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The Effectiveness of Composite Material for River Water Treatment

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Abstract

River ecosystems, including water quality and aquatic life, are negatively affected by river pollution caused by human activities. The water pollution parameters treated are Total Suspended Solid (TSS) and Chemical Oxygen Demand (COD). These parameters were detected to have critical pollution readings. To remove the concentration of pollutants in water, this study used a physical-chemical technique, namely the adsorption method. From the study conducted, the adsorption properties of composite materials consisting of zeolite, clamshell, and activated carbon mixed with ordinary Portland cement (OPC) successfully treated the parameters that pollute the Muar River. The effectiveness of this adsorbent product was evaluated through several experiments under various river water pollution situations. The test results proved that the composite adsorbent successfully reduced the COD and TSS content, both with 50% and above. In addition, this composite material can reduce dissolved organic matter, which is one of the causes of eutrophication in aquatic ecosystems. It is proven that the composite adsorbent produced has great potential to be used in the treatment of water contaminated with organic matter and heavy metals in an economical, effective, and environmentally friendly manner. This study provides an important contribution to water treatment methods, especially for rivers polluted by organic waste and heavy metals, while at the same time supporting long-term environmental balance, ensuring the sustainability of river ecosystems, and improving water quality management.

1. Introduction

Muar River is a natural source of water to the treatment plants which provide the upstream water to the surrounding people. Nevertheless, water quality has declined because of these pollutants that include ammoniacal nitrogen, chemicals, and organic domestic, industrial, and agricultural wastes [1]. This depletion means that there is an acute need to have new water treatment solutions. This paper analyses the process of adsorption of natural material such as activated carbon, zeolite, clam shells in combination with Ordinary Portland Cement (OPC) to produce a composite adsorbent. The major objective is to minimize suspended solids and toxic wastes which

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enhances better water quality of Muar River. The strategy is economical, green and can be applied on a continuous basis.

Past research shows that granular activated carbon (GAC) and zeolite have a great influence on COD reduction of up to 63.11 percent and TSS reduction of 53.11 percent [2]. The potential capability of the composite adsorbent in removing more pollutants is likely to be increased by mixing these materials with clam shells that have high calcium carbonate (CaCO 3) content. The study is focused on the assessment of these composite efficiencies through analyzing its properties, preparing the ideal conditions of its treatment by performing tests in batch mode and analyzing its performances in the fixed-bed column experiments.

The results of the given research will not only have a positive impact on the water quality of the Muar River, but also in combination with sustainable water management and creation of eco-friendly technologies. Pure water is needed to maintain human welfare, agriculture, and even industry whereas if the water is contaminated there is potential to cause diseases like skin infections and stomach problems [3]. Further, maintenance of the river ecosystems will guarantee existence of life in rivers and will aid biodiversity [4]. Green technology which involves making use of natural and recycling materials is also promoted in this study as it is amongst the global available aims [5].

2. Material and Method

Fig. 1 is the flowchart that shows the general methodology of this study which is composed of three big objectives. Objective 1 entails the start of the process or rather the collection of water samples along with the examination of the raw water quality parameters. At the same time, different ratio and volumes of the used adsorbent materials are applied to make the adsorption solutions. Going to objective 2, the conditions that offer the optimum performance of this adsorbent composite are identified by carrying out some experiments through which different ratios of adsorbent and the size of adsorbent's particles are evaluated. Each combination tested is evaluated according to its reductions of major factors of water quality, especially Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS). In case the levels of reduction correspond to the required standards, the process goes further to the Objective 3. At this step, the optimized mixture of adsorbent is mixed with Ordinary Portland Cement (OPC) to achieve the final mixture of composite adsorbent. This methodical process will see to it that the most effective formulation is therefore found prior to the study being concluded. The impact of adsorbent ratio was determined by evaluating 5 samples, including blanks, with ratio of (Clam Shell : Zeolite) is (1:5), (2:4), (3:3), (4:2), (5:1) and for (Clam Shell : Activated Carbon) is also (1:5), (2:4), (3:3), (4:2), (5:1). etc.

