

# Experimental Study on Water Filtration System by Using Clay-Kenaf-Biochar for Agriculture Uses

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## Abstract

In this study, researchers developed a water filtration system for reducing heavy metals and anions in Malaysian water sources using Clay, Kenaf, and Biochar in optimal ratios. The study successfully produced effective filter bricks, emphasizing the potential of natural resources for sustainable water treatment. Clay-Kenaf-Biochar (CKB's) brick effectively reduced heavy metal content. However, limitations included excluding other potential materials, small-scale testing, and limited water sample locations around Parit Raja. Despite these, the study contributes to eco-friendly water treatment, prompting future research. The research focused on mixing ratios and filter element evaluation, highlighting effective heavy metal reduction but inefficiencies for anions and mercury. Recommended improvements include expanding mixing ratio experimentation, individualized material studies, and increased water sample locations for a comprehensive assessment. These suggestions aim to fortify the knowledge foundation and contribute to more effective and adaptable water treatment solutions.

## 1. Introduction

With its robust economic position, Malaysia relies on diverse sectors such as agriculture, industry, mining, services, and tourism to drive its national economy [1]. The agricultural sector, encompassing activities like farming and animal husbandry, plays a pivotal role in providing raw materials for the nation [2]. High-quality water resources are crucial for the sector's success, influencing the growth and reproduction of flora and fauna [3]. Chemically composed of two hydrogen atoms and one oxygen atom, water is essential for agriculture and influences soil usage and plant growth through pH levels [4].

Malaysia is endowed with abundant surface and underground water resources, particularly in the form of rivers and lakes [5]. Effective water management is vital for agriculture, and modern filtration systems using natural materials like clay, zeolite, and kenaf are employed to enhance water quality [6]. Water's significance in crop production is evident in the research indicating that fruit and vegetable crops in Malaysia require 25,710 million cubic meters of water, with efficient water management practices contributing to year-round production [7]. High-value crops, especially those grown under rain protection structures, have proven to be economically advantageous [8].

The research project concentrates on the agricultural sector in Malaysia, particularly the cultivation of oil palm trees in the Batu Pahat area of Johor. Oil palm trees, crucial for the nation's economy, rely on mineral-rich

water sources [9]. The study aims to develop a water filtration system using natural materials like clay, kenaf, and biochar to optimize water quality for agricultural activities.

The challenge lies in determining the optimal ratio of materials for the water filter system to effectively reduce heavy metals and anions. This iterative process involves multiple trials and experiments, testing various combinations to find the most efficient configuration. The study focuses on achieving a balance that removes contaminants while maintaining desired flow rates and filtration capacities. The researchers anticipate that their efforts will lead to a tailored water filtration system meeting the specific needs of agricultural activities in Malaysia.

The research design encompasses two primary objectives: the study of the mixing ratio of Clay, Kenaf, and Biochar for water filter element fabrication and the subsequent evaluation of the performance of filter elements employing these materials. However, it's crucial to acknowledge the inherent limitations of this study. Firstly, the exclusive use of clay, kenaf, and biochar may restrict the potential exploration of other materials or combinations that could potentially yield superior results. Additionally, the testing of the water filter system is confined to a smaller scale, implying that the results obtained might not entirely extrapolate to the system's performance on a larger scale or in different environmental conditions.

The study's limitations include the use of limited materials (clay, kenaf, and biochar) for the water filter system, potential variations in results on a larger scale, and the focus on specific water sources around Parit Raja, Batu Pahat. The small-scale testing may not fully represent system performance in diverse conditions. The study emphasizes anions and heavy metals in water samples, potentially overlooking other water quality parameters. Sintering of clay before use may impact its filtration performance, necessitating further research on a larger scale with a broader range of materials and water sources.

The integration of beneficial water content in agriculture is vital for sustainable farming, impacting plant growth, soil health, and environmental conservation. Quality water enriched with essential nutrients supports optimal plant nutrition while minimizing contaminants and ensuring food safety [10]. Efficient water management practices, such as precision irrigation and monitoring, maximize the advantages of quality water content [11]. This approach enhances crop yield and quality and contributes to environmentally friendly pest management and soil health preservation [12].

