were found to be reliable surrogates for physical removal and during filtration studies. Dual-media filtration BOPS/sand ES 1.0/0.5 mm is operating optimum condition of removing 82.40% of turbidity, 76.75% of suspended solid and 59.90% of colour. Furthermore, physical properties of BOPS were found to be equivalent or superior to those commercialized available granular filter media with ball-pan hardness of 97.30%. The BOPS was identified as a potential filter media that will help in reducing the cost of water treatment and enhancing environmental sustainability. The results from this study suggested that BOPS should be used as a new biodegradable medium filter in water treatment process, specifically for the removal of physical contaminants such turbidity, suspended solid and colour.

***Keywords**: Burnt Oil Palm Shell, Single-Media, Mix-Media Filter, Colour, Turbidity, Suspended Solid.*

INTRODUCTION

Water is the most indispensable requirements in our daily life. It is now universally agreed that by providing the community with safe water, the plague of water-borne diseases can be prevented. Thus, the primary objective of the water supply scheme is to provide safe water supply for the community. However, with the increasing global concern on the environment, the utilization of agricultural waste transformed into wealth material for value-added products such as coconut shells, cocoa shells, banana peels, bamboo and oil palm kernel shell should be given priority. Using agricultural waste as filtering media in water and wastewater treatment has been a more popular method compared to anthracite, sand or granular activated carbon. In fact, during the last decades, the literature and knowledge on natural filter media in water treatment industry has increased substantially [1]. Although the important consideration in producing a new media filter is abundantly available, easy to maintain and economical are the reasons for the need to discover new filter media in water/wastewater treatment industry. Therefore, new agricultural waste product such as oil palm shell was introduced as an alternative new filter media material. The high rate oil palm shell generated has increased tremendously due to the advancement of oil palm industries in Malaysia. It was reported that the total oil palm kernel production in January 2012 was about 336,421 tonnes [2]. Therefore, the use of oil palm shell as in filter media production is highly essential and beneficial since it will help to reduce the cost of treatment and could reduce dependency on other raw materials [3]. The burnt oil palm shells (BOPS) are prepared from solid waste of oil palm fruit shells which are the by-product from oil palm factories and are abundantly available in Malaysia [1, 4].

Studies by numerous researchers confirm that granular media filtration is a significant process for physical removal and sufficient to meet the standard requirement for water purity in water treatment industry. Granular media filtration offers several advantages which are vital, simple and economical as well aim to produce higher production of water quantity and optimum quality. In this study, BOPS were used as filtration media. Therefore, this study discusses the performance of BOPS as media filter in single-, dual- and tri-media filter layer and was running under rapid depth filtration condition. In order to determine the

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performance of BOPS as physical parameter removal, four (4) types of water quality parameter were chosen for the removal performance of BOPS; namely, Turbidity, Suspended Solid, Colour and pH. On the other hand, two (2) types of flow rate at 5 and 10 $m^3/m^2/hr$ were evaluated in profile filter operation study.

MATERIALS AND METHODS

Design and Construction of Filtration Unit

In this study, conventional deep bed filtrations were used, influent (raw water) was pumped into the header tank and the rest of the process was governed by gravity flow. This study used transparent PVC as the filter column which was made of 5.2 cm diameter and 150 cm height. The filtration unit stands for a total of 3.22 m from the influent basin to the top header tank. The design maximum available head is 2.28 mm and equip with a backwashing facility. The head loss was determined by the level of water from the installed 11 manometer tubes at every 10 cm depth from the bottom of the column until 1 meter high of column. The column was also installed with an over flow pipe to prevent over flow of water as shown in Figure 1.0.

The filtration unit is consisted of single- and dual- media filter. The single media filter were determined by the optimum depth value and consisted of BOPS 1.0, 1.5 and 2.0 mm, sand 0.5 mm and anthracite 0.9 mm. The dual-media filter consisted of 60cm of BOPS (ES = 1.0, 1.5 and 2.0 mm, UC = 1.5) over 40 cm of sand (ES = 0.5 mm, UC = 1.5). Meanwhile, 60cm of anthracite (ES = 0.9 mm, UC = 1.5) over 40 cm of sand (ES = 0.5 mm, UC = 1.5) as a control. The procedure was made based on method [5, 6].