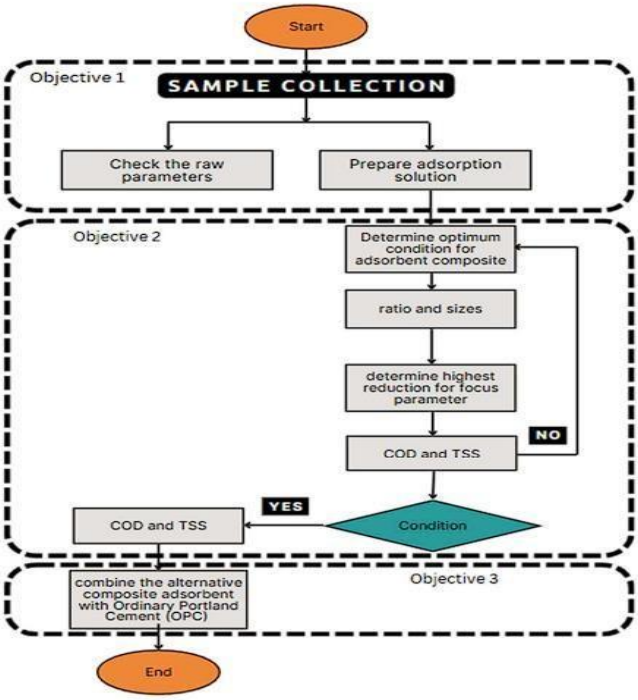

Fig. 1 *Flowchart of the study*

Table 1 *Types of adsorbents and details*

Absorbents	Details
Zeolite	Zeolite is a complex aluminosilicate mineral with a highly defined structure consisting of interconnected passages and water and cations filled pores within it. Its ion-exchange property enables it to exchange ions within its structure with ions in solution, thereby making it highly effective at removing pollutants [6].
Activated Carbon	Activated carbon has long been utilized in the United States and Europe to treat water contaminated by solid waste, industrial effluents, and heavy metals. In this study, it serves as an effective adsorbent for removing metal ions, such as iron, cadmium, and lead, via adsorption and ion-exchange processes.
Clam shell	Calcium carbonate (CaCO3) and chitin majorly constitute clam shells [7]. They have been widely investigated as eco-friendly adsorbents in the treatment of heavy metal contaminated water due to their strong magnetic affinity with metals and the high content of CaCO3 as reported earlier [8].

In summary, composite adsorbents such as zeolites, activated carbon, and clam shells offer an exciting and sustainable approach to water purification. Zeolite excels at removing pollutants thanks to its unique porous structure and ion exchange abilities. Meanwhile, activated carbon significantly boosts the composite's performance in capturing heavy metals like iron, cadmium, and lead due to its expansive surface area. Clam shell, abundant in calcium carbonate ($CaCO_3$), is an environmentally friendly choice that effectively binds dangerous metals. Together, these remarkable materials create an outstanding adsorbent composite, significantly enhancing water quality while adhering to environmental standards.

2.1 Material

The water treatment method using the adsorption method is one of the most efficient processes in reducing pollutants from water. This method involves the process of absorbing pollutants through adsorbent materials that will trap pollutants from river water. Among the materials chosen are zeolite, activated carbon, and shellfish because of their high adsorption capacity, low cost, and ease of availability [9]. Table 1 gives the key three adsorbents, such as zeolite, activated carbon and clam shells with their properties and water treatment functions. Zeolite is emphasized with its ion-exchange ability, porous crystalline structure that also makes it effective in the removal of dissolved ions as well as organic pollutants. Activated carbon, which has a high surface area and possesses a high adsorption capacity, especially traps heavy metals (like iron, cadmium, and lead). Calcium carbonate (CaCO3) in the form of clam shells is a kind of natural and environmentally friendly adsorbent that improves the process of coagulation and binding of toxic heavy metals. It is through such a combination of materials that a composite adsorbent is made to be able to remove efficiently both suspended solids and dissolved organic matter in water. In the present study, the mixture of clam shells, zeolite and activated carbon with Ordinary Portland Cement (OPC) synthesized the composite adsorbent.