Beyond the farm, the use of quality water protects the environment, minimizing contamination risks to groundwater and surface water bodies. Sustainable practices, like precision irrigation and mulching, promote water sustainability and support long-term agricultural productivity [13]. High-quality water ensures safe and healthy food production, instilling confidence in consumers [14].

Clay, composed of hydrated aluminum silicate particles [15], is a versatile natural material with a layered structure, enabling water retention and serving diverse purposes. Essential in agriculture, construction, art, and water treatment, clay's significance is particularly pronounced in water filtration. Its high surface area and negative charge facilitate the effective adsorption of contaminants like heavy metals and organic compounds [16]. The fine and porous structure acts as a physical barrier, trapping suspended particles during filtration. Additionally, clay minerals engage in ion exchange, removing dissolved contaminants and adjusting water pH, making it suitable for agricultural applications. Clay's adaptability to slow sand filters and ceramic filters underscores its cost-effectiveness and environmental friendliness [16]. Its multifaceted properties contribute to enhanced water quality in various applications [15].

Kenaf (*Hibiscus cannabinus*), an annual herbaceous plant cultivated globally, stands out for its versatile fibers and rapid growth, serving as an eco-friendly alternative to conventional fibers in textiles, paper, cordage, composites, insulation, and biofuels [17 - 18]. In water filtration, kenaf's fibrous stalks contribute significantly, creating a porous material that traps particles and adsorbs contaminants such as heavy metals and organic pollutants. With ion exchange capabilities and pH-adjusting properties, kenaf fibers offer an effective and sustainable solution for water treatment, improving water quality and reducing contaminants in agricultural, industrial, and domestic applications [19].

Biochar, a sustainable carbon-rich material produced through biomass pyrolysis, is gaining recognition for diverse applications, from soil improvement to carbon sequestration, with a prominent role in water filtration [20]. Derived from sources like rice husk, bamboo, and coconut shell, biochar's unique characteristics position it as an innovative solution for environmental challenges. Emphasizing its porous structure and chemical composition, this introduction explores biochar's production from various sources and its effectiveness in removing contaminants from water, addressing water scarcity and pollution concerns. In water filtration, biochar's exceptional adsorption capacity, physical filtration, chemical adsorption, and pH-modifying capabilities contribute significantly to water purification, with its high Cation Exchange Capacity playing a vital role in nutrient retention, promoting a healthier water environment [21]. Understanding biochar and water filtration synergy is crucial for developing environmentally friendly solutions that integrate sustainability with technological advancement.

In conclusion, this research seeks to contribute to sustainable agriculture in Malaysia by developing an optimized water filtration system tailored to the unique needs of the agricultural sector.

## 2. Methodology

### 2.1 Material Preparation

The preparation of research materials is crucial for ensuring the consistency, correctness, and reliability of study findings. Researchers first identify necessary materials based on study objectives, then subject them to cleaning, sorting, drying, or other treatments to ensure suitability. Strict protocols are established to maintain consistency and minimize variability or contamination. Quality control measures, including sample testing and property verification, are implemented during the preparation stage to enhance validity and robustness. In the water filtration system, three essential ingredients—clay, kenaf, and biochar—are meticulously prepared. Clay is mixed with water, sintered, and heated to enhance filtration capabilities. Kenaf, sourced as fiber pieces, undergoes a thorough cleaning process for optimal performance. Rice husk, bamboo, and coconut shell biochar undergo washing, rinsing, and drying to eliminate impurities and ensure uniformity. Overall, material preparation ensures that each component meets specific requirements, contributing to the effectiveness and efficiency of the water filtration system.

### 2.2 Mixing Method

In the water filtration system, the material ratios are pivotal in determining the filtration process's effectiveness. These ratios represent the system's relative amounts of clay, kenaf, and biochar. The study establishes sets of ratios based on prior research, leveraging insights into optimal combinations that reduce contaminants and achieve desired filtration outcomes. Multiple ratio sets provide a foundation for experimentation, allowing researchers to assess performance through laboratory tests. The goal is to identify sets consistently yielding the best outcomes, such as high reduction of heavy metals and hazardous chemicals. Using ratios derived from prior studies streamlines experimentation, increasing the chances of finding efficient material combinations. Following predetermined mix ratios (CKR, CKB, CKC), bricks serve as the filter medium in the filtration process. Weighing ingredients individually, mixing according to sets, and subjecting them to furnace burning ensures precision and consistency in brick creation. Determining material ratios involves using the density formula to calculate required volumes and densities, ensuring accurate proportions for effective water filtration. Tables 1 to 4 provide details of material ratios for each set.