Preparation of Burnt Oil Palm Shell (BOPS) Media

Raw Oil palm shells (Figure 2.0) were burned in the furnace at 300^oC for two hours without oxygen [10]. Then, the oil palm shells after carbonization process (Figure 3.0) were grounded into smaller granules before being sieved to establish a particles' size distribution curve by using a sieve mechanical machine. The purpose of cleaning and washing BOPS before sieving is to remove any available ashes and particles during the burning and grounding processes of the BOPS. BOPS were dried at 103-105^oC in incubator for 24-28 hours. Finally, Raffle Box was used to determine the size distribution of the BOPS media. Burnt oil palm shell and sand were then graded into granules to obtain the required specific uniformity coefficient and effectives sizes. The effective size for sand is 0.5 mm while for BOPS is 1.0, 1.5 and 2.0mm.

Determination of Turbidity and pH

Turbidity of influent and treated water was measured using 2100P Turbidimeter (HACH) by nephelometric method [7]. Removal efficiently of turbidity was obtained using the following Equation 1.0.

$$\text{Turbidity Removal (\%)} = \frac{X_i - X_f}{X_i} \times 100 \qquad (1.0)$$

Where:
X_i = Initial turbidity value
X_f = Final turbidity value

The pH influent and effluent water resulted was measured by pH meter (HACH SensION3) which was determined electrometrically using a combination electrode [8]. The drinking water quality analysis should be in acceptable pH unit as stated by WHO (pH 6.5 – 7.5). This method was applied in accordance to the Standard Methods for the Examination of Water and Wastewater [10].

Determination of Suspended Solid

Suspended solid was measured using DR 2800 spectrophotometer (HACH) by photometric method with 810 nm sample absorbed and resulted in mg/l [9]. The suspended solid percentage is calculated as the following Equation 2.0.

$$\text{Suspended Solid Removal (\%)} = \frac{C_i - C_f}{C_i} \times 100 \qquad (2.0)$$

Where :

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C_i= Initial Suspended Solid Concentration
C_f = Final Suspended Solid Concentration

Determination of Colour

Colour determination was measured using DR 2800 Spectrophotometer (HACH) by spectrophotometric method. Method No. 2120C and reported in Platinum – Cobalt (PtCo) with 455 nm sample absorbed. This method was done in accordance to the Standard Methods for the Examination of Water and Wastewater [10]. Removal efficiency of colour was obtained as following Equation 3.0.

