Fabrication of Sugarcane Bagasse Based Mesh as an Adsorbent of Copper (Cu^{2+}) Metal Contaminant for Wastewater Treatment

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Abstract –Water pollution is one of the main problems faced in the present due to contaminants from industrial areas discharged to the environment such as toxic heavy metals. Sugarcane bagasse as a raw waste material can be utilized to adsorb known metal contaminants such as copper. In this study, the percent reduction of the fabricated bagasse mesh was investigated. The testing of the product involved exposure of the mesh to known concentrations of synthesized wastewater. The final concentrations were then analyzed using the UV-Vis spectrophotometer. Results show that the mean of percent reduction amongst 5 replicates is 37.2 31.5 percent. Certain parameters, such as contact time and pore size, affect the adsorption rate of the mesh yielding low in value. From these results, it is concluded that sugarcane bagasse based mesh is viable for copper adsorption. Modifications is recommended to further increase the adsorption rate of the product.

Introduction. – Water is an essential resource due to its importance to human survival. Industrial use and commercial use are examples of water usage that rely on large quantities of water. Different industries may be a great source of income in some developing countries; however, it brings negative consequences to aqueous environments near industrial sites. Industrial applications such as processing, rinsing, scrubbing, and cooling of water cause industrial wastewater, a source of harmful contaminants, to increase that may be discharged to the environment if not properly observed [3]. Textile factories, an example of an industrial site, can be a major cause of water pollution due to its discharge of contaminants such as harmful chemicals and dyes. Over 2,000 types of chemicals and 7,000 types of dyes from textile production were identified and could potentially contaminate the water near its site [13]. These chemicals and dyes that are exposed to water systems cause water pollution, which is a serious concern that needs to be addressed. These chemicals include heavy metals, such as copper, cobalt, and zinc, which are considered the most harmful pollutants that pose a serious threat to human health [6]. Copper is a toxic heavy metal, which causes death if ingested in high concentrations. Copper in its dissolved state is unfilterable, thus difficult to remove in the water system. There are numerous ways to remove copper from contaminated water. One of these methods is chemical precipitation, which removes copper via hydroxide and sulfide; however, it may pose negative effects to the environment from the ionic exchange process [8]. Another method is the use of bio filtration systems that accumulate contaminants from urban storm water runoff, preventing discharge to the water; however, this method is expensive since mechanical parts being used in this system are costly [5]. Aerobic biodegradation, the breaking down of organic contaminants when oxygen is present, is a method for conventional wastewater treatment. This can also decrease the concentration of contaminants; however, it possesses low removal efficiency due to low biodegradation of these contaminants such as dyes [11]. Aside from the methods stated, there are other alternatives that can be used for removing contaminants. There is an increase of popularity in using agricultural wastes to treat wastewater since it is low-cost, efficient and practical to use for water clean-up [9]. One of these wastes is sugarcane bagasse, or bagasse, which are fiber residues after sugar extraction from sugarcane [2]. In the Philippines, the largest sugar output is located in the Visayas region, the Negros Island particularly has the biggest hectarage of bagasse [12]. Bagasse can be utilized for product making and as an energy resource; however, a significant portion of it is stockpiled and may be considered waste if not used in the long run. Using bagasse for wastewater treatment could be a possible application. There have been several studies such as the study by Rana et al. [10] that uses bagasse as an adsorbent for copper. Using raw agricultural waste material as an adsorbent to remove metal contaminants is a solution that is both low-cost and time-efficient. From this advantage, bagasse can be utilized to create a product that could increase the adsorption efficiency of the material. Possible modifications such as mesh structure could increase adsorption efficiency due to increase of surface area and also contribute in filtering unwanted filterable solids in the water. There are no studies or methods regarding the synthesis of mesh made from bagasse fibers to treat wastewater, thus, this study aims to create a mesh from bagasse fibers to adsorb Cu^{2+} ions from copper contaminated water. This study specifically aims to fabricate a mesh from sugarcane bagasse, test the mesh against contaminated water, and determine the percentage of bagasse mesh. As more industries rely on water usage for production, greater amounts of contaminated water are discharged and cause water pollution to the environment. Creating alternative technologies to remove unwanted toxic particles, such as copper, is preferred to decrease the pollution rate of environmental waters. Studies of copper removal in drinking water have been conducted to minimize the casualties of copper intoxication that may affect negatively to human health. In addition, implementing mesh based design using raw materials could also solve the problem of suspended solids in water through filtration. Using wastes such as sugarcane bagasse to adsorb harmful chemicals in contaminated water will not only help in wastewater treatment but will also promote the use of wastes as low-cost adsorbents to remove pollutants in the environment.