**Table 1** Volume Ratios of Material

Set's Name	Clay	Kenaf	Biochar (Rice Husk)	Biochar (Bambo)	Biochar (Coconut Shell)	Total Ratio
Pure Clay	100%	-	-	-	-	100%
CKR	75%	10%	15%	-	-	100%
CKB	75%	10%	-	15%	-	100%
CKC	75%	10%	-	-	15%	100%

**Table 2:** Density of All Materials

Material	Clay (g/cm <sup>3</sup> )	Kenaf (g/cm <sup>3</sup> )	Rice Husk (g/cm <sup>3</sup> )	Bamboo (g/cm <sup>3</sup> )	Coconut Shell (g/cm <sup>3</sup> )
Density	1.6557	0.1680	0.1520	0.7919	0.5040

**Table 3** *Weight of All Materials*

Material	Clay (g)	Kenaf (g)	Rice Husk (g)	Bamboo (g)	Coconut Shell (g)
Material Weight	41.4	4.2	3.8	19.8	12.6

**Table 4:** *Brick's Weight for Each Set*

Brick's Set	CKR (g)	CKB (g)	CKC (g)
Material Ratio with Weight	75% Clay = 31.05 10% Kenaf, = 0.42 15% Rice Husk = 0.57	75% Clay = 31.05 10% Kenaf, = 0.42 15% Bamboo = 2.97	75% Clay = 31.05 10% Kenaf, = 0.42 15% Coconut Shell = 1.89
Total Weigh of Brick	32.04	34.44	33.36

### 2.3 Sintering Method

In this study, the clay material utilized in the water filtration system undergoes a sintering process to enhance its properties and ensure effective water filtration without contamination. The objective is to identify a sintering method that produces hardened clay suitable for refining the water. The selection of the sintering method depends on results, prioritizing clay that demonstrates efficient water filtration and minimal contamination risks. The study employs electric furnace sintering as the chosen methodology, involving meticulous clay preparation, furnace loading, controlled heating, sintering, systematic cooling, and unloading with finishing options such as polishing or glazing. This precise and efficient method is widely used in crafting ceramics, ensuring clay-based products possess the desired strength and durability characteristics for effective water filtration. Fig. 1 and Fig. 2 show the furnace and the sample arrangement in the furnace, respectively. This study aims to identify the most suitable technique for producing hardened clay that meets the requirements of the water filtration process. Table 5 provides details of the settings for the electric furnace sintering process.

**Table 5:** *Sintering Process Setting*

Temperature changes	0° C → 400°C	400° C → 700°C	700° C → 24°C
Heat Rate	2° C/min	3° C/min	5° C/min
Cooldown duration	2 hours rest	3 hours rest	-