$$\text{Colour Removal (\%)} = \frac{C_a - C_b}{C_a} \times 100 \qquad (3.0)$$

Where:
C_a = Initial Colour Concentration
C_b = Final Colour Concentration

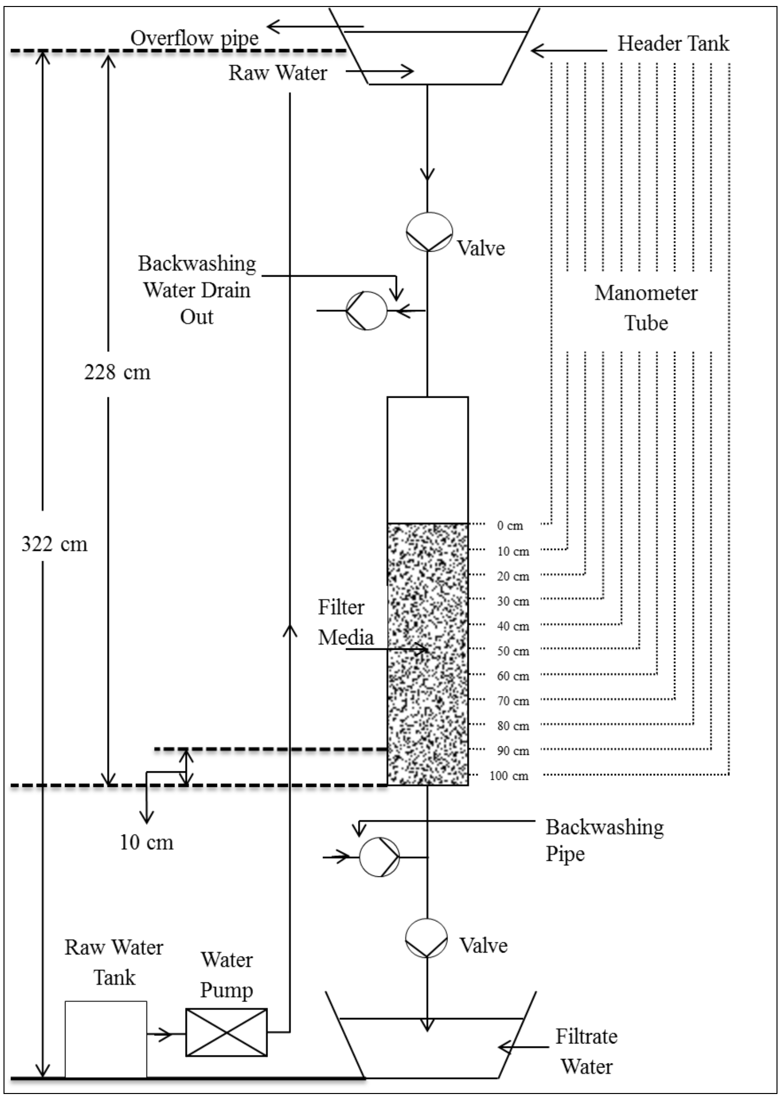

Fig. 1: Schematic diagram of filtration unit in rapid depth filtration

Determination of Ball-Pan Hardness

The ASTM D3802 methods were followed for the purpose of this study. Burnt oil palm shell was sent to Laju Group of Companies in Shah Alam for ball-pan hardness testing. BOPS samples from the particle size distribution test were screened to remove the fractions above the maximal (5% mass retention) and below the minimal (95% mass retention) nominal particle size. 50 g of sample were weighed into 20 cm hardness pan, followed by an addition of fifteen 12.7 mm steels balls and fifteen 9.5 mm steels balls. After 30 minutes in the mechanical sieve shaker, the steel balls were taken out and the sample was then transferred to a hardness test sieve with openings of one half of the minimal nominal particle size of the BOPS sample (estimated from the particle size distribution). The hardness test sieve was shaken for 10 minute on the mechanical sieve shaker, and the mass of BOPS sample retained on the sieve was recorded [11, 12]. The ball-pan hardness number was derived accordingly as stated in Equation 3.6.

$$H = 100 \times (B/A) \qquad (3.6)$$

Where:
H = Ball-pan hardness
B = Mass of sample retained on hardness test sieve (g)
A = Weight of the original BOPS sample (g)

Fig. 2: Raw oil palm shells

Fig. 3: Oil palm shells after carbonization process

RESULTS AND DISCUSSIONS

Physical Contaminants Removal

Overall, all the results are showing great findings where BOPS was investigated as an alternative filtration media and could exhibit almost the same characteristics as sand, anthracite and granular activated carbon in treating raw water and at the same time is able to produce good quality of filtrate water. BOPS have shown its capability in producing a moderately higher removal of physical parameters effluent. Besides, the performance of BOPS might be able to be improved by utilizing much smaller effective sizes and multiple layer of media filter [4].

The influent used in this study was changeable at any times as stated in Table 1.0. Among all filters, the best performance of granular media filter was the dual-media filter, at the same time; tri-media filter is also comparable with dual-media filter performance, and followed by single media filter. The scenario was the same between all filters in physical parameters characteristic which are turbidity, suspended solid and colour. Significantly all the patent of the percentage removal begin with turbidity and followed by suspended solid and finally by colour parameters as state in Figure 4.0.

