Effect of Activated Carbon Compaction on Water Filtration Efficiency

Mohd Elfy Mersal,[a] Kuok King Kuok,[a,]* Md. Rezaur Rahman,[c,]* Chiu Po Chan,[b] Muhammad Khusairy Bin Bakri,[d] Md. Didarul Alam Chowdhury,[e] and Md Abdul Majed Patwary [f]

Water contamination in rural Malaysian areas, mainly caused by logging activities leading to soil erosion and river pollution, presents a significant threat to water supplies. In response, a specialized activated carbon water filtering device was developed to target the absorption of organic molecules. The impact of compaction of activated carbon on water filtering efficiency was evaluated. Testing both compacted and uncompacted activated carbon filters with contaminated river water, the study utilized the Malaysia Department of Environment's (DOE) water quality index (WQI) to assess filter effectiveness. The results revealed that water filtered through compacted activated carbon was clearer and less yellowish compared to the uncompacted counterpart. Moreover, the compacted filter showed higher dissolved oxygen levels, lower ammoniacal nitrogen levels, and a lower pH, resulting in a significantly higher WQI score of 80.4 compared to 78.8 for the uncompacted filter. Further analysis *via* an adsorption isotherm test demonstrated the superior ability of compacted activated carbon to absorb acetic acid, as evidenced by higher lines in the Freundlich isotherm model graphs. These findings emphasize the efficacy of compacted activated carbon in water filtration, advocating for its integration into filter construction to enhance water quality in rural regions.

DOI: 10.15376/biores.19.3.5300-5315

Keywords: Activated carbon; DEO water quality index classification; Compaction; Filtration; Efficiency

Contact information: a: Faculty of Engineering, Computing, and Science, Swinburne University of Technology Sarawak Campus, Jalan Simpang Tiga, 93400, Kuching, Sarawak, Malaysia; b: Faculty of Computer Science and Information Technology, Universiti Malaysia Sarawak, Jalan Datuk Mohammad Musa, 94300 Kota Samarahan, Sarawak, Malaysia; c: Faculty of Engineering, Universiti Malaysia Sarawak, Jalan Datuk Mohammad Musa, 94300 Kota Samarahan, Sarawak, Malaysia; d: Composites Materials and Engineering Center, Washington State University, Pullman, WA, USA; e: Department of Applied Chemistry and Chemical Engineering, University of Chittagong, Chattogram-4331, Bangladesh; f: Department of Chemistry, Comilla University, Cumilla-3506, Bangladesh
** Corresponding authors: [a]kkuok@swinburne.edu.my; [b]rmrezaur@unimas.my*

INTRODUCTION

Water is a crucial natural resource for the existence of humans. It is utilized for food production and energy applications in a society's economic and industrial growth. Thus, an adequate water supply for drinking and domestic use is necessary for towns and homes. Unfortunately, in certain regions of the globe, smaller villages in rural areas have ineffective water collection and delivery systems (Edokpayi *et al.* 2018; Omarova *et al.* 2019). In situations where water sources are contaminated, communities often receive inadequately filtered water due to deficiencies in water delivery infrastructure. Addressing this issue requires the implementation of straightforward and cost-effective alternative techniques to fulfill residential water needs. Moreover, water sourcing in rural Malaysian areas typically relies on precipitation, groundwater, and rivers, as outlined in Vigneswaran and Sundaravadivel (2007). Nonetheless, certain rural regions within Malaysia encounter notable challenges in accessing clean water from these river sources, as highlighted by Idris *et al.* (2016).

Research has shown that certain populations in rural regions suffer serious water contamination difficulties caused by logging and land removal (Cabral 2010). This logging and land removal has exposed the land, making it prone to rain erosion (Wantzen and Mol 2013; Borrelli *et al.* 2017; Wenger *et al.* 2018). Hence, when it rains, the sediments run into the river, rendering it contaminated (Wantzen and Mol 2013; Borrelli *et al.* 2017; Wenger *et al.* 2018). Research suggests that logging has destroyed over 80% of the tropical environment due to Malaysia's wood or oil palm development (Vijay *et al.* 2016). Based on the findings of a survey conducted by Statista (2023), it is estimated that approximately 23.4% of Malaysia's population resides in rural areas. However, data from the Human Development Report by the United Nations Development Program (UNDP) reveals a concerning trend: since 1996, more than 31% of developing nations continue to lack access to clean water, with over three-quarters of this underserved population concentrated in rural settings (Lederer 2023). This statistical evidence underscores the persistence of inadequate water supply systems in many rural regions, indicating that a significant portion of the populace in these areas may still rely on compromised water sources.

