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Water Quality Improvement using Aloe Vera and Coconut Husk as Natural Coagulant for Shah Alam Lakes Malaysia

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Population growth in Shah Alam, Selangor, has increased the demand for water supply, whereby the extraction from water bodies such as rivers and lakes has become the alternative. However, heavy pollution has significantly degraded the water quality in this surface water. Therefore, treatment is compulsory to upgrade drinking water quality before it is supplied to consumers. The coagulation and flocculation processes are crucial in water treatment. Conventionally, chemical coagulants are used, but this practice will generate high residue in the sludge and is deemed dangerous to the environment. Therefore, new alternatives, such as natural coagulants, can be substantial. Here, this innovation aims to evaluate the efficiency of natural coagulants using aloe vera and coconut husk in treating the water samples from Shah Alam lakes, Selangor. From the results, the water quality index (WQI) before the treatment was classified as Class IV, which is only suitable for irrigation. After the treatment, the result shows turbidity removal of 67.98% and 78.96% for aloe vera and coconut husk, respectively. The total suspended solid (TSS) has been achieved for both bio-coagulants (96.50% and 97.77% for the percentage removal). Later, 71.62% and 61.54% were determined for aloe vera and coconut husk for ammonia-nitrogen removal. Meanwhile, for the biochemical oxygen demand (BOD), the highest removal was achieved by the treatment of aloe vera (97.80%). Therefore, it is proven that aloe vera and coconut husk can be substituted for water treatment. They are considered sustainable green technologies that can be adapted to the water treatment processes, providing a reassuring solution for the environment.

Keywords: Aloe vera; coconut husk; lakes, natural coagulant; water quality

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Drinking water is crucial for their sufficiency as it will be used by many consumers, specifically in the Selangor region. However, the population growth in Selangor has increased, causing the demand for drinking water supply. Due to industrial, urbanization, and human activity, water sources such as lakes and rivers contain high impurities that could decrease water quality [1]. The raw water might be contaminated and exposed to harmful ingredients such as heavy metals that can harm consumers' health, especially humans, animals, and plants. Therefore, raw water needs to undergo treatment for a clean water supply. Ensuring this source undergoes appropriate water treatment before consumption is important [2].

Therefore, several water treatment steps for water supply, including coagulation, flocculation, sedimentation, filtration, and disinfection, are crucial [3]. Coagulation is one of the chemical treatments that can be used to treat contaminants in water. Usually, the coagulation process will use chemical coagulants like alum and ferric chloride [4]. The coagulation process happens in the first phase of the water treatment process. Surface water must be treated to remove turbidity, colour, and bacteria. The coagulation process will turn the small particles of colour, turbidity, and bacteria into larger flocs, either as precipitates or suspended particles [5]. During coagulation, the suspended solids and negative colloids will be neutralized to avoid particles parting away from each other and later forming floc particles.

The particles will bind with the common chemical coagulants [6]. Chemical compounds such as ferric chloride and aluminium are important for forming the particles into flocs [4]. Alum is the most

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used chemical coagulant in water treatment; however, combining it with other coagulants, such as polyferric sulfate (PFS), could help its effectiveness throughout the process [7].

However, many studies found that using chemical coagulants is unsafe for human health and the environment. According to [4], chemical coagulants are still not sustainable for their usage during processed water treatment as many aluminiums could lead to health issues such as Alzheimer's disease and are not eco-friendly. The chemical is also not easy to obtain as it is expensive and has a longer production time. Therefore, expediting the substitute for the coagulant's agents is necessary [8]. It can be found that several types of natural coagulants can be used for water treatment, where some of them can be extracted from plants, animals, and microorganisms. One of the natural coagulants from plant-based that can be used for water treatment are aloe vera and coconut husk.