Based on the physical characteristics factor, the performance of BOPS as media filter can be specified in three (3) physical characteristics; namely, turbidity, suspended solid and colour. First characteristics are the percentage of reduction of turbidity. Turbidity removal efficiency was inversely proportional to increase flow rate [14]. BOPS performance as dual- and tri-media filter were able to treat the influent water with higher reduction (Figure 6.0 and 7.0), whereas dual-media filters at flow rate 5

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$m^3/m^2/hr$ produce percentage of turbidity removal by using BOPS/Sand: 1.0mm/0.5mm was 82.40%, followed by tri-media filters BOPS/ GAC/ Sand: 1.0mm/ 0.89mm/ 0.5mm was 73.34%. Meanwhile, anthracite performance as a control in this study was 83.90% and 72.57% for dual-media (anthracite/sand: 0.9mm/0.5mm) and tri-media (anthracite/ GAC/ sand: 0.9mm/ 0.89mm/ 0.5mm) respectively. Furthermore, the flow rate of 10 $m^3/m^2/hr$ reduces the percentage of removal of turbidity other than 5 $m^3/m^2/hr$. Overall, turbidity removal by using BOPS as a media filter were capable to produce higher reduction of feed water quality and also better performance by comparing with anthracite media, also known as the commercial media filter in worldwide water treatment industry.

Table 1: The characteristics of raw water from Klang River taken from 1K02 sampling station

Parameter	Mean	Minimum	Maximum	Class IIIa
Turbidity (NTU)	224.93	56.40	977.00	-
Suspended Solid (mg/l)	228.61	98.00	695.00	150
Colour (PtCo)	1097.62	600.00	3650.00	-
pH	7.17	6.31	7.76	5.0 – 9.0

[a] Class III of Interim National Water Quality Standard (INWQS) recommended by Department of Environment (DOE) Malaysia [13].

A second characteristic is suspended solid. The suspended solid treated water produce the same trend as turbidity removal. Suspended solid percentage reduction increased with the decrease in effective size of media filter at the same flow rate. Dual-media BOPS/sand ES 1.0mm/0.5mm demonstrated 76.75% reduction when compared to BOPS/sand ES 2.0mm/0.5mm resulted 74.27% at a flow rate of 5 $m^3/m^2/hr$. Meanwhile, the percentage of removal reduces at 10 $m^3/m^2/hr$ other than 5 $m^3/m^2/hr$ where 62.79% and 61.64% for BOPS/sand ES 1.0mm/0.5mm and BOPS/sand ES 2.0mm/0.5mm respectively. This result showed is similar as the one reported by literature [15] where it was pointed out that fine grained media produce better filtrate quality than the course grained. Besides, the flow rates also play an important role in producing better performance of granular media filtration, as in Figure 5.0, 6.0 and 7.0, 5 $m^3/m^2/hr$ showed higher percentage of reduction compared with 10 $m^3/m^2/hr$ in similar ES value. This phenomenon happened because of lower of flow rate value is able to capture and trap suspended particles within more layer of filter bed and remove larger amount of suspended particles in feed water

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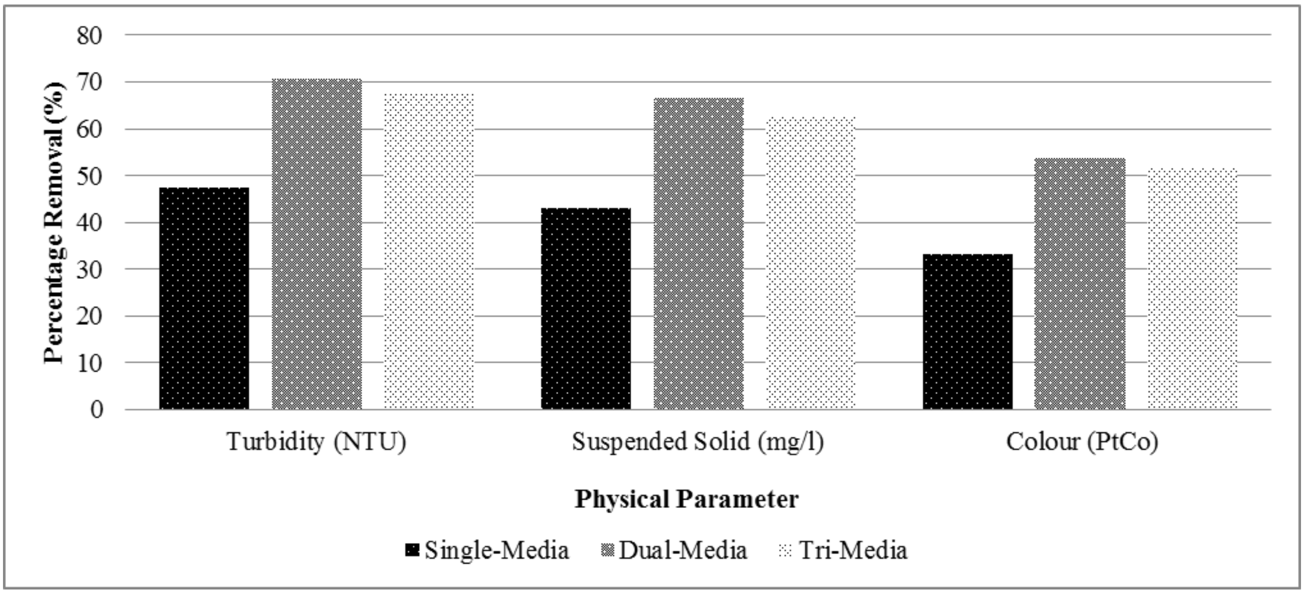