In many cases, the water obtained from these sources is rendered unsuitable for consumption due to various contaminants, potentially leading to the onset of waterborne illnesses if consumed untreated. Therefore, addressing this critical issue in rural areas necessitates the implementation of a rudimentary yet effective water filtration system. While cost considerations remain paramount in such regions, the filtration infrastructure will be designed with cost-effectiveness as a primary objective, ensuring that the filters are straightforward enough for local villagers to construct independently. One method is to use activated carbon filters. Activated carbon is a type of carbon that has been processed physically or chemically to generate a structure that includes microscopic holes, considerably improving the absorptive surface area of the carbon (Feng *et al.* 2020; Sharma *et al.* 2022). Its huge surface area enables activated carbon filters to eliminate organic compounds and remove chlorine from water through adsorption (Feng *et al.* 2020; Sharma *et al.* 2022). Nonetheless, several kinds of activated carbon filters are available for filtering systems. Additionally, depending on its structure, activated carbon may display varying filtering performance qualities depending upon the composition from which it is produced and the method it is created. Consequently, this study will compare compressed and non-compressed activated carbon filters to investigate the influence of activated carbon compaction on water filtering efficiency. Thus, this study will also assist in establishing the most efficient carbon composition that may be employed for the activated carbon filter. It will enable the most effective filter to be created for the villagers.

Effects of Compaction on the Structure of Activated Carbon and Water Filtering

Activated carbon's macro-, meso-, and micropores are categorized according to their functional size. The constitutive and state elements of the carbon, such as the particle size distribution and degree of compaction, greatly influence the volume of these pores. The pore space between the carbon particles in activated carbon is reduced when the carbon is crushed. Compaction of activated carbon primarily affects the macropore structure, reducing flow rates but potentially increasing the adsorption efficiency due to longer contact times. Micropores, crucial for the primary adsorptive capacity, remain largely unaffected, ensuring that the fundamental filtration capabilities are preserved. Balancing compaction pressure is key to optimizing the trade-off between enhanced filtration efficiency and manageable flow rates (De Lima *et al.* 2022). Activated carbon is also more efficient in filtering pollutants because of the smaller pore sizes brought on by compaction. The reduction in pore size resulting from activated carbon compaction serves as a critical barrier against further contaminant intrusion. This compaction process effectively restricts certain smaller contaminants that previously could penetrate the activated carbon barrier due to their minute size, thereby significantly enhancing water filtration efficacy. Moreover, compaction also contributes to reducing voids and enhancing carbon impermeability, as elaborated upon in the study by Hu *et al.* (2019). Water infiltration and drainage are thereby decreased. It occurs due to the carbon's larger pores' superior ability to transfer water through it than smaller pores. As a result, the liquid will pass through the activated carbon in the water filtering process more slowly.

Effect of Compaction on Carbon Adsorption and its Isotherm

The effects of compacting activated carbons (ACs) on their volumetric CO_2 adsorption were shown in a research study by Li *et al.* (2020). The study was conducted at the China University of Petroleum in Qingdao, China. The primary emphasis of the study was on the effects of AC compaction on overall volumetric adsorption performance. The researchers obtained two substances: rice husk- and coconut shell-based ACs. The impact of compaction on the volumetric CO_2 adsorption rate of the ACs was next investigated after these materials were compacted at three different pressures (Li *et al.* 2020). The study revealed that each substance's three distinct degrees of compaction had a different amount of adsorption. It made it possible for the researcher to graph this association. According to the study, compaction improved Acs' overall volumetric CO_2 adsorption performance by as much as 53.8% (Li *et al.* 2020).

The process wherein a gas or liquid solute accumulates on the surface of a solid or liquid substance is termed adsorption (adsorbent). Adsorption isotherms serve as fundamental tools for elucidating this adsorption process, depicting the quantity of gas that the adsorbent can bind at various pressures while maintaining a constant temperature through a characteristic curve, as outlined by Shimizu and Matubayasi (2021). Typically, graphical representations are utilized to visualize and analyze the adsorption process. Proficient comprehension and interpretation of adsorption isotherms play a pivotal role in advancing the understanding of adsorption mechanisms and in the effective design of adsorption systems, as emphasized in the study by Ayawei *et al.* (2017).

Over time, various scientists have created many models that explain the adsorption process. Some adsorption isotherm models are the Hill-DeBoer, Langmuir, Freundlich, and others. The two most popular adsorption isotherm equations, Langmuir and Freundlich's isotherms were first presented roughly 70 years ago (Kinniburgh 1986). These adsorption isotherms represent experimental data from adsorption processes using various equations and techniques. Adsorption isotherm modeling and interpretation success significantly impact the accuracy acquired from adsorption processes (Ayawei *et al.* 2017). Another crucial part of data processing is fitting adsorption isotherm equations to experimental data (Kinniburgh 1986). According to a study by Li *et al.* (2020), the volumetric CO_2 adsorption isotherms of activated carbons based on rice husks grew as pressure rose.

The Water Quality

The drinking water's quality indicates whether it is fit for human consumption (Hu *et al.* 2011; Popkin *et al.* 2010). The composition of the water, which is impacted by both natural and human processes, determines the quality of the water (Hu *et al.* 2011; Popkin *et al.* 2010). Physical, chemical, and microbiological water parameters all contribute to the overall quality of the water (Popkin *et al.* 2010; Hu *et al.* 2011). Human health is at risk if any of these values exceed acceptable limits. To safeguard people, several organizations, including the World Health Organization (WHO) and the Centers for Disease Control (CDC), have established exposure criteria or acceptable limits for chemical pollutants in drinking water.

