

Water Filtration Using Recycled Denim Fabrics for Daily Applications

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Abstract

This study investigates the use of three types of recycled denim fabrics coated with chitosan for household water filtration applications. Chitosan, a biopolymer known for its adsorption capabilities, was applied to enhance the removal of pollutants from raw water. Five layers of each denim type were stacked to form fabric filters. The filtration efficiency was assessed through turbidity and pH tests using river water as the test medium. Results showed that the chitosan-coated denim improved water clarity, with Denim 3 achieving 0 NTU turbidity and exhibiting no significant impact on pH. Although Denim 3 demonstrated high filtration efficiency, the filtration process occurred at a slower rate compared to other fabrics. These results indicate that the combination of chitosan coating on denim can be used as a cheap and sustainable option to treat small water volumes in a decent way, particularly in areas with limited access to clean water.

1. Introduction

Clean and safe drinking water is presently one of the top world challenges and according to reports by WHO and UNICEF, more than 884 million of the world population does not have a basic water service [1]. This deficiency plays a major role in health complications, especially in less-developed areas and disaster-affected areas, where diarrhea diseases still occur, especially since there is poor sanitation and water sources contaminated with waterborne diarrhea diseases [1]. Older traditional water treatment technologies, albeit effective, could usually rely on energy-demanding processes, expensive infrastructure, and non-renewable materials and thus have a limited scaling capacity and environmental impact.

Following the difficulties with these solutions, innovations in the engineering and materials science have opened up the avenue of more decentralized and sustainable water purification solutions. Of these, it was the nanotechnology enhanced filtration as it has been found to have great potential in making low-cost, point of use treatment a very close possibility since they have a great surface area, low energy requirements and they are able to effectively remove the contaminants [2]. The woven and non-woven fabrics have been used long in filtration applications because of their porosity and mechanical strength of textiles. The use of recycled textile, however, has not been fully utilized although it has both environmental and economic advantages [3].

In this research work, recyclable denim fabrics were coated with chitosan which is a polysaccharide produced by deacetylation of chitin in obtaining an eco-friendly water filtration system. Chitosan would be a perfect option in the improvement of filtration media because it is non-toxic, biodegradable, has high antimicrobial, and has high adsorptive properties [4]. The study will compare and contrast the turbidity reduction, pH stabilization and flow rate efficiency of coated and uncoated fabrics to assess their effectiveness when determining the effectiveness of

filtering river water. This project incorporates both renewable bio-nanomaterials and textile waste, therefore matching the ideals of sustainable engineering and circular economy, and assuring the urgent requirements of water access.

The article will add to the literature on functionalized fabrics used in the treatment of water and will show the promise of low cost, recyclable, sustainable and biodegradable filtration using readily available material [5][6]. Finally, the results will be used to create further designs in efficient and resource-saving water treatment systems, especially where the traditional ones will not be possible.

2. Methodology

2.1 Materials

Three post consumer denim fabrics were obtained from bundle shop in Malaysia which will be named as Denim 1, Denim 2, and Denim 3. The physical properties of all the Denim fabrics were recorded based on the weight, thickness and surface of the fabrics. The structure and density of three different fabrics were examine and shown twill woven structure of fabrics. For denim 1, denim 2 and denim 3 fabric density is recorded 660 in², 714 in² and 1280 in² respectively. The chitosan powder used as coating material was obtained from ChitoLytic, brand Spectrum. To imitate the natural environmental situation, the raw water to be tested was collected from Panchor River, Muar, Johor, Malaysia. All materials were cleaned and dried prior to use in order to deal with correct test and coating procedure.

2.2 Procedures

Prior testing, the fabrics were washed and air dried at room temperature to eliminate possible dirt and contamination. Physical attributes of the fabrics, such as thickness, weight per unit area, structure, and density were determined with the use of common instruments e.g. thickness gauge (Electronic Micrometer Digital Thickness Meter Gauge), electronic scale (Model No. ZK200C), optical microscope (Olympus BX53M), as per ASTM standards.

Then, a coating solution of chitosan was prepared by dissolving 8 g of a free-flowing chitosan powder in a combination of 8 ml acetic acid and 792 ml distilled water. The mixture was stirred with a magnetic stirrer until homogenous approximately 6 hours. After the coating solution ready, the single layer of fabrics, subsequently cut into 15 cm x 15 cm areas were immersed in the chitosan solution 3 times to make sure the fabrics were coated well with the solution. The coated fabric were then dried in the oven at 50°C for 3 hours.

