© Universiti Tun Hussein Onn Malaysia Publisher's Office

JAESRR

http://publisher.uthm.edu.my/ojs/index.php/jaesrr

e-ISSN : 2821-2819

Journal of Advancement in Environmental Solution and Resource Recovery

An Overview of Activated Carbon Coconut Shell and Banana Trunk Fiber as Bio-Filter for Kitchen Wastewater Treatment

Nurul Syakila Nasaruddin[1], Radin Maya Saphira Radin Mohamed[2]*

[1]Department of Civil Engineering, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, MALAYSIA

[2]Micropollutant Research Centre (MPRC), Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/jaesrr.2021.01.01.004
Received 02 November 2021; Accepted 01 December 2021; Available online 07 December 2021

Abstract: Kitchen wastewater from the cafeteria is the presence of the Chemical Oxygen Demand (COD), Total Suspended Solid (TSS) and organic substances in the runoff that required rapid action. The aim of this research is to determine the concentration of COD and TSS from kitchen wastewater and to measure the influence of Activated Carbon Coconut Shell (ACCS) and Banana Trunk Fiber (BTF) in optimization the percentage of kitchen wastewater with tap water and time using RSM. ACCS is an activated carbon using agricultural waste which is coconut shell that act as an adsorbent to reduce pollutant. Banana trunk fiber is a bio-waste that is available in abundance to be used as bio filtration. The use of ACCS and BTF can potentially reduce the environmental impact due to improper practice of disposal. ACCS and BTF material have been proven by previous studies on the effectiveness to reduce the pollutant. The effectiveness of ACCS and BTF was measured by its removal efficiency. This review has discovered that ACCS and BTF is capable to reduce the COD and TSS concentration from kitchen wastewater based on the previous studies.

Keywords: Kitchen Wastewater (KWW), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Coconut Shell Activated Carbon (ACCS), Banana Trunk Fiber (BTF)

1. Introduction

The world population is on the verge of water shortage that demands correct water resources management to satisfy the needs of the apace growing population. Wastewater is produced through the everyday activities such as cooking and cleaning. These wastewaters may have harmful impact on the environment and water bodies due to the organic and inorganic pollutants [1]. In Malaysia, it is found that the effluent discharge from the kitchen can be caused the water pollution from the high concentrations of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Total Suspended Solid (TSS) due to the food operation have its own traits [2]. Organic matter, soap, and detergent constitute the majority of the kitchen wastewater generated by households, restaurants, and the food industry [3]. Food materials and oil and grease contribute to organic composition in the kitchen wastewater. Therefore, it is crucial to eliminate the pollutants before discharge and reduce environmental pollution.

Activated carbon has been used in the bio-filtration as an adsorbent. Activated carbon is well known for removing the compound from containment waters [4]. Coconut Shell Activated Carbon (ACCS) is one of the raw material adsorbents for removal of COD and TSS and found high efficiency of reduction up to 52.1% and 47.53% [5]. In addition, the use of Banana Trunk Fiber (BTF) has been studies and showed it has high removal adsorption for oil and grease [2]. Hence, these materials are expected to improve the kitchen effluent runoff from the cafeteria.

Corresponding author: maya@uthm.edu.my

The main problem of kitchen wastewater from the cafeteria is the presence of the COD, TSS and organic substances in the runoff that required rapid action. The amount of meal prepared daily by Tun Dr Ismail Resident College (KKTDI) cafeteria can affect the quality of the wastewater released. Food preparation and washing dishes activities were mainly contributed to the high concentration of COD and TSS. Dishwashing detergent used for washing dishes can cause high COD content. Clay and sand from the rinsing of vegetables and fruits make a significant contribution to a high concentration of TSS. These problems need immediate action because high concentrations of COD, TSS and organic substance can harm the public health and the environment. Thus, it can pollute the primary source of water and cause an unpleasant smell that affect the environment and resident's health.

The aim of this research is to determine the concentration of COD and TSS from kitchen wastewater from previous studies and to measure the influence of ACCS and BTF in optimization the percentage of kitchen wastewater with tap water and time using RSM. ACCS is an activated carbon using agricultural waste which is coconut shell that act as an adsorbent to reduce pollutants. BTF is a bio-waste that available in abundance to be used as bio filtration. The use of ACCS and BTF can potentially reduce the environmental impact due to improper practice of disposal. Sand is standard natural media that has the potential to act as filter in kitchen wastewater.