In Malaysia, the classification of river water quality is made by the Department of Environment (DOE). The DOE has set a water quality index (WQI) and national water quality standards (NWQS) as a base for water quality classification. The WQI is regarded as one of the most efficient ways to gauge water quality. The WQI can relate a group of water quality determinants to a common scale and merge the data into a single value following the chosen model of computation. It allows the data to be logically expressed (Ammeera *et al.* 2013). Horton initially developed this index in 1965 to measure water quality using 10 of the most used water parameters like dissolved oxygen, pH, coliforms, chloride, alkalinity, *etc.* (Uddin *et al.* 2021). Since then, many scientists and experts have modified the WQI concept. Hence, it has led to various computation methods for the WQI value. Malaysia uses its own WQI, which comprises six water quality parameters to determine the level of water quality.

The parameters used are total suspended solids (TSS), ammoniacal nitrogen (NH_3-N), pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) (Ibrahim and Kutty 2013). The formula used for WQI calculation is shown in Eq. 1. This formula is from the National water quality standard for Malaysia. The siDO-subindex stands for dissolved oxygen, while the siBOD-subindex, siCOD-subindex, siAN-subindex, siTSS-subindex, and sipH-subindex stand for biochemical oxygen demand, ammoniacal nitrogen, total suspended solids, and pH value, respectively. The Malaysian WQI formula uses these six subindex values. An equation of best fit for estimating various subindex values is used from Malaysia's National water quality standard to obtain the six subindex values from the parameter measured. When the six subindex values are determined, they are put into Eq. 1 to calculate the WQI value:

$$WQI = 0.22\,(siDO) + 0.19(SiBOD) + 0.16\,(siCOD) + 0.15\,(siAN) + 0.16\,(sits) + 0.12\,(sipH) \quad (1)$$

EXPERIMENTAL

Activated Carbon Preparation

A Small Benchtop Muffle Furnace was used to develop activated carbon. The furnace depth (metric) interior was 13 cm. The type of furnace was a single setpoint where the temperature (metric) was 100 to 1100 °C and the frequency was 50/60 Hz. It was supplied by Thermo Fisher Scientific USA. A physical activation process was adopted to prepare the activated carbon. During the physical activation, carbonaceous source materials, which were coconut shells in this study, undergo initial processing through exposure to hot gases, resulting in carbon formation. The constituents with carbon content underwent pyrolysis within a temperature range of 600 to 900 °C, facilitated by an inert atmosphere comprising nitrogen gas. Subsequently, the carbonized material was subjected to an oxidizing atmosphere containing oxygen, operating within temperatures ranging from 600 to 1200 °C. This sequential process effectively activates the carbon. This activated carbon is used to form uncompacted and compacted filters.