Methods. – This study aims to create a mesh from bagasse that can adsorb Cu^{2+} ions from synthetic copper contaminated water. Five meshes were coated with raw sugarcane bagasse with epoxy. The mesh made from the bagasse was treated with sulguric acid for thirty (30) minutes and then dried in an oven for 24 hours at 100C. Testing of the products involved using polyvinyl chloride (PVC) pipe with the attached fabricated mesh as a makeshift adsorbing column and let the synthetic wastewater flow through the pipe three times. The concentrations were then measured using the ultraviolet visible spectrophotometer (UV-Vis).

Preparation. One kilogram of bagasse was acquired from Central Hawaiian, Silay City, Negros Occidental. It was pre-washed and dried in an oven at 150C for 2 hours. Glasswares used were acquired from the SRA Chemistry at PSHS-WVC and were pre-washed, dried and calibrated. For the copper stock solution, 0.200g of solid $CuSO_4$ was diluted with 25.0 mL of distilled water to achieve a concentration of approximately 0.0500M. The solution was then further diluted by mixing 15.0 mL of the 0.05M copper solution with 735.0 mL distilled water in a 1L beaker to acquire a 750.0 mL of 1.00×10^{-3} M copper solution. 500.0 mL of the copper stock solution were used for the testing of the mesh while the remaining 250.0 mL were stored and further diluted to be used as standards for analysis.

Mesh fabrication and treatment. The mesh was created by using sterile gauze as base. The base was used because of the bagasse fibers short length. Then, the epoxy was beforehand diluted with 100 percent denatured alcohol to effectively spread the epoxy between the fibers. The solution was then added to the mesh to hold the fibers. The mesh is then left to dry overnight. The bagasse meshes were treated with concentrated sulfuric acid for 30 minutes and then were kept in an oven at 150C for 24 hrs to activate the adsorbent.

Fig. 1: Treatment of the bagasse

Testing. The fabricated mesh was attached to one end of the PVC pipe using a rubber band. The set-up served as a makeshift adsorbing column. The synthetic wastewater, 100mL of the copper stock solution, was then poured to the other end of the pipe. This process was then repeated thrice to acquire maximum percent adsorption of copper [1]. Afterwards, the synthetic wastewater will be stored in a container for UV-Vis spectroscopy. This was repeated five times for a total of five replicates.

Fig. 2: Mesh testing

This process was then repeated thrice to achieve a much higher adsorption capacity for five mesh replicates. Five varying concentrations were prepared from the copper stock solution.

Fig. 3: Five concentrations

Then, two drops of aqueous ammonia were added to each test tube. Then these concentrations were analysed using the UV-Vis spectrophotometer to acquire the standard curve.

Analysis. Five unknown concentrations from the testing were also analysed. Again, two drops of ammonia were added to each flask and the concentrations of the tested wastewater were analysed using the UV-Vis spectrophotometer. After acquiring the data, percent reduction of copper was calculated using this equation.

$$\%\ Reduction = 100 - \left(\frac{Concentration\ of\ adsorbate}{Initial\ concentration\ of\ adsorbing\ solution}\ x\ 100\right)$$

Disposal. Proper disposal was then observed. Remaining bagasse wastes were put in a separate bag and was properly disposed. Materials and chemicals used during testing were kept in secured waste containers and was disposed in hazardous bins.