The weight per unit area, thickness and surface structure of the coated fabrics were analysed. The experimental setup for filtration testing is shown in Fig. 1. The fabric filters were developed by stacking five layers of fabrics and tied over a clean beaker to collect filtered water. A movable lid was placed over the fabric followed by a container positioned to hold the raw water. A total of 300 ml raw water was poured in the container. The movable lid was then removed to initiate the filtration process.. The filtration time for 300 ml of raw water was recorded, followed by turbidity and pH measurements to evaluate water clarity and chemical balance.

For the turbidity test procedure, each of the filtered water is poured into the small bottle and wiped with a tissue paper and then inserted into the measuring cells. As soon as the measuring cells are sealed press the start button to commence a reading. The display window will display the reading data in NTU. Turbidity tests were used three times to obtain accurate and dependable results. The filtered water is used to test pH by adding it to each of the 300 ml beakers. Once the pH electrode has been immersed into the filtered water, the results are displayed on the digital screen. The pH value is measured only once.

The surface morphology of the fabric under investigation was performed on Olympus BX53M. In order to have a clear representation of the surface, every cloth will be placed under a 10x optical microscope and adjusted. The picture which was shown on the screen and captured to notice the difference.



Fig. 1 Filtration Process

3. Results and Discussion

The physical properties of the denim fabrics were studied before and after coating to the purpose of understanding their predisposition to water filtration uses. Upon coating with chitosan, all fabric samples registered a small increment in thickness and weight of the fabric (as shown in Table 1) and this was a demonstration of effective absorption of the coating agent. Structural study with the help of optical microscope indicated that the coated fabrics were more smooth and dense on their surface than the control ones and it is very likely that it has helped the coated fabrics to retain the contaminants better in the case of filtration (as shown in Fig 2, 3 and 4). These modifications allowed developing an effective, cost-efficient, and sustainable filtration medium on the basis of recycled fabrics according to modern trends in the field of environmentally friendly engineering solutions. In Fig. 5, Show the filtered water after the process.

Table 1 Thickness and weight of denim

| Sample | Weight per unit area (g m^{-2}) | | Thickness (mm) | |
|--------------|--|--------------------|-------------------|-------------------|
| | Uncoated fabric | Coated fabric | Uncoated fabric | Coated fabric |
| Denim 1 (D1) | 5.686 ± 0.236 | 5.582 ± 0.654 | 0.587 ± 0.006 | 0.610 ± 0.010 |
| Denim 2 (D2) | 5.692 ± 0.047 | 5.969 ± 0.410 | 0.623 ± 0.006 | 0.633 ± 0.006 |
| Denim 3 (D3) | 10.723 ± 0.068 | 10.957 ± 0.278 | 1.017 ± 0.006 | 1.047 ± 0.006 |



(a)



(b)

Fig. 2 Surface morphology Denim 1 (a) Uncoated (b) Coated

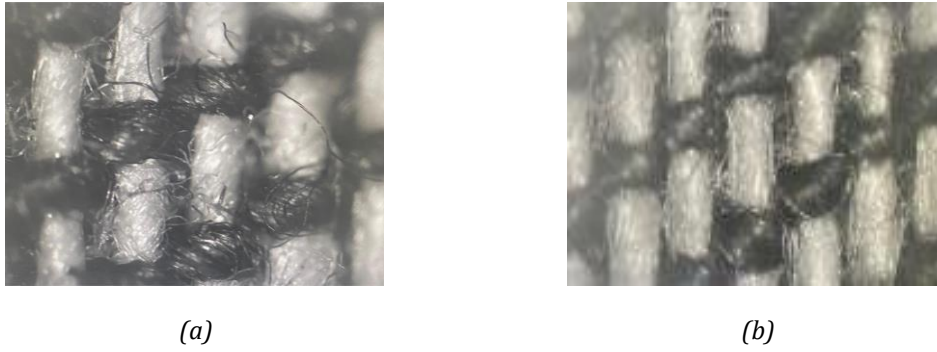


Fig. 3 Surface morphology Denim 2 (a) Uncoated (b) Coated



Fig. 4 Surface morphology Denim 3 (a) Uncoated (b) Coated

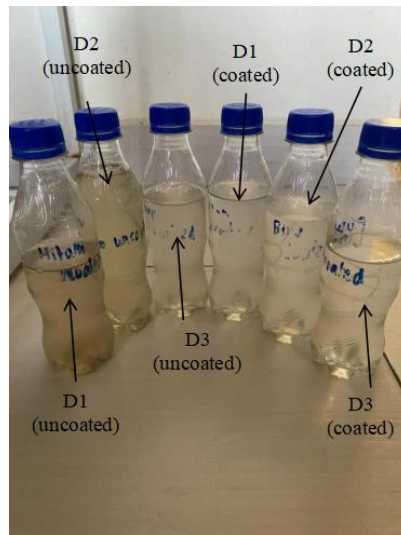


Fig. 5 Filtered water

The duration in which 300 mL of raw water was flowed was observed and the flow rate determined by equation (1) with Q is flow rate (mL/s), v is volume (mL) and t is time (s).