2. Kitchen Wastewater

2.1 Types of Kitchen Wastewater

Kitchen wastewater has a variety of waste contains depend on the production of food services establishment. Typically, kitchen wastewater consists of fats, oils and grease (FOG) and an additional surfactant (dishwashing detergent) to remove oil and grease on a plate or spoon. Meat, sauces, gravy, appetizers, deep-fried food, baked goods, cheese, and butter are examples of waste from the restaurant that causes the presence of FOG. The impact of these product discharge without any treatment can solidify the FOG contain in the sewage system [6].

Kitchen wastewater is made of organic matter, soap and detergent, produced by households, restaurants and food industries [3]. The food materials, oil and grease are mainly contributed to organic composition. The amount of effluent generated in the kitchen depends on kitchen installations (kitchen sink and tap water) and the number of food and beverages eaten per day. The wastewater production is different for each place and their composition is according to the cooking activities, dishwashing in the kitchen, hand wash soap and vegetable or fruit washing at the kitchen [7].

Table 1 indicates the kitchen sources and their constituent from two different residential. The constituents from a household depend on individual cooking activities. Residents' dietary habits contain vegetables, protein, fruits, carbohydrates, and other types of waste [8]. For instance, most common carbohydrates in the domestic source derived from the kitchen effluent wastewater were rice and noodles. Malaysian consume white rice during lunch and dinner twice a day [9]. Based on this finding, rice was the staple lead food for Malaysian. The chemical compound from several washing agent and detergent are linear alkylbenzene sulphonate and methylene blue active substances [10]. A constituent from the kitchen also contains microorganisms, high level of suspended solids, turbidity, organic substances. The composition of kitchen effluent was related to the food, beverages and the chemical used in the dishwasher by household difference depending on consumer preference.

Table 1 - Constituents of kitchen effluent wastewater from a domestic source

Researchers	Constituents
[8]	Vegetable peels, spoiled fruits, food remains after consumption, meat waste, fish waste, rice, noodles, bread, tea leaves.
[10]	Dishwashing detergents, oil and fats, food residue, hot water, raw meat washing, fruit and vegetable peels, tea or coffee, traces of food preservatives, sand and clay particles.

2.2 Parameter Associated with Kitchen Wastewater

Significant influence physicochemical parameter for kitchen effluent is Chemical Oxygen Demands (COD), Total Suspended Solids (TSS), pH and oil and grease (O&G). Previous studies on the characteristics of kitchen effluent from various research are shown in Table 2.

The highest amount of pH values indicate from the previous studies was from Cranfield University Café, which was 10.5 to 12 in alkalinity state. Factor affecting the pH value was the sources contain a variety of food particles that contaminate the kitchen effluent. COD value is recorded to analyze the biodegradability of an effluent. Different sources contain difference constitutes. Student cafeteria had the highest concentration of COD which in range from 1950 mg/L to 34100 mg/L due to the cafeteria constituent from the kitchen effluent which was boiled rice, vegetables, fruit, tea, cooked meat and bones, tofu, and tempeh [11]. The highest COD value contribute by the chemical used in the food ingredient and chemical contains in the dishwashing detergent. The highest amount of TSS in the kitchen effluent recorded by Asian Cafeteria which was 2400 mg/L. Highest concentration of TSS generated from the cafeteria was due to large particles of foods. TSS contains in the kitchen effluent wastewater is related food composition particle discarded at the kitchen sinks. The highest concentration of O&G was in range from 415 mg/L to 1970 mg/L derived from student canteen due to the type of cooking oil been used [12]. The presence of O&G in the effluent would cause blockage to the pipes, clogging and corrosion to the lines. Thus, it can affect the effluent operation system. A high concentration of COD, TSS, and O&G in kitchen wastewater were dependent on the cafeteria's food service. As a result, the kitchen wastewater may have a high concentration of organic chemicals, and it is crucial to treat it for safe disposal and to avoid environmental problems.