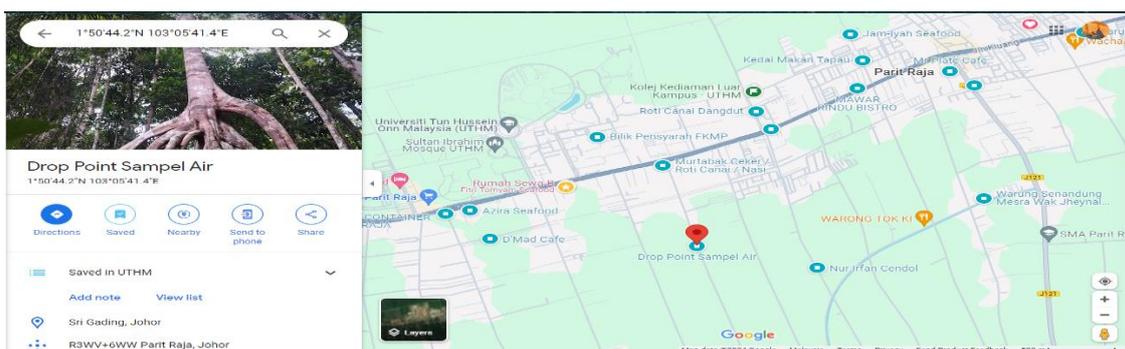
**Fig 1** Electric Furnace



**Fig 2** Bricks Placed In Furnace

## 2.4 Water Sample Collection

In the research study, understanding water quality and evaluating the filtration system's effectiveness involves the crucial step of collecting water samples from the Parit Raja area. These samples are obtained from identified contaminated water sources, potentially including rivers, lakes, or other nearby bodies of water. Rigorous care is taken during the collection process to ensure the representativeness of the samples, utilizing appropriate techniques and equipment to minimize potential contamination or alteration of water quality. The collected water samples are stored in 5-liter water bottles to facilitate research analysis, providing an adequate amount for testing and analysis. This approach allows for replication and statistical analysis, ensuring study reliability and validity. Subsequently, the samples undergo laboratory testing and analysis, measuring parameters such as heavy metal concentrations, anions, and hazardous chemicals like Mercury. These tests generate essential baseline data on the initial state of the water, serving as a reference for comparison with the filtered water after passing through the clay, kenaf, and biochar filtration system. By collecting samples from the contaminated sources in the Parit Raja area, researchers gain valuable insights into water quality and assess the filtration system's efficiency in removing contaminants, contributing to the design of effective water filtration systems applicable to agricultural activities in Malaysia. The selection of the ditch in the palm oil plantation area at Jalan Parit Hj Abd Kadir as the collection location (Fig. 3 and Fig. 4) is based on thoughtful consideration of factors contributing to potential water pollution. Proximity to the palm oil plantation, where common agricultural practices include fertilizer and pesticide application, makes this location significant. Such activities can introduce various chemicals into the water system, posing contamination risks as shown in Fig. 5. Additionally, runoff during rainfall events may carry sediments and agrochemical residues into the ditch, further impacting water quality. Focusing on this location enables a comprehensive assessment of agricultural activity's impact on water quality, providing valuable insights for sustainable land management practices in the region.



**Fig 3:** Water Sample Location in Google Map



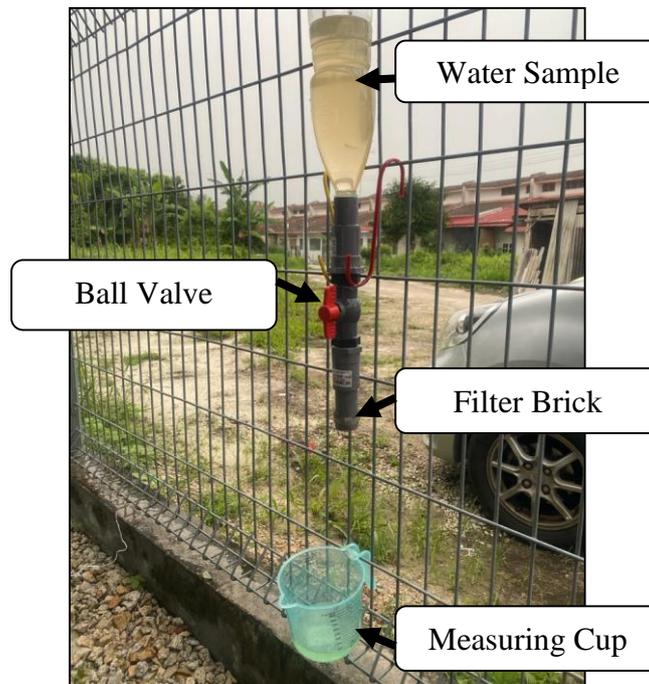
**Fig 4:** Actual Location of The Water Sample



**Fig 5:** Foreign Objects in The Water Sample

### 2.5 Filtering Experiment

In this study, once water samples are collected, a filtering experiment (Fig. 6) will test predetermined sets of mixing ratios specified in the table below. The mixing ratios, arranged accordingly, will be prepared in 1000ml water bottles as a medium for the filtration system. Using clay, kenaf, and biochar in the predetermined ratios, water samples from Parit Raja will pass through the filtration system, undergoing one, two, and three filtration cycles, as detailed in the table. After filtration, the carefully separated and labelled water samples will be subject to laboratory testing for quality assessment. Parameters, including heavy metal concentrations, anions, and hazardous chemical levels, will be analyzed to evaluate the filtration system's effectiveness in removing contaminants and enhancing water quality. The study aims to identify the most effective ratio and filtration technique by conducting the experiment on different mixing ratios and analyzing the resulting filtered water samples. This information will aid in determining the optimal combination of clay, kenaf, and biochar and the appropriate number of filtration cycles, contributing to achieving desired water quality for agricultural activities in Malaysia.