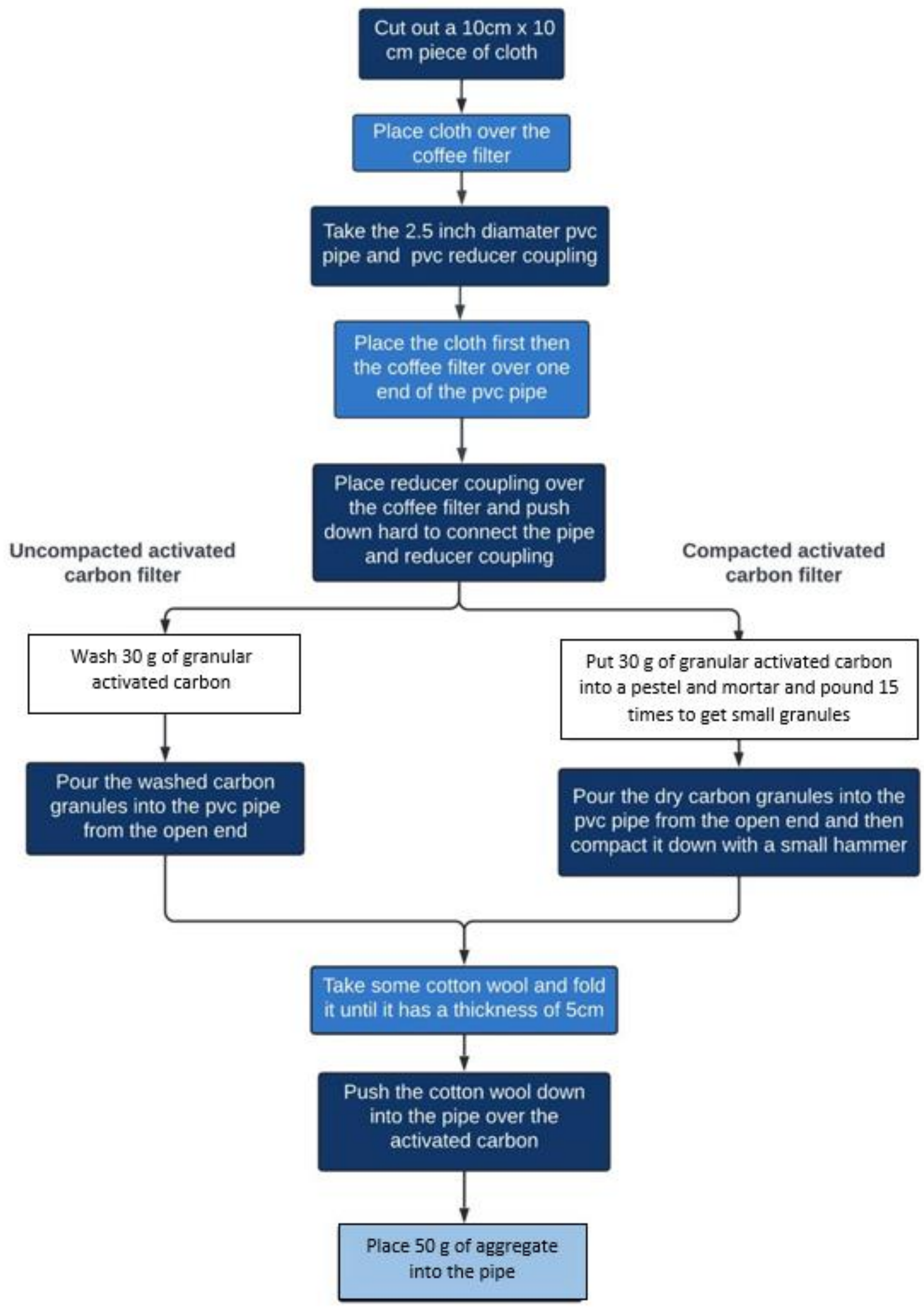


Fig. 1. Flowchart for creating the two filters

Water Sample Collection

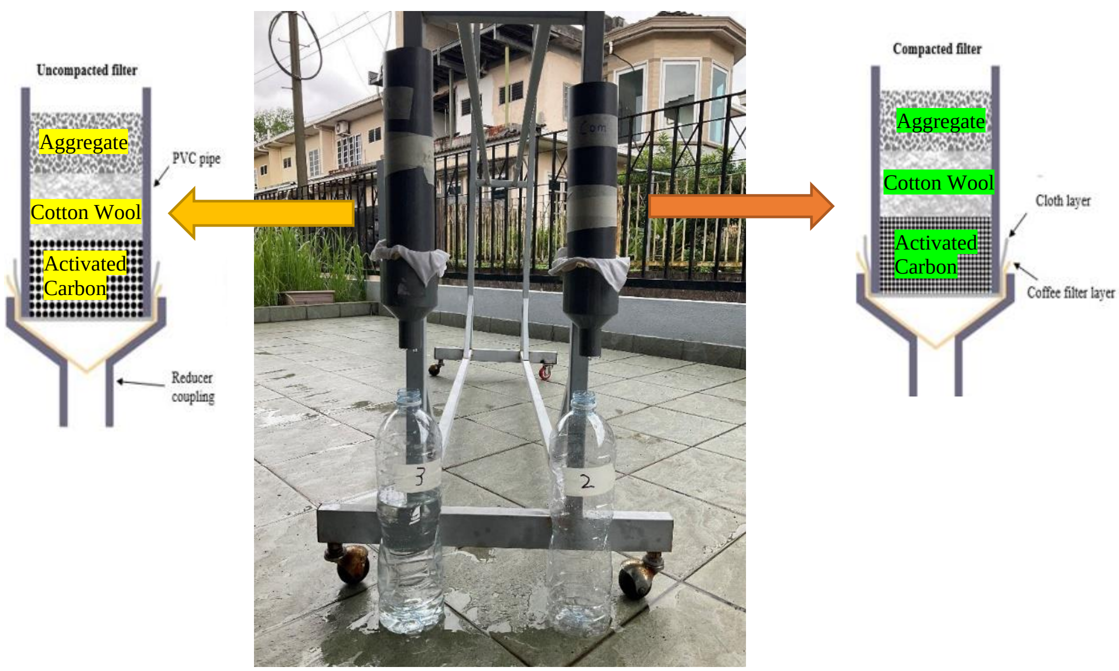
A 20-liter sample of water was collected from a specific segment of the Sarawak River for testing purposes, as depicted in Fig. 2. This water sample exhibited signs of contamination from both soil particles and general pollution. Visibly, the water appeared hazy and had a brownish hue, indicating its unsuitability for consumption. The collection process involved using a clean plastic bottle to ensure the integrity of the sample, which was then securely sealed for subsequent testing of its filtration efficiency. Moreover, forestry operations significantly contribute to river water pollution in the Sarawak River. The trees and shrubs that protect the land from the effects of rain are removed during logging. This results in soil erosion by causing soil particles to erode and dislodge them from the soil's surface. The contamination caused by these soil particles eventually enters the river water (Abdullah 2018).

Fig. 2. Location of water sample collection at Sarawak River (Digital Location: 1.562, 110.345)

Filters Design and Preparation

The layers inside the filter were built using various materials, with polyvinyl chloride (PVC) pipe serving as the major structural component. The remaining layers were cotton wool, small aggregate, cloth (finely woven cotton), and a coffee filter. The amount of each layer of material utilized was kept constant in both filters to guarantee accuracy and fairness in the results. Granular activated carbon weighing 40 g was utilized for each filter, cotton wool measuring 5 cm in thickness, and 50 g of aggregate were employed. In addition, two layers of fabric and coffee filters were used. The PVC pipes used to build the filters had a diameter of 2.5 in, and two PVC reducer couplings were also utilized in building both filters. Its uniformity will prevent one filter from having a layer structure that is thicker than the other. In the beginning, two distinct activated carbon filters were made. Although the construction of each activated carbon filter was the same, the carbon composition varied from filter to filter. Uncompacted activated carbon was used in one filter, whereas compacted activated carbon was used in the other. When it was put into the pipe, the activated carbon in the uncompacted filter was still in granular form because it had not been crushed. In this filter, the carbon granules were also not compressed. In contrast, the activated carbon employed in the compacted filter was crushed to produce smaller carbon granules. The little granules were then tightly packed together after being put into the pipe and compressed with a small hammer. The materials and procedures needed to make both filters are shown in Fig. 3.