Table 2 - Characteristic of kitchen wastewater from various sources

Sources	pH	TSS (mg/L)	COD (mg/L)	Oil and grease (mg/L)	Researchers
Student Canteen	6.82 – 8.76	124 – 1320	900 - 3240	415- 1970	[12]
Student’s Mess	5.5	-	100 -1100	-	[13]
Cranfield University Cafe	10.5-12.0	272 - 912	309 - 1790	112 -494	[14]
Asian Café Cafeteria	7.1	2400	8100	1110	[14]
Cafeteria	0.45 – 3.11	-	1950 - 34100	-	[9]

(-) not mentioned

3. Activated Carbon

3.1 Types of Activated Carbon

Activated carbon has been proven to work best as an adsorbent for treating natural organic compounds, taste, odour compounds and synthetic organic chemicals. An adsorbent efficiency depends on various factors such as surface area, pore size distribution, adsorbate molecule size, temperature, pressure, moisture content, and concentration of adsorbate [4]. For activated carbon, surface area and pore size distribution are the main factors that contribute to large adsorption capacity [15]. Basically, plenty of adsorbent with various range of materials has been tested for wastewater treatment.

Many variables influence the choice of a precursor. The precursor should be easily accessible, cheap, high carbon levels in the adsorbent are required for effective adsorption outcomes. Table 3 indicates the removal efficiency of COD, TSS, O&G from difference type of activated carbon. COD removal efficiency after 150 min was 95.4% by using date palm waste AC [16]. The removal efficiency of COD, TSS, O&G from domestic wastewater were 33.85%, 45.8% and 47.19%, respectively [17]. Removal efficiency for O&G by palm kernel shell was 99.89% [18]. The removal efficiency for COD and TSS were 56.45% and 42.11%, respectively, by using palm kernel shell activated carbon [19]. COD and TSS removal efficiency were 73.84 % and 78.67% respectively using coconut shell activated carbon [20]. The removal efficiency for COD and TSS were 97.21% and 93.84% by using coconut shell activated carbon [21].

Table 3 - Comparison of COD, TSS, oil and grease (O&G) removal efficiency of activated carbon made from date palm waste, sugarcane bagasse, palm kernel shell and coconut shell by previous studies

Types of effluent treatment	Activated Carbon Material	Removal Efficiency (%)			Researchers
		COD	TSS	O&G	
Sewage Wastewater	Date Palm Waste	95.40	-	-	[16]
Domestic Wastewater	Sugarcane Bagasse	33.85	45.80	47.19	[17]
Industrial Wastewater	Palm Kernel Shell	-	-	99.89	[18]
Greywater	Palm Kernel Shell	56.45	42.11	-	[19]
Industrial Wastewater	Coconut Shell	72.84	78.67	-	[20]
Greywater	Coconut Shell	97.21	93.84	-	[21]

(-)- not mentioned

The results showed different activated carbon has different removal efficiency. Coconut shell activated carbon proven by [20] and [21] as the most effective activated carbon and capable of removing pollutant from effluent. Therefore, the activated carbon from coconut shell was selected to be used in this study based on the effectiveness and its ability to remove COD and TSS.

3.2 Coconut Shell as Adsorbent Material

Table 4 presents the roles of ACCS as an adsorbent to remove the pollutants in wastewater. The table indicates that the researcher used a different duration of contact time. According to [22], an hour contact time is the best duration for coconut shell adsorption process to remove organic pollutants. Meanwhile, the optimum absorption time for coconut shell was 0.5 hours according to [23]. Based on finding from [22], the longer contact time reduce the removal efficiency of pollutant. The adsorption decrease as the time increase and it also depend on the behavior of the ACCS's surface [22]

COD concentration was detected at 80 mg/L before treatment and 16 mg/L after treatment by using ACCS as an adsorbent [22]. Meanwhile, [23] reported that COD concentration was ranged between 258 mg/L before treatment and 40 mg/L after treatment with ACCS. It can conclude that, [23] achieved higher removal percentage of pollutant which was 84% compared to [22] which was 80%. Besides that, the initial amount of TSS in the effluent was 22 mg/L and the concentration was reduced to 15 mg/L [22]. The removal percentage of TSS used ACCS adsorbent achieved 32%.