**Fig 6:** Filtration Experiment Setup

## 2.6 Data Collection

Once the filtered water samples were obtained, they were transported to the laboratory for further analysis. In the laboratory, three key tests were conducted to assess the quality and content of the filtered water samples: the Inductive Coupled Plasma-Mass Spectrometer (ICP-MS), Ion Chromatography (IC), and Mercury Analyzer. The ICP-MS is crucial for identifying and quantifying heavy metals in the water sample, employing inductively coupled plasma and mass spectrometry for precise measurements. Ion Chromatography (IC) separates and quantifies ions, providing accurate concentrations of anions like nitrate, sulphate, chloride, and fluoride. The Mercury Analyzer measures mercury concentration, crucial due to its toxicity. The laboratory tests aim to obtain precise measurements of metals, anions, and mercury content, providing essential data to evaluate the efficiency of the water filtration system in removing contaminants. These values include metal concentrations, anion levels, and mercury concentration, all contributing to the assessment of the filtration system's overall performance. The figure below outlines the steps for running lab tests, illustrating the systematic approach to obtaining valuable information about the composition and quality of water samples. These results are crucial for developing effective and sustainable water filtration systems, promoting environmental protection, and safeguarding human health in agricultural activities in Malaysia.

## 3. Result and Discussion

### 3.1 Sintering Result

The sintering results unveil a consistent heat rate and cool-down time applied to all brick sets, with positive outcomes observed for CKR, CKB, and CKC sets (Fig. 7), indicating successful sintering. However, an unfortunate outcome is noted for the CLAY brick set, where the brick exploded during the sintering process (Fig. 8). A comparative experiment with CKR and CLAY bricks highlights the stark contrast in survival and hardening, leading to the conclusion that the heat rate setting is unsuitable for a 100% clay ratio, more fitting for mixed materials. Based on this crucial observation, adjustments in the heat rate setting are deemed necessary for favourable results in pure sintered clay.

Furthermore, the impact of the sintering process is evident in the shrink effect, as observed by comparing brick weights before and after sintering. The noticeable decrease in weight post-sintering is attributed to structural changes during sintering, impacting volume and overall weight. The examination of weight variations (Table 6) provides valuable insights into molecular-level transformations during the sintering phase. Brick shrinkage is explained by two main reasons: the high temperatures causing the removal of water and volatile components, reducing overall volume, and the sintering process rearranging and bonding particles, resulting in a denser and more compact structure. In simple terms, water expulsion and particle rearrangement during sintering directly cause brick shrinkage.