$$Q = \frac{v}{t} \tag{1}$$

The result of flow rate for each sample is shown in Fig. 6. The higher the flow rate means the shorter the time taken for the filtration. Denim 3 show the longer time to filter the 300 ml of water compared to the other two denim.

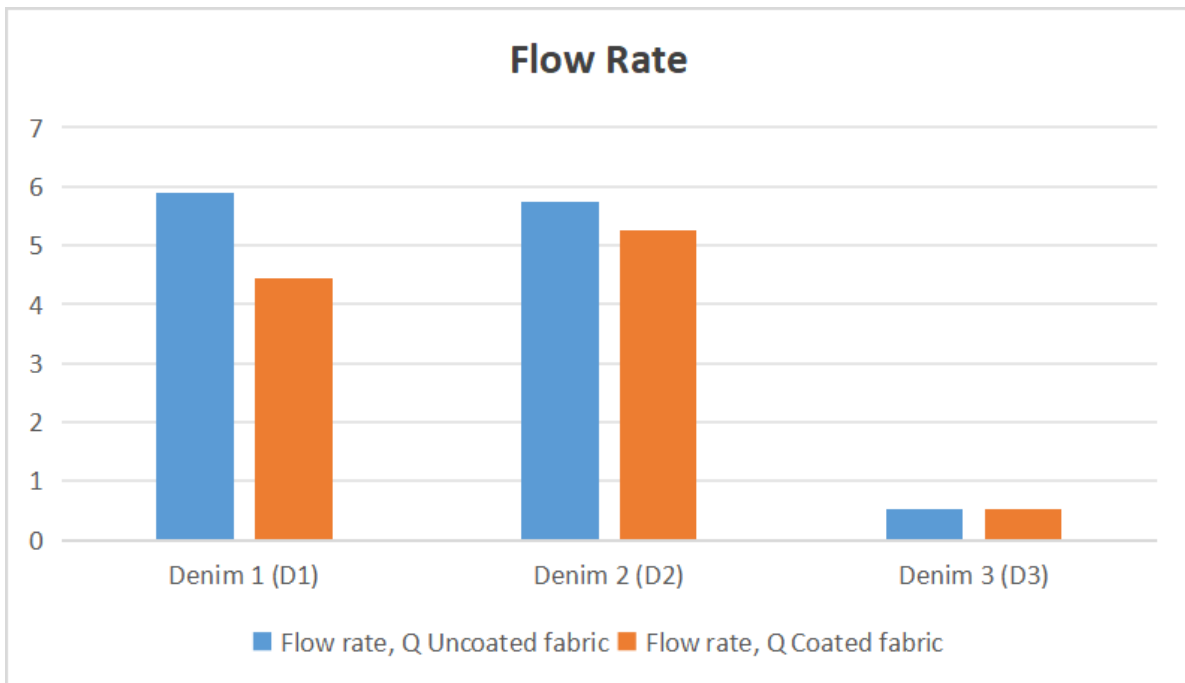


Fig. 6 Flow rate

3.1 Turbidity Test

Among the three denim samples tested for turbidity as shown in Fig. 7, the Denim 3 coated fabric exhibited the highest turbidity removal efficiency, achieving 0 NTU. This suggests that both the fabric's structural characteristics and the adsorption capacity of chitosan played a significant role in enhancing filtration. In contrast, Denim 1 showed an unexpected increase in turbidity after coating, potentially due to issues such as uneven coating distribution, pore blockage, or altered fabric rigidity that affected the water flow path. Denim 2 displayed a moderate improvement, with turbidity reduced from 37.9 NTU to 21.7 NTU after coating, indicating partial adsorption effectiveness. These results highlight that the filtration performance of chitosan-coated fabrics is not solely dependent on the coating itself, but also on the compatibility between the fabric weave and the applied biopolymer. Future optimization may involve refining coating techniques or selecting fabrics with more favorable microstructures for effective pollutant entrapment.