Fig. 4: Percentage reduction of turbidity, suspended solid and colour in single-, dual-and tri-media filters.

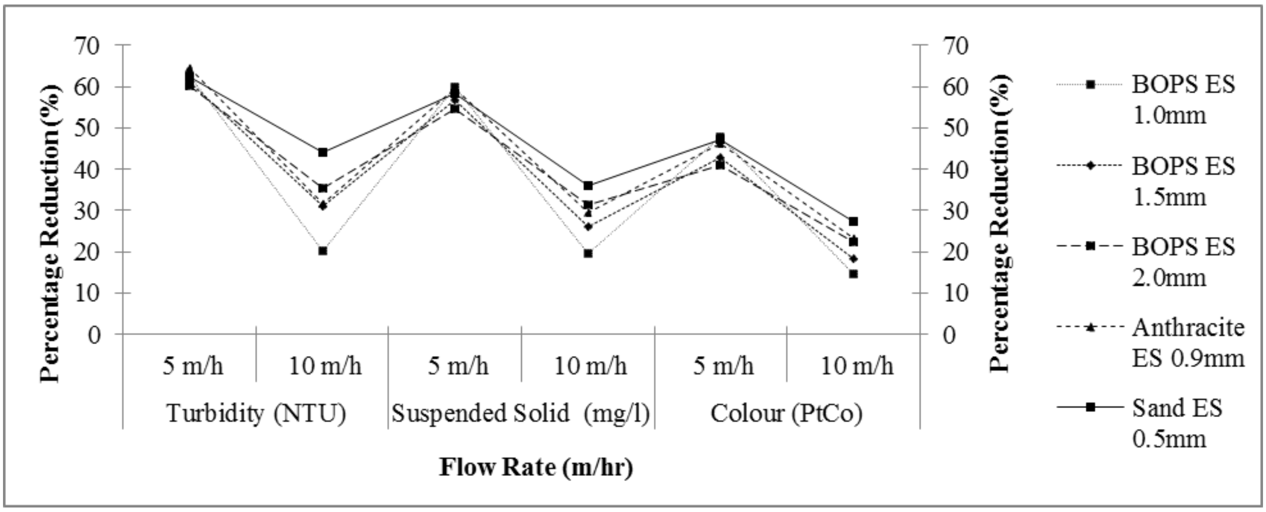

Fig. 5: The percentage reduction between two flow rates and effective size in single- media filtration.