Table 4 - The use of ACCS as an adsorbent from previous studies

Times (hours)	COD (mg/L)		TSS (mg/L)		Removal Percentage (%)	Researchers
	Before	After	Before	After		
1	80	16	22	15	COD: 80 TSS: 32	[22]
0.5	258	40	-	-	COD: 84	[23]

The removal efficiency of COD, TSS, O&G are increase over the contact time. A large number of vacant surface sites are available for adsorption. After sometimes, the efficiency of removal pollutant can be reduced due to the active sites' bonding is filled by the substances. At the beginning of the stages, adsorption ability to absorb pollutant into the mesopores is high. However, over time mesopores is filled with pollutant at the adsorbent surface. As a result, mass transfer between the bulk liquid phase and the solid phase decreases and slower down the adsorption ability [2].

4. Natural Material

4.1 Natural Media as A Key Media for Treating Kitchen Wastewater

Table 5 shows the concentration of COD, TSS and O&G in kitchen wastewater before and after treatment with natural materials. Before treated with banana trunk fiber, COD concentration for kitchen wastewater was 851 mg/L and 246.79 mg/L for before and after treatment, respectively [2]. Meanwhile sisal fiber and areca nut husk were capable of reducing COD concentration in range from 193 mg/L to 65 mg/L. COD concentration recorded by peat soil natural material was in range from 149 mg/L to 85 mg/L. It can be concluded that BTF was the best material to reduce the effluent's COD concentration compared to sisal fibre, areca nut husk and peat soil. Cellulose content in the BTF is beneficial to remove the pollutants [2].

Table 5 - Concentration of kitchen wastewater treated with natural materials

Material	COD (mg/L)		TSS (mg/L)		O&G (mg/L)		Researchers
	Before	After	Before	After	Before	After	
Carbonised glass and clay	-	-	-	-	248.30	3.72	[24]
Banana trunk fiber	851	246.79	363	61.71	632	265.44	[2]
Sisal fibre and areca nut husk	193	65	115	21	8.9	4.7	[17]
Peat soil	149	85	312	43	136.6	25.24	[25]

The higher concentration of TSS in the kitchen effluent was reported by [2] compared to [17] and [25]. TSS concentration before treatment was found to be 363 mg/L, 312 mg/L and 115 mg/L respectively from study conducted by [2], [17] and [25]. After treatment, the TSS concentration recorded was 61.71 mg/L, 43 mg/L and 21 mg/L respectively [2,25,17]. The removal efficiency percentage was 80% for BTF, 72% for peat soil and 45.8% for Sisal fibre and areca nut husk. It is concluded that BTF was the most effective material to remove TSS concentration.

The highest initial concentration of O&G indicates from kitchen wastewater was 632 mg/L [2]. The O&G concentration was lower with an average measured were 8.9 mg/L, 248.30 mg/L and 136.6 mg/L respectively [17, 24,25]. After filtration with the different natural materials, it is shown that the concentration of O&G reduced to 265.44 mg/L (BTF), 3.72 mg/L (carbonised glass and clay), 25.24 mg/L (peat soil) and 4.7 mg/L (Sisal fibre and areca nut husk). In conclusion, BTF was proven as excellent in O&G removal. Therefore, BTF is the best natural material to reduce the COD, TSS and O&G. Hence, banana trunk fiber was selected as another adsorbent material to treat the kitchen wastewater effluent.

4.2 Chemical Composition of Banana Trunk Fiber

Banana is a tropical herbaceous plant easily found in Malaysia and it is one of the most popular consumed fruits in the world. The previous researcher has studied the chemical composition of banana trunk fiber. [2] and [26] found out that the banana trunk contains three essential chemical compositions which were cellulose, hemicellulose and lignin. This chemical composition is essential to enhance the fiber strength and make it difficult to break. The cellulose, hemicellulose and lignin content in the banana trunk differed significantly. Table 6 indicates the percentage of the chemical composition of the banana trunk fibers. Cellulose composition content in the banana trunk fiber was 58.5% which is the high amount compared to hemicellulose (15.4%) and lignin (13.2 %). According to [2], cellulose, hemicellulose and lignin were determined followed the TAPPI standards method T 222 om-88 (lignin content).