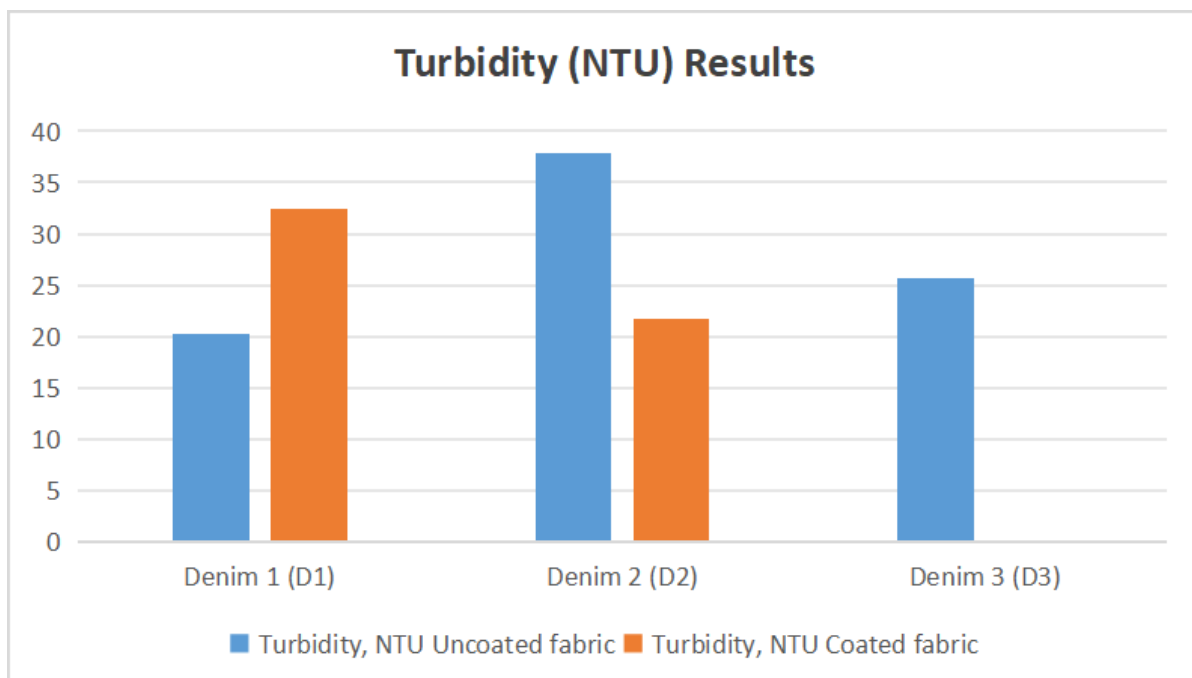


Fig. 7 Turbidity data

3.2 pH Test

As in Fig. 8, it shows clearly the pH level for both uncoated and coated denim fabric. The water pH after being filtered through the three types of coated and non coated denims was taken. There is no any considerable difference between pH levels of filtered water dried by the two of the denim.