The choice of these materials was based on the high adsorption capacity, affordability and availability. Various ratios of mixing that would be effective combination have been tested and they include clam shell to zeolite ratios 1:5, 2:4, 3:3, 4:2, and 5:1 and the clam shell to activated carbon ratios of 1:5, 2:4, 3:3, 4:2 and 5:1. In order to analyze how particle size affects the performance of the adsorbent towards the removal of pollutants, the adsorbents were prepared with a size of 0.60 mm, 1.18 mm, 2.00 mm and 3.35 mm, and the weights are standardized with regard to the weight ratios mentioned in Tables 3. The adsorbents were done in different stages to achieve quality and consistency. Seafood waste clam shells were used, and the clam shells were washed thoroughly to rid the organic materials and allowed to dry in the sun and crushed into a powder then sieved to obtain the desired particle size. Zeolite was in a granular form and was washed to remove impurities then sieved to have uniform particle distribution. The activated carbon was commercially obtained, cleaned using deionized water to remove fine dust and sieved to correspond with the range of particles used in experimentation. The adsorbent materials then left in the collected and prepared samples were then combined back with OPC giving the final composite adsorbent material, and this mix was subsequently tested in its ability to remove both Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS).

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2.2 Model Design of Adsorbent

The adsorbent model design is based on the need to produce an effective composite adsorbent that takes the form of a mixture of zeolite, activated carbon, clam shell powder, and Ordinary Portland Cement (OPC). The composite is formed into a solid structure to be durable, while still maintaining enough surface area and porosity to remove pollutants. The purpose of this model is to determine the optimal proportions of adsorbent material components, particle sizes, and contact time to achieve maximum removal of suspended solids and organic waste. Fig. 2 represents the product design of the developed adsorbent model.



Fig. 2 *Adsorbent model*

The COD and TSS efficiency of reduction of the composite was measured as per equation (1):

$$Percentage\ Reduction = \left[\frac{(Initial\ Value - Final\ Value}{Initial\ Value}\right] \times 100 \quad (1)$$

2.2.1 Chemical Oxygen Demand (COD)

COD is the amount of oxygen consumed to oxidize the organic water constituents completely chemically to inorganic end products. COD is an important, rapidly measured variable for determining the organic matter content of water samples. During digestion, the sample is gently stirred in a 250-mL beaker using a magnetic stir plate. The DRB200 Reactor is preheated to 150 °C, and two COD Digestion Reagent Vials, one for the sample and one for the blank, are prepared by adding 2.00 mL of sample and deionized water, respectively the capped vials are tightly sealed, rinsed, and mixed before being placed in the preheated reactor for a two-hour heating period. After cooling, the vials are inverted several times, placed in a rack, and cooled to room temperature. In the colorimetric determination, the Hach DR6000 is turned on, and the appropriate COD test range is selected. After cleaning and zeroing with the blank, the sample vial is inserted, providing COD results in mg/L. The entire process ensures accurate and reliable COD measurements General Guidelines Avoid hyphenation at the end of a line. Symbols denoting vectors and matrices should be indicated in bold type. Scalar variable names should normally be expressed using italics. Weights and measures should be expressed in SI units. All non-standard abbreviations or symbols must be defined when first mentioned, or a glossary provided.

2.2.2 Total Suspended Solid (TSS)

To determine Total Suspended Solids (TSS) as in equation (2), one should initially place a filter paper in a desiccator for a brief duration to facilitate moisture absorption by the silica gel. Following this, the filter paper must be weighed, and the reading should be recorded accurately. The filter disc should then be positioned on the base and securely clamped onto the funnel. Subsequently, 5 mL of the water sample should be introduced onto the filter disc. The vacuum pump must be activated to extract any residual water.