Table 6 - Chemical composition of banana trunk fiber from the previous study

Properties	Percentage (%)
Cellulose	58.5
Hemicellulose	15.4
Lignin	13.2

5. Design Criteria of Bio-Filtration System Prototype

Bio-filtration is commonly used as water treatment method due to its effectiveness in extracting biodegradable organic matter and low maintenance costs [27]. In addition, the use of ACCS and BTF can provide optimized active support to the wastewater treatment. Table 7 illustrates various bio-filtration design with different dimension, shape, material and layer of materials.

The suggested size of bio-filter was 800 mm × 900 mm × 650 mm and separated by six parts with 150 mm for each part. Each compartment is filled with three packets of sponge, 5 kg coarse gravel, 10 kg sand, 40 pieces mudball, 15kg charcoal activated carbon and 3 kg empty fruit bunch. An inlet pipe is used for the wastewater to flow into the filter [28]. Meanwhile, [29] designed the bio-layer filter contains two materials: sand and activated carbon. The dimension of column filtration prototype is 80 mm diameter with 700 mm height. Column filter was filled with 240 mm of ACCS for the first layer, 360 mm sand for the second layer and on top of the column with 100 mm wastewater samples. The similarity of both studies indicates the utilization of sand in the bio-filtration. According to a review by [30], TSS concentration in the wastewater decreased to 40% after treated with sand filtration. The application of sand in the filtration as a treatment media to remove nutrients and organic has been reported by [25]. The function of sand is as a filtering support for the wastewater treatment [29].

Table 7 - Design of the bio-filtration from previous studies

Researchers	Dimension (mm)	Shape	Material	Layering
[28]	800 × 900 × 650	Rectangular	acrylic	1. coarse gravel 2. sand 3. mud ball 4. activated carbon by charcoal 5. Empty Fruit Bunch (EFB)
[29]	Diameter (Ø): 80 Height: 700	Cylinder	PVC	1. Sand 2. Activated carbon

6. Conclusion

The kitchen effluent has a high concentration of COD, TSS and O&G from the previous studies, which in a range of 1950 – 34100 mg/L, 124 - 2400 mg/L, 415 - 1970 mg/L, respectively. Therefore, it is crucial to treat the kitchen effluent before the major effect on the environment occur. The kitchen effluent should be designed to treat these three pollutants for safe disposal. For this study, activated carbon made of agriculture waste which is ACCS. ACCS and natural fiber from the BTF are used as an adsorbent and it is suitable to use in the bio-filter to reduce the effluent contaminants. ACCS and BTF is a material has been proven by previous studies on the effectiveness to reduce the pollutant. The ACCS has a suitable porous structure and surface area to absorb the pollutant. The higher the porous structure and surface area the higher potential for the removal efficiency. Meanwhile, banana trunk has cellulose, hemicellulose and lignin for O&G removal in kitchen wastewater.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Mohamed, R. M., Al-Gheethi, A. A., Aznin, S. S., Hasila, A. H., Wurochekke, A. & Kassim, A. H. (2017). Removal of nutrients and organic pollutants from household greywater by phycoremediation for safe disposal. *International Journal Energy Environment Engineering, 8,* pp. 259-272. Retrieved January 4, 2021 from doi:10.1007/s40095-017-0236-6

[2] Daud, Z., Suhani, N., Mohamed, R. M. & Awang, H. (2015). Feasibility of Banana (Musa sapientum) Trunk Biofibres for Treating Kitchen Wastewater. *Nature Environment and Pollution Technology, 16*(4), pp. 1205 – 1210.

[3] Parwin, R., & Paul, K. K. (2020). Overview of applications of kitchen wastewater and its treatment. *Journal of Hazardous, Toxic, and Radioactive Waste*, *24*(2): 0401904, pp. 1-11. Retrieved January 6, 2021 from doi: 10.1061/(ASCE)HZ.2153-5515.0000482

[4] Gopalswami, P., Ponnusamy, S., Sivakumar, N. & Ilamparithi, A. (2010). methylene blue adsorption onto low cost powdered activated. *Nature Environment and Pollution Technology, 9*(2), pp. 317-322.