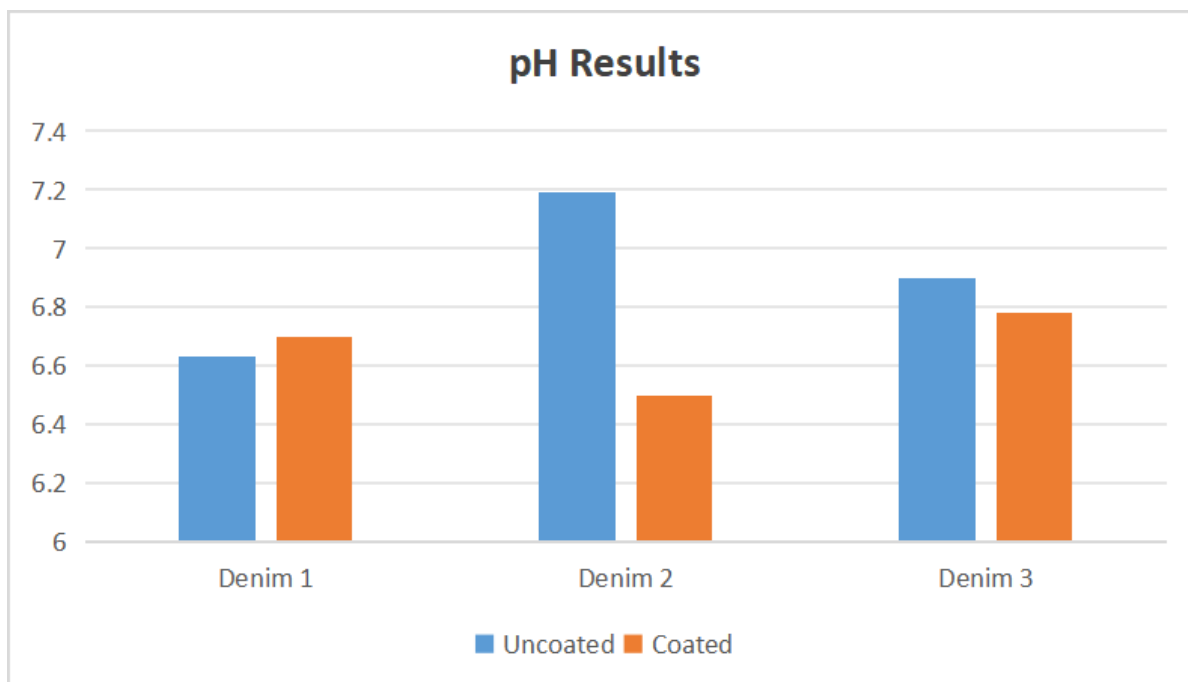


Fig. 8 pH Data

It was found that the coated and uncoated denim fabrics worked on the pH of the filtered water to be in the safe drinking range of 6.5 to 8.5 as prescribed by the health standards. The differences between samples were also not significant despite showing minor variations between the samples. The pH of coated denim 3 was 6.78 and of the uncoated denim 3 was 6.9, which means that the chitosan coating did not have an adverse impact on the chemical balancing of the water. The consistency of pH established this filtration process as physically effective in minimizing the turbidity levels and also being chemically safe to be used regularly. The finding justifies the use of bio-based coating such as chitosan in coming up with non-toxic and green water purification systems as part of the drive of the objectives of green engineering solutions.

4. Conclusion

This project showed that denim, a sort of fabric that can be recycled, has the potential to become an innate water filtration medium by coating the fabric with chitosan. The research has been efficient as it was able to compare the coated and uncoated fabric based on testing the turbidity, pH, and flow rate. Findings revealed that coated denim particularly denim 3 was the most promising as it attained a zero NTU turbidity and safe pH level, yet it had a low flow rate because of high density and absorption. Through the research, it has been affirmed that low costs, sustainable, and eco-friendly materials can be used to carry out small-scale water purification, especially in regions where clean water is scarcely available. Finally, it also helps to develop the inclusive and sustainable filtration with the use of recycled textile wastes.

Improvements in the future are suggested to be achieved through the experimentation of having more layers of fabric (e.g. 8 layers), alter the chitosan solution by adding ingredients such as glycerol or citric acid, and experiment with hybrid coatings to increase the water repellent and bacterial resistant properties. Standard operating procedures on coating and testing would also provide wider application and expansiveness of this low-cost alternative in the real-life situations.

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References

- [1] Liu, H., Tang, X., & Liu, Q. (2014). A novel point-of-use water treatment method by antimicrobial nanosilver textile material. *Journal of water and health*, 12(4), 670-677. <https://doi.org/10.2166/wh.2014.197>
- [2] Nasrollahzadeh, M., Sajjadi, M., Iravani, S., & Varma, R. S. (2021). Carbon-based sustainable nanomaterials for water treatment: state-of-art and future perspectives. *Chemosphere*, 263, 128005. <https://doi.org/10.1016/j.chemosphere.2020.128005>.
- [3] Eyvaz, M., Arslan, S., Gürbulak, E., & Yüksel, E. (2017). Textile Materials in Liquid Filtration Practices: Current status and Perspectives in water and Wastewater Treatment. In *InTech eBooks*. <https://doi.org/10.5772/intechopen.69462>.
- [4] Jalvo, B., Aguilar-Sanchez, A., Ruiz-Caldas, M. X., & Mathew, A. P. (2021). Water filtration membranes based on non-woven cellulose fabrics: Effect of nanopolysaccharide coatings on selective particle rejection, antifouling, and antibacterial properties. *Nanomaterials*, 11(7), 1752. <https://doi.org/10.3390/nano11071752>.
- [5] Sharkawy, A., Barreiro, M. F., & Rodrigues, A. E. (2020). Chitosan-based Pickering emulsions and their applications: A review. *Carbohydrate Polymers*, 250, 116885. <https://doi.org/10.1016/j.carbpol.2020.116885>
- [6] Petrisor Samoila, Andra Cristina Humelnicu, Ignat, M., Cojocaru, C., & Harabagiu, V. (2019). Chitin and Chitosan for Water Purification. 429–460. <https://doi.org/10.1002/9781119450467.ch17>