It has been found in their research that coconut husk as activated carbon is effective for removal in wastewater treatment [9]. Their research evaluated the performance of coconut and rice husk as activated carbon to reduce the pollutants in wastewater. They conducted the jar test experiment with different concentrations of coconut husk and rice husk as activated carbon. Later, they found that a coconut and rice husk mix could achieve a high removal percentage. Other research shows that aloe vera can be a natural coagulant for water treatment [10]. According to the research of [10], liquid and aloe vera powder were used for the coagulant types. Their experiment showed that the optimal dosage for natural coagulant in water treatment for aloe vera powder was 10 mg/L, while the amount of 0.1 mL/L for the aloe vera was liquid.

Thus, this research has been done to quantify the water quality parameters for surface water before treatment and evaluate the efficiency of natural coagulants using aloe vera and coconut husk for water samples collected from Shah Alam lakes, Selangor.

MATERIALS AND METHODS

Sampling Collection

The surface water was collected for the samples at one selected case study area, Seksyen 7 Lake in Shah Alam, Selangor, Malaysia, with coordinates of 3.0754765,101.4922243 (see Figure 1). Grab sampling methods were used to collect the water samples, which were preserved in a container and transported to the laboratory for further analysis [11]. About 20 L of sample water was retained for the jar test experiments. Safety precautions were taken to avoid any incident while collecting the water samples from the site area.

Parameter Testing

The parameters tested before the jar test experiment were based on six parameters: pH, total suspended solids, dissolved oxygen, chemical oxygen demand (COD), biochemical oxygen demand (BOD) and ammonia-nitrogen. These parameters indicated the sample's water quality index (WQI) classification [12]. In-situ testing for pH, dissolved oxygen for BOD, and total suspended solids was done using a digital probe [13]. Laboratory testing for ammonia-nitrogen, COD and total suspended solids was detected using a DR 2800 Spectrophotometer [14].

Figure 1. The images of the location site for the collection of samples in Google Maps (coordinates of 3.0754765,101.4922243).

Figure 2. The images of aloe vera plant (left) and the aloe vera solution after being processed (right).

Later, after the jar test experiment, these parameters were again evaluated. The turbidity test was also carried out before and after the jar test experiment to identify the removal efficiency [11]. All the testing was done in situ (on the site area), and the laboratory tests were done in Environmental Laboratory 1, School of Civil Engineering, College of Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia.

Preparation of Natural Coagulant

The natural coagulants used for these studies were coconut husk and aloe vera. The aloe vera was collected at a private garden in Johor town. After collection, aloe vera leaves were washed with distilled water to remove dirt from the leaves' surfaces. Later, the aloe vera gel was recovered by separating the thick green covering the leaves. The gel part was mixed in a mixer without adding water until it became a liquid solution. The solution was later kept in the refrigerator before being used in the jar test experiment [15].

The coconut husk was purchased from the local store and exposed to the sun until it completely dried. Later, it was sieved with 600-micron sieves to get the desired size. After the sieving process, this substance was made into fine powder. Then, the coconut husk was ready to use as a bio-coagulant [16].

Jar Test Experiments

The jar test is one of the methods used for the coagulation process. The coagulation process is a process where the suspended matter, turbidity, colour, odour, and microorganisms are removed [17]. Chemical coagulants such as ferric and alum were usually used for the experiment. However, for the alternatives, the natural coagulant of coconut husk and aloe vera were used in the study.

Figure 3. The images of the coconut husk (left) and the coconut husk powder after being processed (right).

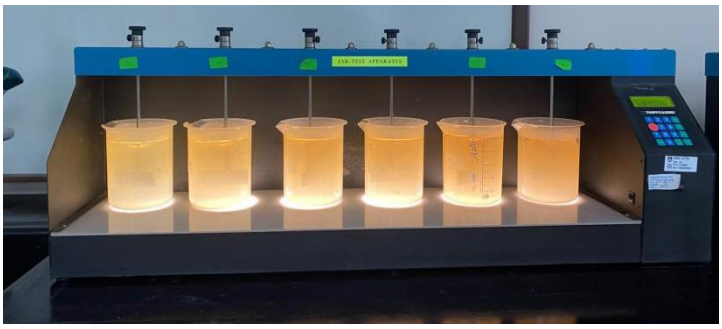

Figure 4. Jar test experiment.