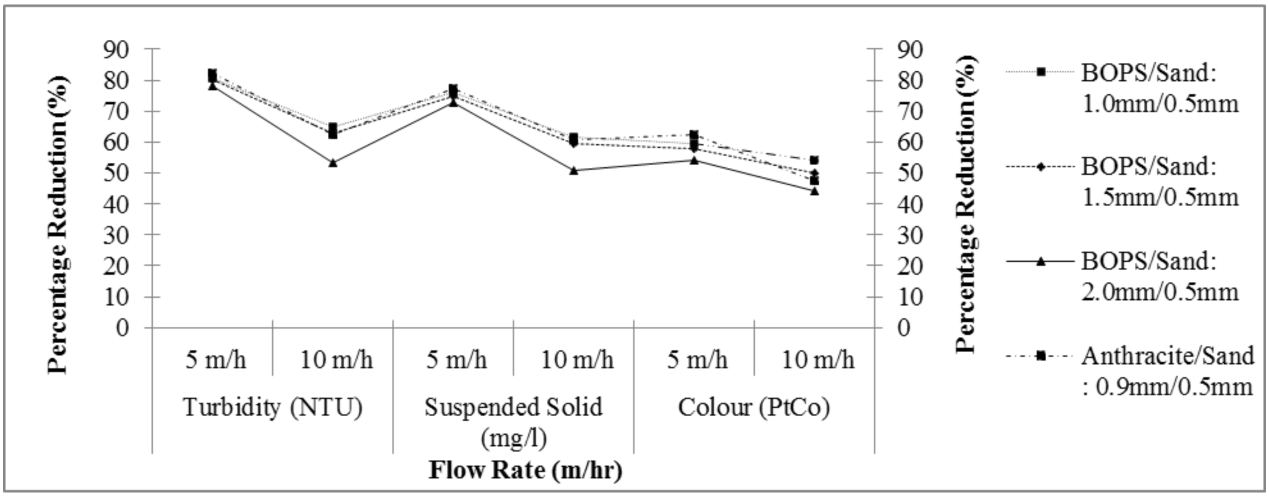

Fig. 6: The percentage reduction between two flow rates and effective size in dual- media filtration.

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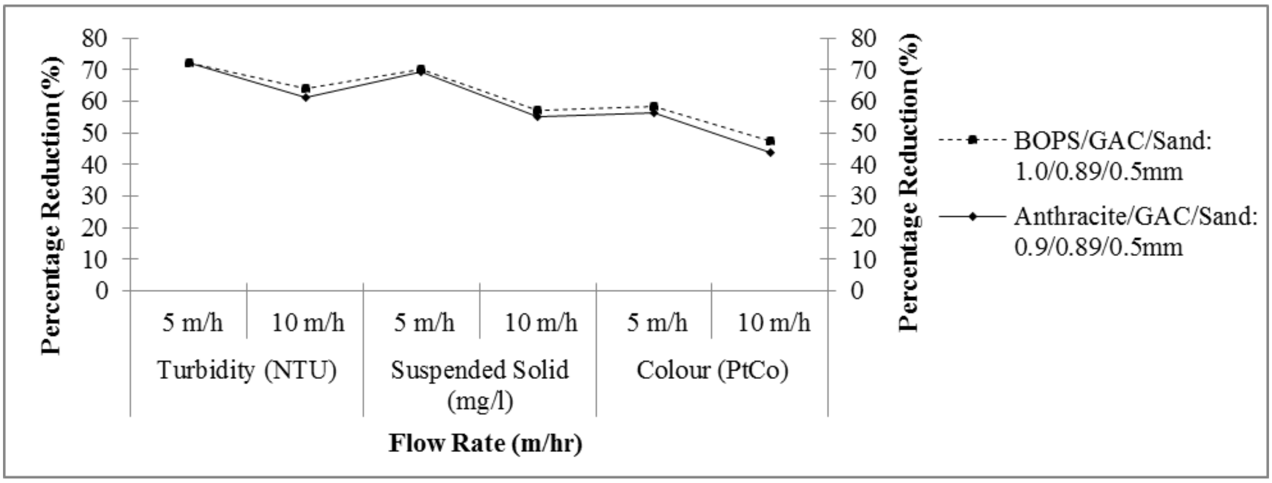

Fig. 7: The percentage reduction between two flow rates and effective size in tri-media filtration.