After the suction process, the filter paper should be dried in an oven at a temperature ranging from 103 to 105 degrees Celsius for a period of one hour. Upon completion of the drying process, the filter paper should be removed and allowed to cool in the desiccator to reach thermal equilibrium. Finally, the filter paper must be reweighed, enabling the calculation of the solid weight accurately.

$$TSS\left(\frac{mg}{L}\right) = \frac{(Weight\ of\ filter\ with\ solids - Weight\ of\ filter)}{Volume\ of\ water} \quad (2)$$

2.2.3 Ammonia Nitrogen

Ammoniacal nitrogen is a measure for ammonia, a toxic pollutant often found in Muar River. It can also be used as a measure of the health of water in neutral bodies such as rivers or lakes, or in man-made water reservoirs. To prepare the sample, a mixing cylinder is filled to the 25-ml. line with the sample, while a blank is created using deionized water. Three drops of Mineral Stabilizer are added to each mixing cylinder, followed by the insertion of the stopper, and several inversions to ensure thorough mixing. Subsequently, three drops of Polyvinyl Alcohol Dispersing Agent are added, and the mixing cylinders are inverted again. Using a pipet, 1.0 mL of Nessler Reagent is added to each cylinder, followed by stoppering and further inversions. The instrument timer starts with a I-minute reaction time. After the timer expires, 10 mL is poured from the blank cylinder into a sample cell, which is then cleaned. Program 380 N for Ammonia, Nester is initiated, and the blank is inserted into the cell holder, followed by clicking ZERO. The display reads 0.00 mg/L NH3-N. Next, 10 mL from the sample cylinder is poured into a second 23 sample cell, the prepared sample cell is cleaned, and the sample is inserted into the cell holder.

2.2.4 pH Analysis

The pH meter is used to analyse the pH value. The pH analysis is conducted immediately by putting pH probe into the sample water to gain results from pH meter after the water sample is collected from the Muar River's drain. In general, a water with a pH < 7 is considered acidic and with a pH > T is considered basic (Table 2). The normal range for pH in surface water systems is 6.5 to 8.5 and for groundwater systems 6 to 8.5.

Table 2 *Range of pH*

Acidic	Neutral	Basic
0	7	14

3. Analysis

This study was conducted to demonstrate that adsorbent mixing can reduce pollution before use for the local community. Based on the data obtained from the experiments conducted, Total Suspended Solid and Chemical Oxygen Demand (COD). It can demonstrate the adsorbent's effectiveness in treating Muar River water and the optimal result for this study. The primary reason for focusing on Chemical Oxygen Demand (COD) and Total Suspended Solid in this study is due to their significant roles in indicating the level of organic pollution in water. In previous COD and TSS experiments, it was observed that the levels of COD and TSS in the water samples were significantly high. Raw water parameters such as COD and TSS are 24 mg/L and 1206.67 mg/L. The significant presence of organic contaminants, as indicated by these elevated levels, calls for efficient treatment before release into lakes or rivers [10]. Fig. 3(a) and (b) show the effects of different clam shell-to-adsorbent ratios on TSS and COD removal, using zeolite and activated carbon as the adsorbents, respectively. Table 3 summarises the experimental parameters and the corresponding COD and TSS removal efficiencies for the cement-to-adsorbent ratio, particle size, and contact time.

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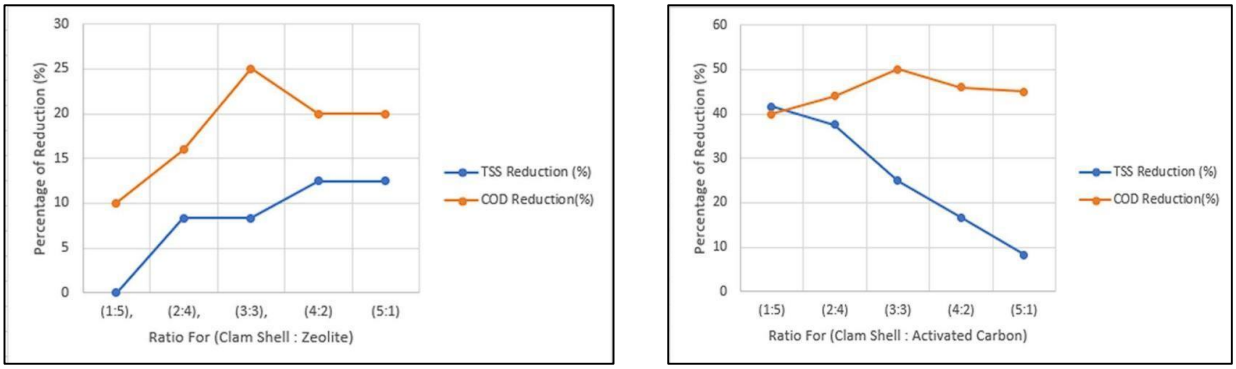