**Fig 7** Final Mix Material Bricks After Sintering Process



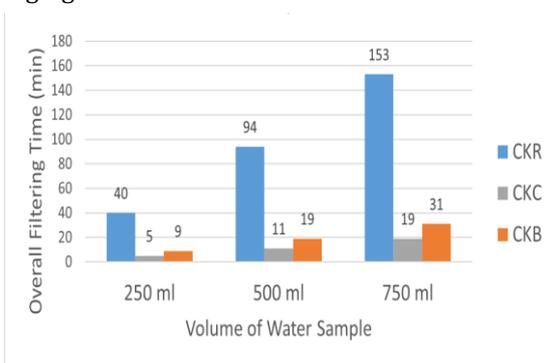
**Fig 8** Broken CLAY's Brick

**Table 6** Weight of Each Set of Bricks

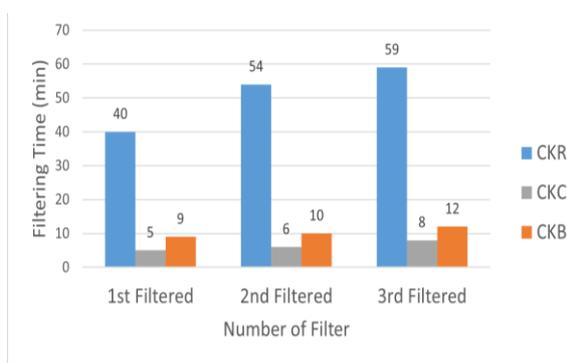
Mixing Material	Weight Before Sintering (g)	Weight After Sintering (g)	Differences (g)	Percentage Change Between Weight Before and After (%)	Percentage Change Between Weight Actual and After (%)
<b>Weight Actual: Clay-Kenaf-Rice Husk (CKR) = 32.04 g</b>					
I	32.2	20.0	12.2	37.89	37.58
II	30.5	19.8	10.7	35.08	38.20
III	28.7	17.1	11.6	40.42	46.63
<b>Weight Actual: Clay-Kenaf-Bamboo (CKB) = 34.44 g</b>					
I	34.0	20.3	13.7	40.29	41.06
II	32.7	19.7	13.0	39.76	42.80
III	34.8	20.7	14.1	40.52	39.90
<b>Weight Actual: Clay-Kenaf-Coconut Shell (CKC) = 33.36 g</b>					
I	32.7	19.6	13.1	40.06	41.25
II	32.8	20.0	12.8	39.02	40.05
III	33.5	20.4	13.1	39.10	38.85

### 3.2 Filtration Result

During the screening session for each brick, a systematic filtering process is initiated, subjecting the water sample to three filtration cycles. The filtering duration for CKR, CKB, and CKC bricks is meticulously recorded to evaluate their respective efficiency. Following filtration, the processed water samples are carefully transferred into labeled bottles, streamlining subsequent laboratory analysis. Variations in filtering durations are notable in the time records, with the CKC brick demonstrating the fastest session at 19 minutes and the CKR brick registering the longest duration at 153 minutes. Results consistently show increasing time periods for successive filtrations, particularly for the first 250 ml, 500 ml, and 750 ml increments. These findings provide insights into the filtration efficiency of each brick type and the dynamic nature of the filtration process with varying water volumes. The escalating time for each filtered session is likely attributed to the accumulation of particles and contaminants in the filtering material. As filtration progresses, whether through the brick or an additional medium, impurities from the water are captured, leading to increased resistance. This slowdown in water flow necessitates more time for thorough removal of contaminants. Initially, when the filter is cleaner, water passes through more quickly, but as impurities accumulate, the process becomes slower, emphasizing the dynamic nature of filtration influenced by changing water characteristics.



**Fig 7:** Overall Filtering Time for Bricks

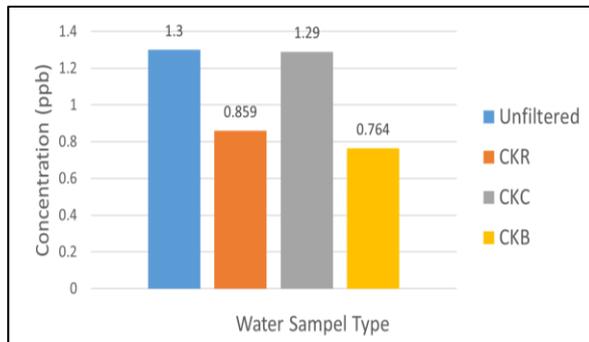


**Fig 8:** Filtering Time for Each Filter

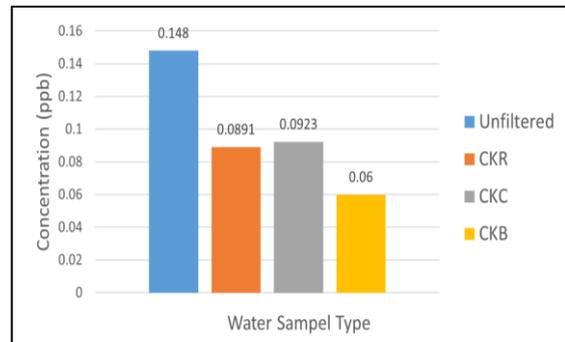
### 3.3 Heavy Metal Result

This study assessed heavy metal content in water samples using the ICP-MS machine in the environmental analysis engineering laboratory at FKAB. The analysis identified various heavy metals, including Arsenic (As75) (Fig. 11), Cadmium (Cd111) (Fig. 12), Nickel (Ni60) (Fig. 13), Chromium (Cr52), Strontium (Sr88), and Lead (Pb208). The data obtained from the ICP-MS machine is tabulated for reference. Notably, the study's results indicate that all three types of bricks effectively reduced concentrations of Arsenic, Cadmium, and Nickel. This