In this experiment, both bio-coagulants were divided into different concentrations using jar test experiments with two sets of six beakers labelled with several dosages of coconut husk and aloe vera bio-coagulants and control without adding bio-coagulant. All the experiments were done in triplicate for both batches of bio-coagulants (coconut husk and aloe vera).

Here, 0 mg, 50 mg, 100 mg, 150 mg and 200 mg of coconut husk were measured and put in each beaker separately. Later, all the beakers were filled with water samples until they reached 1 L each. This gives the final dosages of 0 mg/L, 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L and 250 mg/L of coconut husk.

The second batch of jar test experiment added 0 g, 10 g, 20 g, 30 g, 40 g, and 50 g of aloe vera in liquid form, measured individually in each beaker. All the beakers were added with water samples until they reached 1 L. Thus, the final dosages were 0 g/L, 10 g/L, 20 g/L, 30 g/L, 40 g/L and 50 g/L of aloe vera in the beakers. The jar test experiment was conducted for those batches.

The mixture was stirred for 3 minutes at 140 RPM and then for 5 minutes at 70 RPM. Later, the samples were left for 15 minutes without any more stirring so that the particles could settle down by gravity.

RESULTS AND DISCUSSION

The Result Parameters of the Sample before the Treatment

Based on Table 1, the pH result for the water sample meets Class II [12]—the total suspended solid is practically in Class I for the WQI [12]. Then, the ammonia-nitrogen result was 3.77 mg/L, which exceeded the range for the WQI and is classified as Class V, meaning the water required treatment. For the dissolved oxygen result, 4.49 mg/L was classified as Class IIA for the WQI [12]. The chemical oxygen demand (COD) value was 17 mg/L, classified as Class IIA for the WQI. The value for biochemical oxygen demand (BOD) is 54.6 mg/L, where the value had been classified as Class III, which means extensive treatment is required. The turbidity for the sample water value was 38.4 NTU, Class I for WQI [12]. However, the water sample still needs adequate treatment because the overall WQI value was calculated as 50.39 and classified as Class IV, which means the water sample needed further treatment [12].

Table 1. Results of the water sample before the jar test experiment.

Parameters	Unit	Results	Classification [12]
pH	-	6.69	IIA
Total suspended solids	mg/L	314	I
Ammonia nitrogen	mg/L	3.77	V
Dissolved oxygen	mg/L	4.49	IIA
COD	mg/L	17	IIA
BOD	mg/L	54.6	III
Turbidity	NTU	38.4	I
WQI	-	50.39	IV

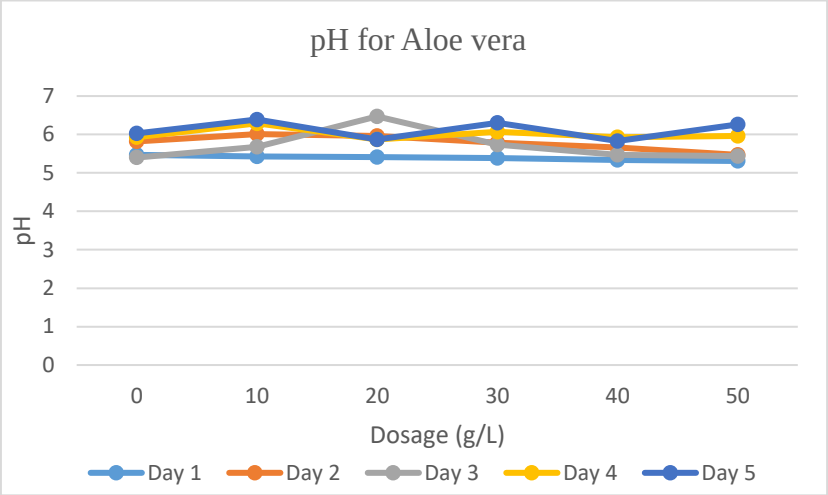

Figure 5. Result of pH for aloe vera as a natural coagulant.

