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Ability of Ceramic Composite Beads as a Pre-treatment for Laundry Wastewater and Preparation of the Process

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Abstract. The escalating demand for laundry services, particularly in university districts, has raised concerns about its impact on biodiversity. The situation becomes even more critical when wastewater is discharged into drainage systems without adequate treatment. This study aimed to enhance laundry wastewater treatment by employing ceramic composite beads using ceramic sanitary ware waste and chitosan. The investigation began by characterizing laundry wastewater to identify its specific attributes. Subsequently, the study quantified the removal of zinc as a metal during the laundry wastewater treatment process. Laundry wastewater characteristics were assessed using various parameters, including pH, chemical oxygen demand (COD), total suspended solids (TSS), and turbidity. The result revealed that the treatment of laundry wastewater with ceramic composite beads adsorbent successfully achieved over 50 % reduction in zinc concentration. These findings showed that the ceramic composite bead exhibited an efficiency for metal removal from the laundry wastewater for safe disposal.

Keywords: Biodiversity, laundry wastewater, ceramic waste, ceramic composite beads, and zinc removal.

1. Introduction

In most countries, the rapid growth of the laundry industry in cities has led to environmental degradation, given its generation of substantial volumes of wastewater. The deteriorating quality of water resources and the direct discharge of such sewage into the environment have been found to exert detrimental effects on water bodies and exacerbate water pollution on a national scale [1]. Laundry wastewater contains heavy metals, nitrogen, phosphate, and other elements, which can cause toxic effects on the ecosystem and induce changes in biodiversity [2][3]. Braga & Varesche [2] stated that Zn was the most abundant (0.56 mg/L) compound discovered in the wastewater, followed by Fe (0.22 mg/L) and Pb (0.06 mg/L). In line with that, the content of heavy metals in laundry greywater is generally low. However, the direct discharge of laundry greywater to open channels contributed to the heavy metal concentration load due to the addition of environmentally hazardous substances from cleaner products such as bleaching and detergents. In addition, a high volume of heavy metals and phosphates in laundry greywater decreases the biodegradability of greywater [3]. This can lead to accumulated and increased toxic levels in any organic living like plants, animals, and any living substances.

Adsorption is easy to perform, has a high metal-binding capacity, and is functional at a wide pH range [4]. In line with that, the use of these magnetic adsorbents for water purification gives a significant advantage over other adsorbents, such as their low cost and ease of separation of suspending adsorbents to be used again to reduce cost, as well as the ease to synthesize [5]. Secondly, biosorbents have an advantage over other adsorbents because they occur naturally in abundance, are associated with no cost, and can constantly be renewed. Typically, from the previous study, the circular economy approach by converting low-value lignocellulosic materials into added-value products [6], as the material herein was successfully synthesized with a surface area of 1368 m2/g from waste materials [7].

Chitosan is a promising and environmentally safe adsorbent with no secondary pollution, and it is well known. A significant amount of chitosan contains amino (eOH) and hydroxyl (eNH^2) groups, both of which can adsorb a range of pollutants, including heavy metals and dyes [8]. In line with that, chitosan can be derived into a type of adsorbent. For this purpose, shrimp shells were modified into chitosan with multiple advantages. However, since it possesses properties that make it quickly soluble in acidic situations and give it poor mechanical stability, natural chitosan is not presently advised for usage in practical settings [9]. Additionally, chitosan can be combined with other adsorbents to form chitosan composites, which may increase the efficiency of removing heavy metals. Kayalvizhi et al., [10] revealed that modifying the biosorbents improves metal ion adsorption capacity. Due to its robust metal chelating properties and accessibility, chitosan, a glucosamine biopolymer, has attracted significant interest in removing transition metal ions and organic species. Amino and hydroxyl groups in chitosan molecules have a high metal chelating ability, improving the stability in acidic media by forming Schiff bases [11]. Moreover, chitosan has the property of being hydrophilic [12] and soluble [13]. These characteristics enable it to treat heavy metals in laundry greywater.