a) Material for fabricating uncompact and compact filters



b) Filter assemblies for the two types

Fig. 3. Materials and design for the filtration system

Department of Environment Water Quality Index Classification

The contaminated water samples were run through both activated carbon filters. Next, two bottles were used to collect the outputs from the two water filters. The two filtered water samples were then tested to get the six parameters needed for the WQI formula. The parameters measured were total suspended solids (TSS), ammoniacal nitrogen (NH_3-N), pH, dissolved oxygen (DO), and biochemical oxygen demand (BOD) (Ibrahim and Kutty 2013). After that, the values of these six parameters were noted. Best fit equations in Fig. 4 were used to determine the values of the six subindexes once the data had been recorded. The WQI value was then calculated by substituting these numbers into Eq. 1. The DOE water quality index categorization was used for analysis after determining the WQI value. The assessment of water filtration effectiveness between uncompacted and compacted activated carbon filters relied on the Water Quality Index (WQI), where a higher WQI number indicates better and cleaner water quality. This crucial metric directly reflects the impact of the filtering process on water purity and safety. The study’s findings based on WQI values from filtered water samples offer compelling evidence of the filtration systems' performance, driving curiosity and interest for reviewers to delve deeper into the research's methodology and results.

BEST FIT EQUATIONS FOR THE ESTIMATION OF VARIOUS SUBINDEX VALUES

Subindex for DO (in % saturation)	
SIDO = 0	for $x \leq 8$
SIDO = 100	for $x \geq 92$
SIDO = $-0.395 + 0.030x^2 - 0.00020x^3$	for $8 < x < 92$
Subindex for BOD	
SIBOD = $100.4 - 4.23x$	for $x \leq 5$
SIBOD = $108 * \exp(-0.055x) - 0.1x$	for $x > 5$
Subindex for COD	
SICOD = $-1.33x + 99.1$	for $x \leq 20$
SICOD = $103 * \exp(-0.0157x) - 0.04x$	for $x > 20$
Subindex for NH_3-N	
SIAN = $100.5 - 105x$	for $x \leq 0.3$
SIAN = $94 * \exp(-0.573x) - 5 * \mid x - 2 \mid$	for $0.3 < x < 4$
SIAN = 0	for $x \geq 4$
Subindex for SS	
SISS = $97.5 * \exp(-0.00676x) + 0.05x$	for $x \leq 100$
SISS = $71 * \exp(-0.0061x) - 0.015x$	for $100 < x < 1000$
SISS = 0	for $x \geq 1000$
Subindex for pH	
SIpH = $17.2 - 17.2x + 5.02x^2$	for $x < 5.5$
SIpH = $-242 + 95.5x - 6.67x^2$	for $5.5 \leq x < 7$
SIpH = $-181 + 82.4x - 6.05x^2$	for $7 \leq x < 8.75$
SIpH = $536 - 77.0x + 2.76x^2$	for $x \geq 8.75$

Fig. 4. Best fit equations for subindex value estimation

Adsorption Isotherm Test

Adsorption isotherms, which are mathematical functions connecting the amount of adsorbate on the adsorbent with a liquid’s concentration, were also used to describe the effects of activated carbon compaction. Several models describe this adsorption process. However, the Freundlich isotherm was chosen in this study. Because Freundlich isotherm is an appropriate representation of the adsorption equilibrium between a fluid and a solid, it was chosen. The Freundlich equation, which Freundlich derived as an empirical relation, is another empirical statement that depicts the isothermal fluctuation of a liquid or gas adsorption onto the surface of a solid material. The graph of the adsorption isotherm was produced using this isotherm model for the study in this project. Equations 2 and 3 illustrate the mathematical representation of the Freundlich adsorption isotherm (Chiban *et al.* 2011),

$$\frac{x}{m} = Kc^{\frac{1}{n}} \tag{2}$$

which also can be written as:

$$log\frac{x}{m} = log\, K + \frac{1}{n} log\, c \quad (3)$$

In tests involving an aqueous solution in contact with a dispersed solid phase, *x* is the adsorbate mass, *m* is the mass of the adsorbent, and *c* is the equilibrium concentration of adsorbate. For a specific adsorbent at a specific temperature, *K* and *n* are fixed.

Several adsorbents were used for the two-adsorption isotherm test, whereas granular and powdered activated carbon were the two adsorbents employed. Acetic acid was utilized as the adsorbate. After that, the testing equipment was gathered. All solutions and procedures were kept the same except for the adsorbent to guarantee uniformity between the findings of the two tests. The required equipment consisted of 5 titrimetric flasks with cover, each measuring 250 mL, 1 pipette measuring 2 mL, 1 burette, 1 retort stand, 200 mL of the acetic acid solution, 100 mL of NaOH solution, and 1 L of distilled water with phenolphthalein indicator (50 mL), Granular activated carbon (10 g), powdered activated carbon (10 g), and measuring cylinder (100 mL capacity).