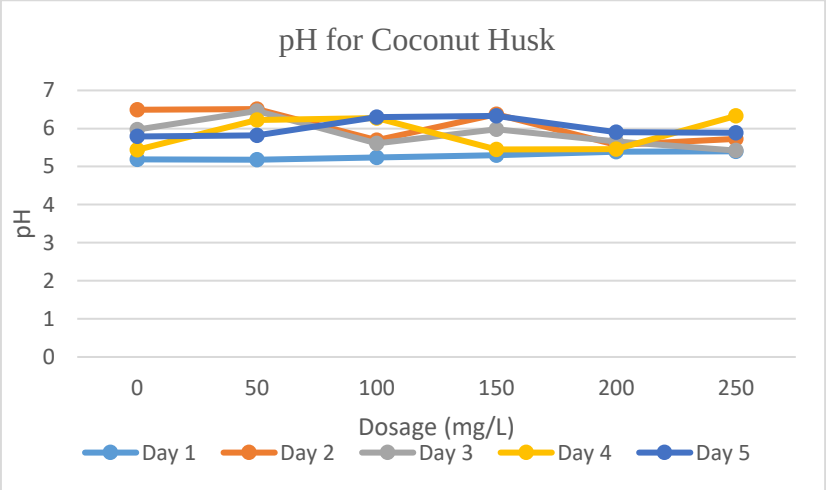

Figure 6. Result pH for coconut husk as a natural coagulant.

Result Parameters of the Sample after the Treatment

The pH value is important in chemical processing in raw waters; it indicates the concentration of hydrogen ions in a water sample. It also signifies the water's acidity level [18]. Water samples with pH values above 7.0 are more alkaline, while those with pH values below 7.0 are considered acidic. The results shown in Figure 5 and Figure 6 display the effect of pH value for the water sample after the jar test experiment containing aloe vera and coconut husk as bio-coagulants in 5 days. The result points out that the pH was in the range of 4.5 to 6.5, and the water samples tended to be more acidic compared to the previous condition before the experiment took place. However, it can be denoted that fewer changes were observed in the pH values for the water samples after the jar test. It showed that the natural coagulant had a minimal effect on the pH condition of the water samples. This study is similar to the research done by [19], where they found that aloe vera also exhibited a minor influence on the pH value in the water sample.

Figure 7 and Figure 8 show the result of the total suspended solids (TSS) after the jar test experiment with various dosages of aloe vera and coconut husk as natural coagulants. The result indications that the natural coagulant seems efficient for the treatment as various dosages of aloe vera, and coconut husk can decrease the value of total suspended solids in the lake water. Based on the result, aloe vera with a dosage of 10 g/L as a natural coagulant can drop the total suspended solid from 314 mg/L to 11 mg/L with 96.50% percentage removal. Moreover, the result discloses that coconut husk with a dosage of 150 mg/L as a natural coagulant reduced the value of total suspended solid from 314 mg/L to 7 mg/L with a percentage removal of 97.77%.

Other research studies found that using natural coagulants, particularly aloe vera, positively lowered the pollutants in the surface water treatment, therefore concurring with the outcome of this investigation [15, 20]. Consequently, these abundant materials, particularly the coconut husk and aloe vera, can be a substitute for the coagulation process.