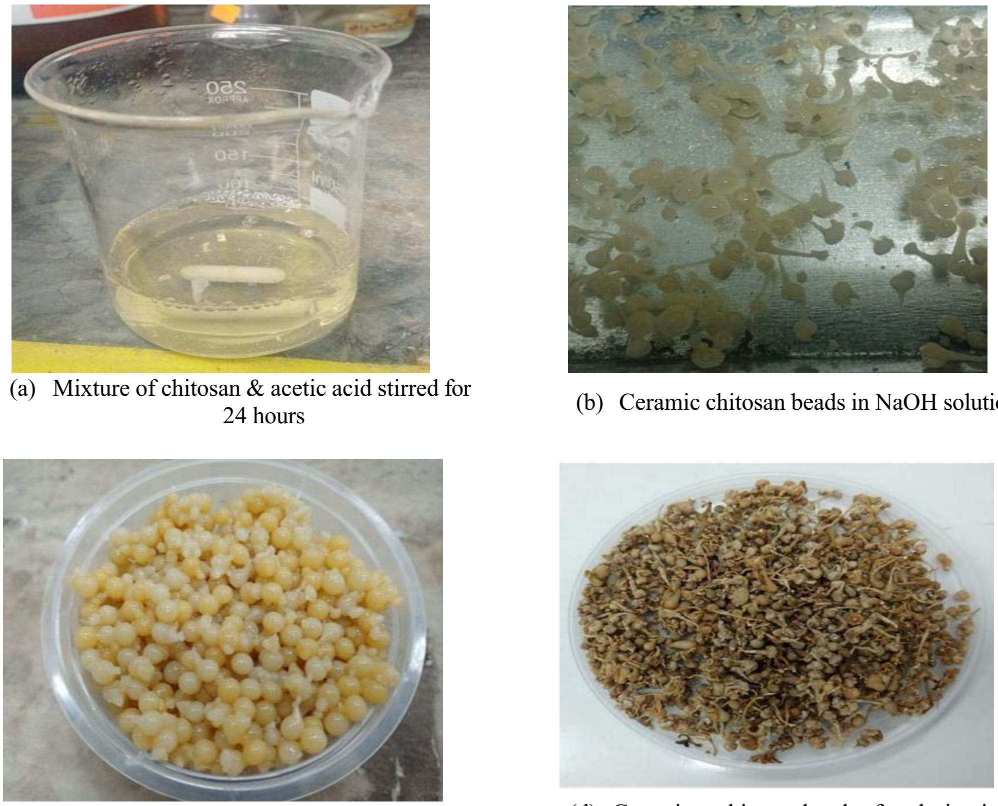
However, ceramic waste dumping on unplanned sites, inside water bodies, and nearby roads and the inadequate management of these wastes pose a problem in present-day society. Alternatively, to achieve sustainable development, ceramic sanitary ware waste can be applied for the adsorption of metal ions. Ceramic sanitary ware waste is the waste generated from households' sanitary ware. Ceramic sanitary ware waste is high in porosity and permeability and contains elements such as Silica (SiO^2), Alumina (Al^2O^3), and Iron Oxide (FeO) that interact well with heavy metals [14]. Just as important, ceramic made of clay has a high ion exchange potential and can adsorb some anions and cations exchanged in an aqueous solution for other anions and cations [15]. Moreover, the combined clays with traces of crystalline albite or crystalline pyroxene and silver compounds have a high adsorption efficiency when extracting metals [13]. Ceramics can also eliminate toxins as the tiny pores serve as filters, and the colloidal silver in the ceramic acts as a natural biocide to destroy microbes [16]. Lastly, the surface of mixed materials mainly consists of diverse active sites, and the pH_{ZPC} represents the average value of components of the solid matrix [17]. Therefore, the use of ceramic sanitary ware waste as adsorbent is selected for the sorption selectivity of mixed materials, and under appropriate conditions, they can attract cationic and anionic particles.

Furthermore, the mechanism and kinetics of the sorption approach depend on many factors such as surface morphology, magnetic behavior of the adsorbent, and experimental conditions like pH, adsorbent concentration, irradiation time, temperature, and the initial dosage of pollutant [5]. A higher adsorbent dosage may increase the metal's adsorption rate [18]. Contrarily, the higher initial concentration of heavy metal will result in lower adsorption of metals [19]. This is because of the unoccupied binding sites on the adsorbent surface at a low metal concentration. When the concentration rises, there will be inadequate sites for the adsorption of metal molecules, thus decreasing removal efficiency. The cationic adsorption decreases at a low pH value and anionic adsorption increases. While at a high pH value, the condition is vice versa [12]. The pH of a medium will control the magnitude of electrostatic charges imparted by the ionized metal molecules. Therefore, this factor is significant in adsorption, especially metal adsorption. In this study, the preparation of ceramic composite beads was expected to be evaluated for their potential application in zinc removal from laundry wastewater. Finally, this study aims to identify the characteristics of laundry wastewater and to assess the percentage removal of zinc using the ceramic composite bead adsorbent in laundry wastewater. The reduced concentration of laundry wastewater pollutants ensures the cleanliness of water for human reuse for the living. It reduces the possibility of risky cancer that can be impacted by water.