After rinsing 10 g of granular activated carbon with de-ionized water to remove dirt contaminants, the next step involved preparing a 0.5 M acetic acid solution. This was achieved by diluting a 1 M acetic acid solution with 200 mL of water. Subsequently, 200 mL of the diluted acetic acid solution was extracted. Following this, a 0.1 M NaOH solution was prepared by diluting a 1 M NaOH solution to a total volume of 200 mL. This could be accomplished by either directly diluting the 1 M NaOH solution or by adding 1 L of water to a 100 mL portion of the 1 M NaOH solution. Once the solutions were prepared, 200 mL of the diluted acetic acid solution was added to a batch equilibrium experiment involving five covered titrimetric flasks. Each flask contained 1 g of activated carbon and varying amounts of the acetic acid solution and distilled water, as outlined in Table 1.

Table 1. The Formulation Plan for Each Bottle

Bottle No.	0.5 Acetic Acid (mL)	Distilled Water (mL)	Amount of Charcoal (g)
1	50	0	1
2	40	10	1
3	30	20	1
4	20	30	1
5	10	40	1

Next, each flask was given a cap and shaken vigorously for 30 min to ensure that the solution was well mixed. The filtrate was then collected in five numbered beakers after the solutions from each bottle had been filtered individually using filter paper.

A total of 10 mL of each filtrate was collected in each beaker after the first 5 mL of each filtrate was discarded. The next stage included performing a pH equilibrium test, and for this, 1 to 2 drops of phenolphthalein indicator were added to each of the 5 beakers. Common pH indicators include phenolphthalein, which is colorless in acidic environments, and fuchsia pink in alkaline environments. The 0.1 M NaOH solution was then titrated into each beaker containing 10 mL of filtrate until the pinking of the solution indicated that the equilibrium concentration had been reached and the pH was almost neutral. Next, the amount of NaOH titrated into the five beakers was noted. The Freundlich adsorption isotherm equation was then used to process the data. Plotting the quantity of acetic acid absorbed by the carbon in $C_o - C_e = \frac{x}{m}$ *versus* the equilibrium concentration of acetic acid before the adsorption of C_e, produced the isotherm graph. In the second test, all the same procedures as in the first were followed, but powdered activated carbon was utilized as the adsorbate. Powdered activated carbon was made by crushing 10 g of granular activated carbon with a pestle and mortar. The experiment was then completed by repeating each step.

RESULTS AND DISCUSSION

The Unfiltered and Filtered Water

The comparison between unfiltered and filtered water samples obtained using both uncompacted and compacted activated carbon filters revealed significant improvements in water clarity and reduction in coloration, indicative of enhanced purification efficacy. As depicted in Fig. 5, Bottle 1 contained raw river water that underwent no filtration process, exhibiting a visibly cloudy appearance and a distinct yellowish hue, characteristic of water contaminated with suspended particles and organic matter. In contrast, the water in Bottle 2, filtered using an uncompacted carbon filter, demonstrated improved transparency and reduced yellow tint compared to Bottle 1. This improvement suggests that the uncompacted carbon filter effectively removed a substantial portion of impurities and particulate matter, contributing to a cleaner appearance of the filtered water.

Fig. 5. Filtered water samples

Furthermore, the water in Bottle 3, filtered using a compacted carbon filter, exhibited even greater clarity and a notable absence of the yellow hue observed in Bottle 2. This marked improvement indicates that the compacted carbon filter was more effective in removing impurities, resulting in significantly cleaner and clearer water compared to the uncompacted filter. These observations align with established principles of activated carbon filtration, where the increased compaction of activated carbon leads to tighter pore structures and enhanced adsorption capacities. Increased compaction of activated carbon leads to tighter pore structures, primarily affecting macropores and resulting in a denser arrangement of mesopores and micropores. This compaction process enhances adsorption capacities by increasing surface area, improving contact time, and strengthening adsorptive forces. The result is a more efficient filtration medium capable of removing a higher quantity of contaminants, albeit with considerations for managing flow rates and maintaining filter longevity. The smaller pore size and reduced voids in compacted carbon restrict the passage of smaller contaminants, resulting in superior filtration performance and cleaner water output. The comparative analysis of filtered water samples from Bottles 1, 2, and 3 underscores the importance of activated carbon compaction in improving water purification efficiency and reducing the presence of visible impurities, thus validating the efficacy of compacted carbon filters for water treatment applications in rural regions facing water contamination challenges.

The Water Quality Index Classification

The determination of Water Quality Index (WQI) values is a crucial step in assessing the overall quality of water samples based on multiple parameters. In this study, the subindex values required for the WQI formula were meticulously calculated utilizing data from six key parameters, a process essential for accurately evaluating water quality. Figure 4, excerpted from the Malaysian National Water Quality Standard, delineates the specific subindex values utilized in the WQI calculation, providing a standardized framework for assessing water quality levels.