Results. – These are the results of the study. Before presenting the numerical results, the characterization of the mesh was discussed. The figures show the bagasse mesh before and after chemical treatment. After treatment, bagasse mesh increased in thickness and there is partial discoloration of the material.

Fig. 4: Bagasse mesh before testing

Fig. 5: Bagasse mesh after testing

Figure six shows the percent reduction of copper among the five mesh replicates. It is evident in the figure that the mesh can adsorb variable amounts of copper. However, values of copper reduction are spread out due to high standard deviation.

Discussion. – It is shown that Replicate 3 had the lowest percent reduction rate of 21.5 percent while Replicate 5 has the highest with 58.9 percent. The mean of the reduction values of five replicates is 37.2 percent with a standard deviation of 31.5 percent.

Effects of contact time. Certain parameters such as contact time, initial concentration, chemical treatment, epoxy, pore size affected the adsorption rate of the bagasse mesh. The contact time was the major parameter that affected the adsorption of the material. Due to small contact

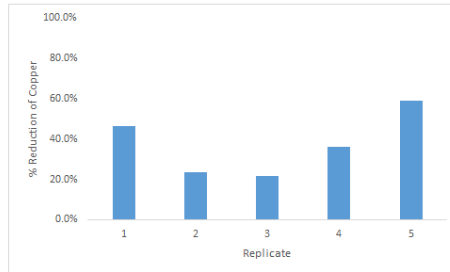

Fig. 6: Percent reduction of copper

periods of the product to the water, the bagasse could not properly form complexes with the copper.

Effects of sulfuric acid. Sulfuric acid treatment to bagasse also increase the adsorption rate of the product. From a study by Mesfin Yeneneh et al. [7], sulfuric acid contributes to the essential stretching of functional groups such as hydroxyl, carboxylic acid, carbonyl, aromatic and phenolic groups which binds the heavy metals. The mechanism behind involves sulfuric acid removing lignin compounds in the bagasse which increases the concentration of hydroxyl and carboxylic acid groups.

Effects of epoxy. The bagasse incorporated with epoxy resin as an adhesive formed a composite. However, the epoxy resin may block the fibers from adsorbing the copper ions which may contributed to the low adsorption rate of the bagasse fibers alone but epoxy is also shown to adsorb metal contaminants [4]. It is not known on what extent the epoxy adsorbed the copper ions during testing.

Conclusion. – To conclude, sugarcane bagasse based mesh is viable to remove copper in wastewater. However, due to its low adsorption rate compared to the average percent copper reduction, the product needs further improvements. This study introduces a new approach of wastewater treatment and this product is open for further development that could potentially increase its efficiency in removing not only copper, but contaminants in general.

Recommendations. – To further improve this study, it is recommended to:

- Apply modifications of the mesh. Increasing the mass of bagasse or increasing layers of bagasse mesh is recommended.
- Create alterations of product such as sponges or cotton made out of bagasse.
- Utilize a smaller pore-sized mesh to decrease the flow time of the water. Decreasing the pore size of the material could possibly increase the adsorption rate of the product due to longer exposure times.
- Use a more precise analysis test for copper concentration, such as AAS (Atomic Absorption Spectroscopy)

in order to test the product in much lower concentrations of copper

- Test the product on other metal contaminants or dyes to know the extent of adsorption.
- Further study the adsorption kinetics of the product as certain parameters, such as pH and temperature, to understand how it affects the adsorption rate of the sugarcane bagasse as a mesh product.
- Use other chemicals, such as succinic anhydride and oxalic acid, as treatment of the bagasse. Comparative studies amongst different chemical treatments can be further studied.
- Characterize the porous structure of treated bagasse mesh to confirm signs of adsorption rate increase.
- Compare copper reduction of raw bagasse and bagasse-epoxy composite to know the effect of epoxy to the adsorption rate of the composite.

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