[5] Sruthi, M. S. & Sheena, N. K. (2019). Dairy waste water treatment using coconut shell activated carbon and laterite as low cost adsorbents. *International Research Journal of Engineering and Technology, 6*(6), pp 3-6-309.

[6] Garza, O. A. (2004). Food service establishment wastewater characterization and management practice evaluation. Retrieved January 5, 2021 from https://hdl.handle.net/1969.1/3220

[7] Noutsopoulos, A. A., Kouris, N., Charchousi, D., Mendrinou, P., Galani, A., Mantziaras, I. & Koumaki, E. (2017). Greywater characterization and loadings Physicochemical treatment to promote onsite reuse. Journal of Environmental Management, 216, 00. 337-346. RetrievedJanuary 1, 2021 from doi: 10.1016/j.jenvman.2017.05.094

[8] Yatim, S., Hamid, K., Ismail, K., Rashid, Z., Zainuddin, N., Shafie, F. & Azmi, A. (2019). Study on waste generation and composition in rapid residential development of sub urban area in Kuala Selangor district, Selangor. *Journal of Wastes and Biomass Management, 1*(1), pp. 01-05. Retrieved January 2, 2021 from doi: http://doi.org/10.26480/jwbm.01.2019.01.05

[9] Lipoeto, N., Geok Lin, K. & Angeles-Agdeppa, I. (2013). Food consumption patterns and nutrition transition in South-East Asia. *Public Health Nutrition, 16*(9), pp. 1637-1643. Retrieved January 3, 2021 from doi: doi:10.1017/S1368980012004569

[10] Ahammed, M. M. & Shaikh, I. N. (2020). Quantity and quality characteristics of greywater: A review. *Journal of Environmental Management, 261*(110266), pp. 1-15. Retrieved January 2, 2021 from https://doi.org/10.1016/j.jenvman.2020.110266

[11] Marcelinus, C., Hadiyanto, H., Motto, S. A., Sudarno, S. & Haryani, K. (2020). Performance evaluation of yeast-assisted microalgal microbial fuel cells on bioremediation of cafeteria wastewater for electricity generation and microalgae biomass production. *Biomass and Bioenergy*, *139*(105617), pp. 1-10. Retrieved January 4, 2021 from 10.1016/j.biombioe.2020.105617

[12] Chen, X. C. (2000). Separation of pollutants form restaurant wastewater by electrocoagulation. *Separation and Purification Technology, 19,* pp. 65-76. Retrieved January 3, 2021 from doi: 10.1.1.1072.2899

[13] Bhattacharyya, D. & Katam, K. (2018). Comparative study on treatment of kitchen wastewater using a mixed microgal culture and an aerobic bacterial culture: kinetic evaluation and FAME analysis. *Environmental Science and Pollution Research, 21,* pp. 20732-20742. Retrieved January 6, 2021 from doi:10.1007/s11356-018-2209-6

[14] Gurd, C., Jefferson, B. & Villa, R. (2019). Characterisation of food service establishment wastewater and its implication for treatment. Journal of Environmental Management, 252, pp. 1-8. Retrieved January 3, 2021 from https://doi.org/10.1016/j.jenvman.2019.109657

[15] Changjia, J., Shuang, C., Qing, H., Ping, L., Qikai, Z., Jianhui, S. & Mingrui, L. (2019). Study on application of activated carbon in water treatment. Earth and Environmental Science, 237(022049), pp. 1-5. Retrieved January 8, 2021 from doi:10.1088/1755-1315/237/2/022049

[16] Nayl, A. E. A., Elkhashab, R. A., Malah, T. E., Yakout, S. M., El-Khateeb, M. A., Ali, M. M S. Ali, H. A. (2017). Adsorption studies on the removal of COD and BOD from treated sewage using activated carbon prepared from date palm waste. *Environment Science and Pollution Research, 24*(28), pp. 22284-22293. Retrieved January 4, 2021 from doi: 10.1007/s11356-017-9878-4

[17] Vijayalakshmi, P., Eshanthini P., Vanitha S., R. Sharath Kumar & B. Vigneshwaran. (2019). Reduction of strength of domestic wastewater using natural fibrous materials. *Journal of Chemistry, 12*(4), pp. 2290-2295.