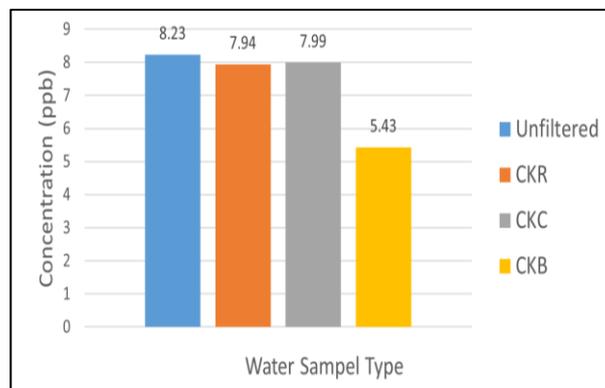
reduction is attributed to the filtration process involving three successive cycles, demonstrating the bricks' efficacy in mitigating the presence of these heavy metals in the filtered water. The tables below present the results of heavy metals for each set of bricks. The provided figures in the table visually depict the decline in heavy metal concentrations in water samples after the completion of the third filtration process. Arsenic, Cadmium, and Nickel are identified as heavy metals successfully filtered by all three brick sets. A comparative analysis reveals that CKB consistently outperformed CKR and CKC in filtering these heavy metals, emphasizing the varying filtration efficiencies of the brick sets. These findings contribute to a nuanced understanding of the distinct filtration performances of the different brick sets in addressing specific heavy metal contaminants.



**Fig 9** Arsenic Contain in Water Filtration Result



**Fig 10** Cadmium Contain in Water Filtration Result



**Fig 11** Nickel Contain in Water Filtration Result

### 3.4 Anion Result

The study revealed that the produced brick sets did not effectively reduce the anion charge in the water sample. Results obtained from the environmental analysis engineering laboratory at FKAB, using the IC machine, indicate an increase in anion charge after the filtration process. Despite the attempt, the brick set did not demonstrate the desired efficacy in reducing the anion charge, prompting further investigation into factors contributing to its limited success in mitigating anionic contaminants. The increase in anion charge may be attributed to the brick set used; if not designed for effective anion removal, the filtration process might not achieve the intended reduction. Certain anionic species may not be efficiently removed, leading to their persistence in filtered water.

Additionally, the filtration process might introduce or release anionic compounds from the filtration medium, contributing to the observed increase. A closer examination of the brick set's characteristics and the nature of anionic contaminants in the water is necessary to understand the exact reasons. Fig. 14 and Fog. 15 display changes in Chloride and Sulphate content in the water sample after filtration. Results indicate that the anion charge for CKC and CKB brick sets increased after filtration, suggesting the process was not effective in reducing these anionic contaminants. On the other hand, the CKR brick set showed a positive effect, with a reduction in the anion charge post-filtration. Interestingly, charged anions like Fluoride, Bromide, and Nitrate did not show significant changes after the filtration process, indicating resistance to the applied filtration method. These findings directly showcase how different anionic contaminants respond to the filtration process and highlight the specific capabilities of each brick set in dealing with anions.