2. Materials and Methods

2.1. Preparation of ceramic sanitary ware waste with chitosan

6 g of chitosan dissolves in 80 ml of 5% acetic acid and is stirred for 24 hours to produce a chitosan gel. Mixing was then done for an hour with 2 g of ceramic sanitary waste aggregate [20]. A syringe was used to inject the ceramic sanitary waste powder with chitosan gel on top of a 1M NaOH solution in a big glass tray. In the NaOH solution, the ceramic sanitary waste aggregate with chitosan beads was collected from the surface and left for 12 hours. Then, carefully extracted from the NaOH solution, delicately rinsed with distilled water, and allowed to dry using an oven at 100°C for 1 hour before being stored. Figure 1 shows the step-by-step preparation of ceramic chitosan beads.



(a) Mixture of chitosan & acetic acid stirred for 24 hours

(b) Ceramic chitosan beads in NaOH solution

(c) Ceramic chitosan beads after 12 hours

(d) Ceramic chitosan beads after drying in an oven at 100 within 1 hour

Figure 1: The preparation of ceramic composite beads

2.2. Laundry wastewater samples

The laundry wastewater samples were collected from a Parit Raja Johor laundry shop station, as shown in Figure 2. For this study, the container used was an HDPE plastic bottle container (5L) with the total sampling taken were three samples using the grab sampling method and then transmitted to the laboratory for determining the characteristics according to APHA (2012) [21] as shown in Table 1.

Figure 2: The sampling point

Table 1: The standard method of parameter according to APHA (2012)

Item	Parameter	Standard Method	Equipment
1	Hydrogen ion (pH)	APHA 4500-H*b	pH meter
2	Chemical oxygen demand (COD)	APHA 5220	DR6000
3	Total suspended solid (TSS)	APHA 2540 D	DR6000
4	Turbidity	APHA 2130	Turbidity meter

The formula used for calculating removal efficiency and the molarity of 5 % of acetic acid were calculated using Eq. (1) and Eq. (2):

$$Percent\ removal = \frac{C_0 - C_r}{C_0} \times 100 \quad (1)$$

Where:
C_0 = Initial concentration (mg/L)
C_r = Final concentration (mg/L)

Acetic acid (5 %):

$$Molarity = \frac{no\ of\ moles\ of\ solute}{1\ Litre} \quad (2)$$

3. Results and Discussions

3.1. Characteristics of laundry wastewater

Table 2 shows the results of each parameter for the characteristics of laundry wastewater. The parameters were pH, Chemical oxygen demand (COD), Total suspended solids (TSS), and turbidity.

Table 2: The results of each parameter

Parameter	Sample 1	Sample 2	Sample 3	Average
pH	9.33±0.58	10.97±0.06	9.77±0.59	10.02
COD (mg/L)	155.67±3.06	130.67±1.15	101.67±1.53	129.34
TSS (mg/L)	100.67±2.52	30.00±2.00	36.33±1.53	55.67
Turbidity	76.49±0.66	29.25±1.19	44.95±1.39	50.23

The pH of Sample 1 was 9.33; Sample 2 was 10.97, which indicated that Sample 2 was the most alkaline among the others, while Sample 3 was 9.77. Sample 2 was influenced by the detergent concentration used during the washing time. Next, the highest value of the COD parameter for laundry wastewater was Sample 1, with a value of 155.67 mg/L. Sample 2 was 130.67 mg/L, and Sample 3 was 101.67 mg/L. This was because the sample was influenced by the different materials or clothing used during washing, so the sample had different concentrations of organic material. Then, sample 1 had the highest TSS parameter value of 100.67 mg/L among the laundry wastewater samples. Sample 3 exhibited a higher value of 30 mg/L compared to sample 3, which had a 36.33 mg/L. This could be attributed to sand, clay, and other elements in the washed laundry, contributing to increased TSS levels. For the turbidity parameter, it was found that Sample 1 had the highest value of 76.49 mg/L. The value of Sample 2 was 29.25 mg/L, while Sample 3 had a higher value of 44.95 mg/L. The turbidity range observed in Greywater Falls was between 19 and 444 NTU. The turbidity of wastewater was likely to increase when it contained suspended matter, mainly when the water was sourced primarily from the laundry.

Washing machines are the primary source of greywater produced by the laundry process. After that, the primary components of the process that were washed off the garment were laundry detergent and filth (such as hair, lint, and dust). The temperature of the laundry wastewater produced by the washing machine may reach up to 95°C, depending on the setting of the washing program. As a result, it must first go through the process of being buffered before it can go on to the biological therapy stage. Laundry wastewater was devoid of solid organic material, as seen in large concentrations of feces and food leftovers. As a result, less organic stuff is discovered after mechanical treatment (like sieve) and sedimentation. Additionally, the organic material does not need to be dissolved to be accessible for subsequent degradation. However, items including surfactants and other complex anthropogenic compounds (such as artificial scents and preservatives) make up most of the organic matter in greywater. They were notorious for having limited biodegradability [22].