(a) **(b)**

Fig. 3 *Effect of different clam shell-to-adsorbent ratios on the removal of TSS and COD: (a) clam shell–zeolite and (b) clam shell–activated carbon*

Table 3 *Effect of experimental parameters on COD and TSS removal efficiency*

Parameter	Sample	Condition	COD (%)	TSS (%)
Optimum ratio between Ordinary Portland Cement with mix of adsorbent	Blank	(0:0)	0	0
	1	(1:5)	42.00	75
	2	(2:4)	43.00	74
	3	(3:3)	45.83	65
	4	(4:2)	45.83	58
	5	(5:1)	41.67	50
Effective size for adsorbent	1	0.600	50	77
	2	1.18	58.33	75
	3	2.00	54.17	60
	4	3.35	54.17	56
Maximum contact time	1	15	16.67	50
	2	25	37.5	60
	3	35	50	74
	4	45	45.83	80
	5	55	37.5	72
	6	65	37.5	72

4. Results and Discussion

Five parameters namely Chemical Oxygen Demand (COD), pH, Ammoniacal Nitrogen (AN), Suspended Solids (SS), and Dissolved Oxygen (DO) were reviewed to determine the water quality at Muar River. Meanwhile while sampling, river water was measured as 23.4oC. Experimental data, characterizing the functioning of the composite adsorbent under experimental conditions by removing pollutants, which is presented in Fig. 4 proves that the most important parameters that demonstrate contamination are COD and TSS.

This research proves that a composite adsorbent, produced using clam shells, zeolite and activated carbon mixed with Ordinary Portland Cement (OPC), has a tremendous effect on water quality. The highest performance

was found in the case of particle size of 1.18 mm and 35-minute contact time with a percentage reduction of COD of 58.33 and TSS of 77 percent. Such findings illustrate that the utilization of natural and recycled materials is not only viable and economically affordable but also sustainable to the environment.