Coloured water sample was contributed by the decomposition of organic matter by presence of humic acid [16, 6]. Furthermore, humic substances also contribute to the colour as well as acidity problems in water supplies [17]. In highly colored water sample, ranging from 600 to 3650 PtCo as stated in Table 1.0, water sample due to highly turbidity and suspended solid was treated by BOPS. Result indicated that higher reduction in dual-media BOPS/sand: 1.0mm/0.5mm (59.90%) and the result was comparable with control, anthracite/sand: 0.9mm/0.5mm (62.60%) in both similar flow rate 5 $m^3/m^2/hr$ (Figure 6.0). The combination media BOPS/sand: 1.0mm/0.5mm at flow rate 5 $m^3/m^2/hr$ exhibited the best results in terms of colour removal. Overall, higher colour removal was obtained by dual-media filtration, followed by tri-media and finally by single-media filtration and the phenomenon was same at flow rate 10 $m^3/m^2/hr$. The experimental result represents turbidity and suspended solid was proportional to colour value. The scenario was the same for both 5 and 10 $m^3/m^2/hr$ where higher flow rate value decreases removal performance.

The influence of pH in this study was investigated for both influent and effluent water sample. There are several findings where pH value is also not affected by layer of media filter and in this study, the pH of the water sample was acceptable in specification of WHO standards (Mean of water sample: pH 7.14) (Table 1.0). In this study, lesser dissimilarities of pH shows no significant effect on removal of turbidity, suspended solid and colour as discovered by literature [6].

It is important to note that during the present investigations, the filter media performance was indicated by the flow rate value. For the flow rates of 5 and 10 $m^3/m^2/hr$, higher flow rate increases particle passage through the filter media and the trend was the same for physical parameter i.e. turbidity, suspended solid and colour and the phenomenon as reported in the literature [14]. For all flow rates, a more significant particle removal occurred in BOPS media either in single-, dual- and tri-media filter. Meanwhile, sand ES 0.5mm (single-media), anthracite/sand ES 0.9/0.5mm (dual-media) and anthracite/GAC/sand ES 0.9/0.89/0.5mm (tri-media) showed that lower particle removal occurs in the filter bed. Based on the experiment, removal performance of physical contaminants is contributed by the flow rate; increases of flow rate was largely contributed to reduces of straining and attachment process, hence turbidity, suspended solid and colour removal significantly reduces in 10 $m^3/m^2/hr$ other than 5 $m^3/m^2/hr$.

Ball-Pan Hardness

Utilization of agricultural waste as a source for filter media has its own value-added and is an environmentally beneficial approach for such waste to wealth product. In this study, the overall quality of burnt oil palm shell was systematically evaluated based on physical performance. Ball-pan hardness was the physical method to determine degradation or attrition to resistance [11]. This method is an important physical characteristic to sustain physical character and resist frictional forces imposed by backwashing process. Higher hardness number suggested stronger resistance to mechanical abrasion. Ball-pan harness for commercial purposes ranges from 70 to 100, while BOPS was 97.30%. Ball-pan hardness for BOPS demonstrated overall quality comparable to the common materials used for producing activated carbon i.e. coconut shell and bituminous coal (Table 2.0).

Table 2: Ball-pan harness of burnt oil palm shell as compared with commercial products

Type of Media	Ball-Pan Hardness (%)
(Burnt Oil Palm Shell)	**97.30**
Bituminous Coal Activated Carbon	98.10
Coconut Shell Activated Carbon	92.40
PUR-RF Carbon (water Filtering)	55.40
Coconut-Shell Derived MC450	95.00

Source: [11]

CONCLUSIONS

This investigation has yielded several important insights the performance of BOPS as a physical contaminants removal in water treatment process. Dual media BOPS/sand as a filter media proved to be a successful combination in turbidity, suspended solid, colour and pH contaminants removal when compared with other commercial filter media.

It is recommended that the optimum performance of BOPS is dual-media filtration BOPS/sand ES 1.0/0.5mm with varied flow rate. It is seen that physical performance of BOPS as a removal agent are higher when compared with other commercial granular filter media used in water and wastewater treatment industry. In addition, during experiments, it is found that colour reduction is significant to the trend of suspended solid concentration removal compared to the turbidity removal and this situation is fairly similar for all type of media, single-, dual- and tri-media filter as well as for varied flow rate.

The results of this study confirmed that burnt oil palm shell can be used as a new filter media and perform in aspect of physical characteristics. In fact, the result of ball-pan hardness test conducted confirms that burnt oil palm shell demonstrated overall quality comparable to other commercial product.

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