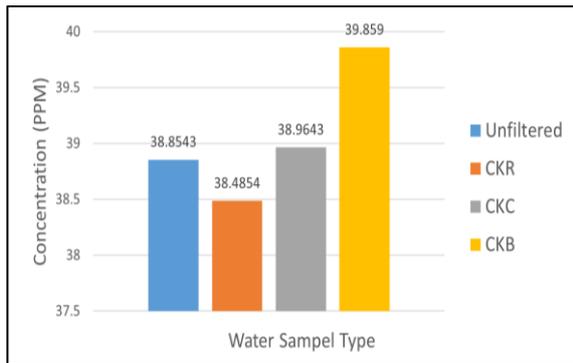


Fig 12: Chloride Contain in Water Filtration Result

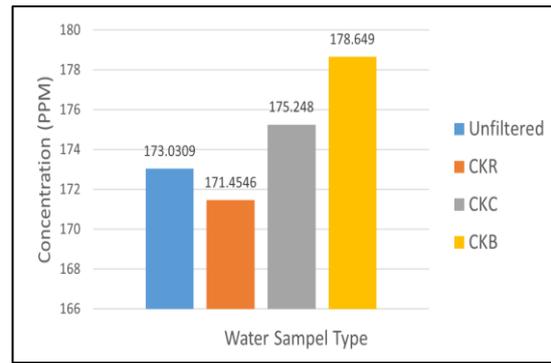


Fig 13: Sulphate Contain in Water Filtration Result

### 3.5 Mercury Result

The analysis of mercury content at the FKAAB Laboratory using a Mercury Analyzer machine reveals an increase in mercury levels after the filtration process, as indicated in the provided table and diagram. A comparative evaluation of performance across different brick sets highlights that the CKR brick set exhibits a relatively lower rate of increase in mercury content compared to the CKC and CKB bricks. While all brick sets show an increase in mercury content post-filtration, the CKR brick set performs comparatively better in limiting the rise in mercury levels. These findings underscore the varying effectiveness of different brick sets in managing mercury contamination during the filtration process. The increase in mercury content after the filtration process could be attributed to several factors. One possible explanation is that the filtration medium, in this case, the brick sets, might not be specifically designed to effectively reduce mercury. If the mercury-containing particles are not efficiently removed by the filtration process, they may pass through and contribute to the observed increase in mercury content. Additionally, the filtration process could potentially release or introduce mercury from the filtration medium into the water, especially if the medium undergoes any chemical changes during the process. Furthermore, if the mercury is present in a form that is not effectively targeted by the filtration method used, it may remain in the water, leading to an increase in mercury content post-filtration. Understanding the specific characteristics of the filtration medium and the nature of mercury in the water is essential for pinpointing the exact reasons behind the observed increase. For this chart, a row-normalized displays the percentages of correct and incorrect classified observations for each true class and a column-normalized shows the percentages of correct and incorrect classified observations for each predicted class.

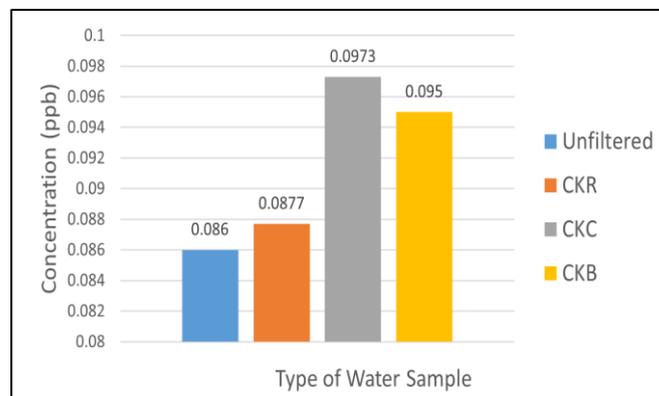


Fig 14: Mercury Contain in Water Filtration Result

## 4. Conclusion and Recommendation

The study focused on utilizing natural materials such as Clay, Kenaf, and Biochar (derived from Rice Husk, Bamboo, and Coconut Shell) to create bricks for water filtration. The first objective, determining the mixing ratio

of Clay, Kenaf, and Biochar for making water filter elements, was achieved by producing filter bricks according to predetermined ratios. The unique properties of each material were considered to optimize their combined effectiveness in filtration, highlighting the potential of using natural resources for sustainable water treatment solutions.

Moving on to the second objective, the evaluation of the performance of filter elements using Clay, Kenaf, and Biochar, involved laboratory analyses on water samples filtered with these bricks. The results provided valuable insights into the filtration efficiency of each material, confirming their capability to remove impurities from water. This successful evaluation aligns with the broader goal of promoting eco-friendly and resource-efficient methods in addressing water quality concerns.

In summary, the study demonstrates the feasibility and effectiveness of using natural materials in water filtration. Achieving the set objectives contributes to the knowledge base of sustainable water treatment and paves the way for further research and development in environmentally conscious practices for water purification.

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## Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

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