[18] Ramli, A. N. & Rozidaini, M. G. (2020). Removal of oil and grease in wastewater using palm kernel shell activated carbon. *IOP Conf. Series: Earth and Environmental Science, 549*(012064), pp. 1-7. Retrieved January 1, 2021 from doi:10.1088/1755-1315/549/1/012064

[19] Razi, M. A. M., Al-Gheethi, A., Al-Qaini, M. & Yousef, A. (2018). Efficiency of activated carbon from palm kernel shell for treatment of greywater. *Arab Journal of Basic and Applied Sciences, 25*(3), pp. 103-110. Retrieved January 8, 2021 from doi: 10.1080/25765299.2018.1514142

[20] Karale, S. S. & Suryavanshi, M. M. (2014). Dairy wastewater treatment using coconut shell activated carbon & laterite as low cost adsorbents. *International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development, 4*(2), pp. 9-14

[21] Saad, F. N., Jamaludin, S. Z. & Izhar, T. N. (2021). Investigation of using sand filter in treating grey water. *IOP Conference Series: Earth and Environmental Science, 646*(1):012056, pp. 1-6. Retrieved January 5, 2021 from doi: 10.1088/1755-1315/646/1/012056

[22] Khaleel, R. M., Ahsan, A., Imteaz, M., El-Sergany, M., Daud, N. N., Mohamed, T., & Ibrahim, B. A. (2015). Performance of GACC and GACP to treat institutional wastewater: A sustainable technique. *Membrane Water Treatment, 6*(4), 339 - 349. Retrieved January 2, 2021 from doi:10.12989/mwt.2015.6.4.339

[23] Pijarn, N., Butsee, M., Buakul, K., Seng, H., Sribuarai, T., Phonprasert, P., Kla, P. & Atthameth, P. (2017). Effect of White Charcoal on COD Reduction in Wastewater Treatment. *IOP Conference Series: Earth and Environmental Science, 216*(1):012002, pp. 1-4. Retrieved January 9, 2021 from doi: 10.1088/1757-899X/216/1/012002

[24] Rahmat, S. N., Ali, A. Z. M., Ibrahim, M. H. W. & Alias, N. A. (2017). Oil and grease (O&G) removal from commercial kitchen waste water using carbonised grass as a key media. MATEC Web of Conferences, 87(01010), pp. 1-4. Retrieved January 1, 2021 from https://doi.org/10.1051/matecconf/20178701010

[25] Mohamed, R. M. S. R., Chan, C. M., ghani, H., Yasin, M. A. M. & Kassim, A. H. M. (2013). Application of peat filter media in treating kitchen wastewater. *International Journal of Zero Waste Generation, 1*(1), pp. 1-16.

[26] Suhani, N., Mohamed, R. M. S. R., Latif, A. A. A., Nasir, N., Ahmad, B., Oyenkanmi, A. A., Awang, H. & Daud, Z. (2020). Removal of COD and ammoniacal nitrogen by banana trunk fiber with chitosan adsorbent. *Malaysian Journal of Fundamental and Applied Sciences, 16*(2), pp. 243-247.

[27] Renang, W.A., Abdul Samat N.A.S., Baini R., Rezaur, M. R. & Selaman O.S. (2018). The effectiveness of a fabricated bio-filtration system in treating the domestic greywater. *Malaysia Applied Biology, 47*(1), pp. 65-72.

[28] Romali, N. S., & Mokhtar, N., (2011). Application of biofilter system for domestic wastewater treatment. *International Journal of Civil Engineering and Geo-Environmental, 2,* pp. 13-18.

[29] Yamina, G., Abdeltif, A., Youcef, T., Mahfoud, H. M., Fatiha, G. & Lotfi,B. (2013). A comparative study of the addition effect of activated carbon obtained from date stones on the biological filtration efficiency using sand dune bed. *Advancements in Renewable Energy and Clean Environment, 36*, pp. 1175-1183. Retrieved January 3, 2021 from https://doi.org/10.1016/j.egypro.2013.07.133

[30] Al-Jayyousi, O. (2003). Greywater reuse: towards sustainable water management. *Desalination, 156*(1-3), pp. 181-192. Retrieved January 5, 2021 from https://doi.org/10.1016/S0011-9164(03)00340-0