3.2. Removing zinc in laundry wastewater

The method used for laundry wastewater treatment for this study was the ceramic composite bead adsorbent, which used chitosan with ceramic sanitary waste to remove zinc. Table 3 shows the effectiveness of ceramic composite bead adsorbent based on the difference in concentration of the laundry wastewater before and after treatment. Before the treatment, the initial zinc concentration in the laundry wastewater was 4.8109 ppb. Next, the concentration of zinc followed by the amount of ceramic composite bead adsorbent used were 1.0 g, 2.0 g, and 3.0 g, as the sequence were 3.5480 ppb, 2.3417 ppb, and 2.259 ppb. It showed that the zinc concentration in the laundry wastewater sample 1 before treatment and after treatment decreased as the amount of the ceramic composite bead adsorbent used in the sample increased for the laundry wastewater treatment.

Table 3: Effectiveness of ceramic composite beads for zinc removal in laundry wastewater

Mass (g)	Control	1.0	2.0	3.0
Concentration of zinc (ppb)	4.8109	3.5480	2.3417	2.2590
Percentage removal (%)	-	26.25	51.33	53.04

Figure 3 shows the percentage removal of zinc in laundry wastewater. The factors that affect the efficiency of adsorption include the strength of the bond between metal ions and the adsorbent surface and the adsorbent's thermal and chemical stability. Additionally, low mechanical strength, incomplete desorption, a decline in the effective adsorbent interaction, and a lack of available adsorption sites can all impact the overall effectiveness of the process. The percentage of metal removal rises as the amount of ceramic composite bead adsorbent increases. It can be observed that the concentration of metals in laundry wastewater was typically minimal. The discharge of laundry wastewater into open channels increased metals concentration. This was due to environmentally hazardous substances in cleaning products like bleaching agents and detergents [2].

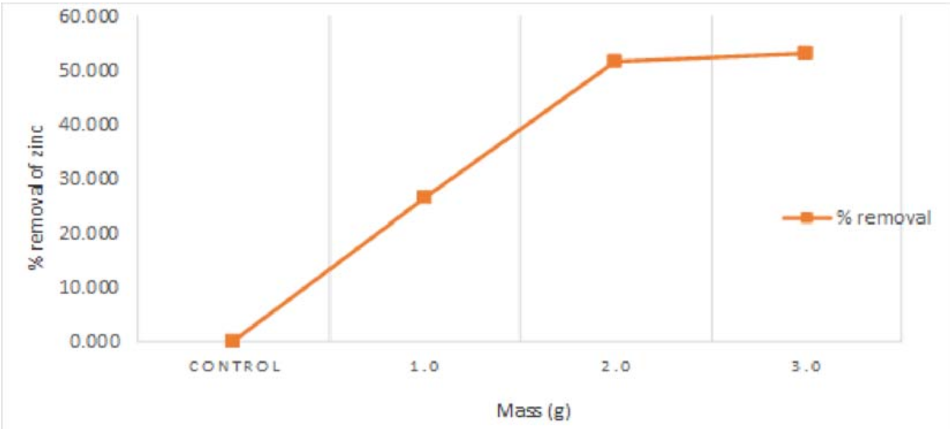


Figure 3: Percentage removal of zinc from laundry wastewater using ceramic composite beads

4. Conclusion

The preparation of ceramic composite bead adsorbent depended on the ratio adjusted during preparation to achieve the maximum viscosity. The characteristics of the ceramic composite bead adsorbent were analyzed based on the ratio used for this study. This study aimed to determine the efficiency of removing metals in laundry wastewater as a pre-treatment—the efficiency of the ceramic composite beads increases, followed by the amount of the treatment alternative used. In conclusion, the results proved the effectiveness of ceramic composite beads adsorbent in removing more than 50
% of metals (zinc) in laundry wastewater, thus identifying the characteristics of laundry wastewater. It concluded that the percentage removal can be doubled as the amount used increases as the zinc concentration in laundry wastewater decreases. The treatment used gave many advantages to the environment, as it had a biodegradable natural source, was eco-friendly and safe from harmful chemicals, and characterized laundry wastewater based on the parameters for this study. In line with that, it would be a good improvement if more elements could be determined to remove metals in laundry wastewater using ceramic composite beads adsorbent. The determination of the ratio of chitosan used can also be investigated for the following study to determine the maximum efficiency where the optimization point of the ceramic composite bead adsorbent towards the laundry wastewater pre-treatment. It was to strengthen this method's efficiency in pre-treatment laundry wastewater and achieve more expected results.

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