To derive the subindex values, the *x* values representing each parameter were substituted into the equations outlined in Fig. 4, facilitating the generation of numerical values indicative of the relative quality of water based on individual parameters. These calculated subindex values were then utilized in the comprehensive WQI formula to determine an overall assessment of water quality, enabling a holistic evaluation that considers multiple water quality parameters simultaneously. Tables 2 and 3 show the values of filtered water by uncompacted and compacted carbon filter.

Table 2. Values Obtained from the Water Filtered with the Uncompacted Carbon Filter

Parameters	Units	Values (x)
Dissolved Oxygen (DO)	mg/L	4.8 (58.08 %)
Biochemical Oxygen Demand (BOD)	mg/L	< 1.0
Chemical Oxygen Demand (COD)	mg/L	18
Ammoniacal Nitrogen (AN)	mg/L	0.39
Total Suspended Solid (TSS)	mg/L	< 5.0
(pH)	-	9.3

Table 3. Values Obtained from the Water Filtered with the Compacted Carbon Filter

Parameters	Units	Values (x)
Dissolved Oxygen (DO)	mg/L	4.9 (59.31 %)
Biochemical Oxygen Demand (BOD)	mg/L	< 1.0
Chemical Oxygen Demand (COD)	mg/L	16
Ammoniacal Nitrogen (AN)	mg/L	0.32
Total Suspended Solid (TSS)	mg/L	< 5.0
(pH)	-	9.2

Tables 4 and 5 within the study document the intricate details of these calculations, showcasing the systematic approach employed to derive subindex values and subsequently calculate the corresponding WQI values for the sampled water. Such meticulous documentation and adherence to established standards not only ensure the accuracy and reliability of the WQI assessments but also contribute to the scientific rigor and validity of the study's findings regarding water quality in rural regions facing contamination challenges.

Table 4. WQI Value from Uncompacted Filter Water

Uncompacted		
Parameters	**Values (x)**	**Units**
Dissolved Oxygen (DO)	58.08	61.62
Biochemical Oxygen Demand (BOD)	1.0	96.17
Chemical Oxygen Demand (COD)	18.00	75.16
Ammoniacal Nitrogen (AN)	0.39	85.18
Total Suspended Solid (TSS)	5.00	94.51
(pH)	9.30	58.61

Table 5. WQI Values from Compacted Filter Water

Compacted		
Parameters	**Values (x)**	**Units**
Dissolved Oxygen (DO)	59.31	63.41
Biochemical Oxygen Demand (BOD)	1.0	96.17
Chemical Oxygen Demand (COD)	16	77.82
Ammoniacal Nitrogen (AN)	0.32	88.25
Total Suspended Solid (TSS)	5.00	94.51
(pH)	9.20	61.21

The Adsorption Isotherm Test

The absorption isotherm analysis conducted in this study plays a pivotal role in assessing the adsorption behavior of activated carbon filters, particularly regarding their efficiency in removing contaminants from water. By constructing absorption isotherms using logarithmic values derived from x/m (the amount of adsorbate per unit mass of adsorbent) and C (the concentration of adsorbate in solution), as outlined in Tables 6 and 7, the study gains valuable insights into the adsorption capabilities of compacted and uncompacted activated carbon. The graphs generated from absorption isotherms, illustrated in Fig. 6, provide a visual representation of the adsorption behavior of both types of activated carbon. These graphs offer critical information about the adsorption capacity, equilibrium adsorption, and adsorption kinetics of the activated carbon filters. A steeper curve on the absorption isotherm signifies higher adsorption capacity, indicating that compacted activated carbon has a greater ability to adsorb contaminants compared to uncompacted activated carbon. The point at which the absorption isotherm curve levels off reflects the equilibrium adsorption capacity, with the data enabling a comparison of the equilibrium adsorption capacities of compacted and uncompacted activated carbon.

Moreover, the rate at which the absorption isotherm curves reach equilibrium provides insights into the adsorption kinetics of the activated carbon filters. A faster rate of adsorption reaching equilibrium suggests better adsorption kinetics, implying that compacted activated carbon achieves adsorption equilibrium more rapidly than uncompacted activated carbon. By analyzing the absorption isotherm data, the study can also assess the effectiveness of compacted and uncompacted activated carbon in removing specific contaminants, such as acetic acid or other pollutants present in the water samples.

The absorption isotherm analysis conducted in this study offers valuable conclusions regarding the adsorption capacity, equilibrium adsorption, adsorption kinetics, and effectiveness of compacted versus uncompacted activated carbon in adsorbing contaminants from water. These conclusions significantly contribute to advancing our understanding of adsorption processes and aid in the optimization of water treatment technologies aimed at mitigating water pollution in rural regions.