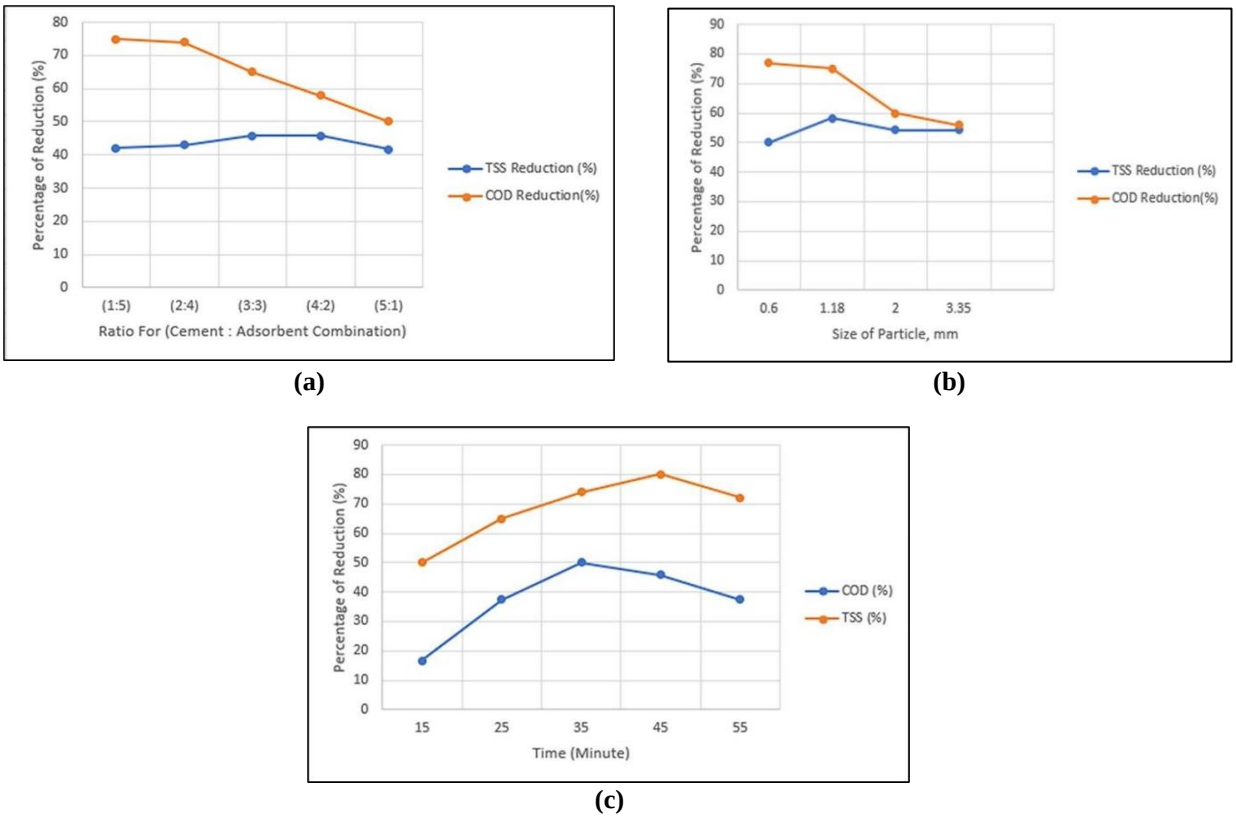

Fig. 4 *Effect of operating parameters on the removal efficiency of TSS and COD using composite adsorbent: (a) cement-to-adsorbent ratio; (b) particle size; (c) contact time*

The technique demonstrates high potential of use in real water treatment systems to restore cleaner rivers and healthier ecosystems. It is advised that future research should scale up this exercise, test its effectiveness on other water quality such as heavy metals and phosphates, and determine its efficacy in terms of long-term monitoring. This may be made to be more efficient and more enduring when other treatment technologies are merged with it.

5. Conclusions

This study proves that clam shell, zeolite, activated carbon composite adsorbent combined with Ordinary Portland Cement (OPC) can enhance the quality of the water in the Muar River significantly. The result of the experiment shows that the best result was obtained at a party size of 1.18mm and after 35 minutes of contact period which recorded a 58.33 reduction in COD and 77 percent reduction in TSS. Such results prove that natural and recycled materials can serve as highly applicable, sustainable and low cost ways of treating water. This study describes the method which has substantial prospects of field implementations particularly in rivers and water bodies that are polluted with organic matters and suspended solids. It would be advisable to explore this method in future to increase its scale and test its efficiency in removing other contaminants e.g., heavy metals and phosphates as well as determining its long-term efficiency under various environmental conditions. The overall effectiveness of this composite adsorbent to the environment can be improved by combining the technology with other treatment technologies

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Muhammad Darwisy Hakim Mohd Nazri, Muhammad Danish Harriz Zuraidy, Nur Alia Maisara Irman;* ***data collection:*** *Muhammad Darwisy Hakim Mohd Nazri, Muhammad Danish Harriz Zuraidy;* ***analysis and interpretation of results:*** *Muhammad Darwisy hakim, Nur Alia Maisara Irman;* ***draft manuscript preparation:*** *Muhammad Danish Harriz Zuraidy, Nur Alia Maisara Irman and Izat Yahaya. All authors reviewed the results and approved the final version of the manuscript.*

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