Table 6. Amount of Acetic Acid Absorbed by Uncompacted Activated Carbon

Bottle No.	Amount of Acetic Acid Adsorbed (C_0- C_e) = (x/m)	log(x/m)	C_e = C	log C
1	39.0	1.59	11.0	1.04
2	33.0	1.52	7.0	0.85
3	25.0	1.40	5.0	0.70
4	17.0	1.23	3.0	0.48
5	8.0	0.90	2.0	0.30

Table 7. Amount of Acetic Acid Absorbed by Compacted Activated Carbon

Bottle No.	Amount of Acetic Acid Adsorbed (C_0- C_e) = (x/m)	log(x/m)	C_e = C	log C
1	40.0	1.60	10.0	1.00
2	34.0	1.53	6.0	0.78
3	26.0	1.41	4.0	0.60
4	17.5	1.24	2.5	0.40
5	8.5	0.93	1.5	0.18

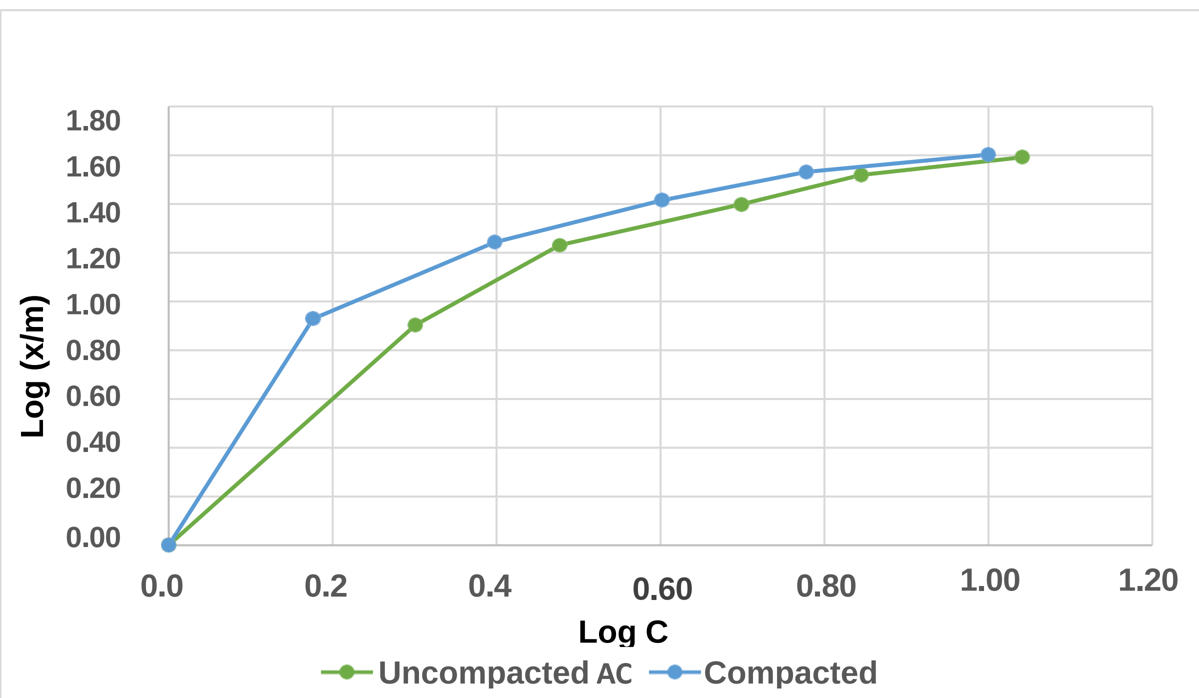


Fig. 6. Adsorption isotherm plots

CONCLUSIONS

1. The study observed that water filtered through compacted activated carbon was notably clearer and exhibited a reduced yellowish tint compared to water filtered with uncompacted activated carbon. This visual assessment underscores the enhanced filtration capabilities of compacted activated carbon in removing particulate matter and impurities from contaminated river water.
2. The filtered water samples from the compacted activated carbon filter showed higher levels of dissolved oxygen, alongside lower concentrations of ammoniacal nitrogen and pH levels, as compared to water filtered through uncompacted activated carbon. These findings align with established indicators of improved water quality, indicating the superior purification efficiency of compacted activated carbon filters in mitigating contaminants.
3. The calculated water quality index (WQI) values for water filtered with compacted activated carbon yielded a significantly higher score of 80.4, in contrast to a WQI score of 78.8 for water filtered with uncompacted activated carbon. This substantial difference in WQI scores emphasizes the superior water quality achieved through the use of compacted activated carbon filters, correlating higher WQI ratings with cleaner and more potable water.
4. The adsorption isotherm test results revealed that compacted activated carbon exhibited greater adsorption capacity for acetic acid compared to uncompacted activated carbon. This was evident in the higher adsorption isotherm lines observed for compacted activated carbon, indicating its enhanced ability to bind contaminants and pollutants in water.
5. Based on the comprehensive analysis and findings, the study concludes that compacted activated carbon should be favored in the construction of water filters due to its demonstrated effectiveness in improving water clarity, enhancing water quality parameters, achieving higher WQI ratings, and exhibiting superior adsorption qualities compared to uncompacted activated carbon. This recommendation aligns with enhancing water filtration systems to combat water pollution effectively.

ACKNOWLEDGMENTS

This research was supported by the Yayasan Sarawak Grant under the project titled “Development of Borneo Bamboo Nanocellulose Membrane for Water Treatment in Rural Areas of Sarawak (GL No: 2-4102)". We express our sincere gratitude to Yayasan Sarawak for their financial support and encouragement throughout this s project.

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Article submitted: December 7, 2023; Peer review completed: March 29, 2024; Revised version received: June 5, 2024; Accepted: June 6, 2024; Published: June 19, 2024.
DOI: 10.15376/biores.19.3.5300-5315