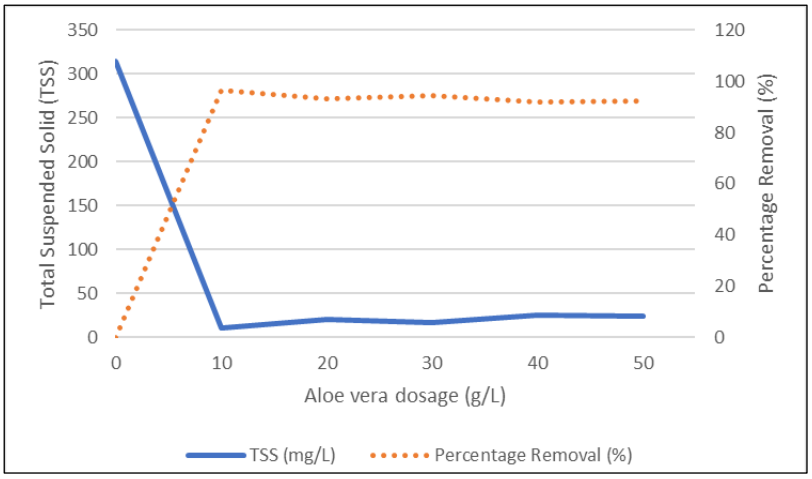

Figure 7. Result of total suspended solids (TSS) and percentage removal for aloe vera as the natural coagulant.

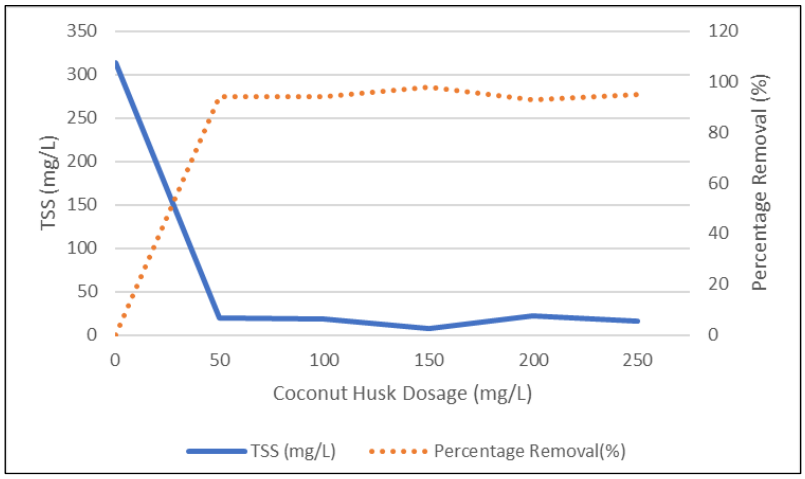

Figure 8. The result of total suspended solid (TSS) and percentage removal for coconut husk as the natural coagulant.

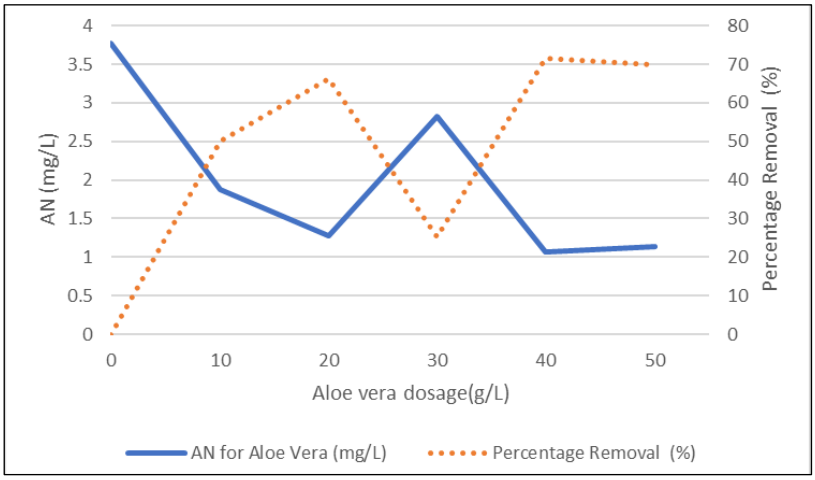

Figure 9. Result of aloe vera as natural coagulant in different dosages of ammonia-nitrogen for water sample.

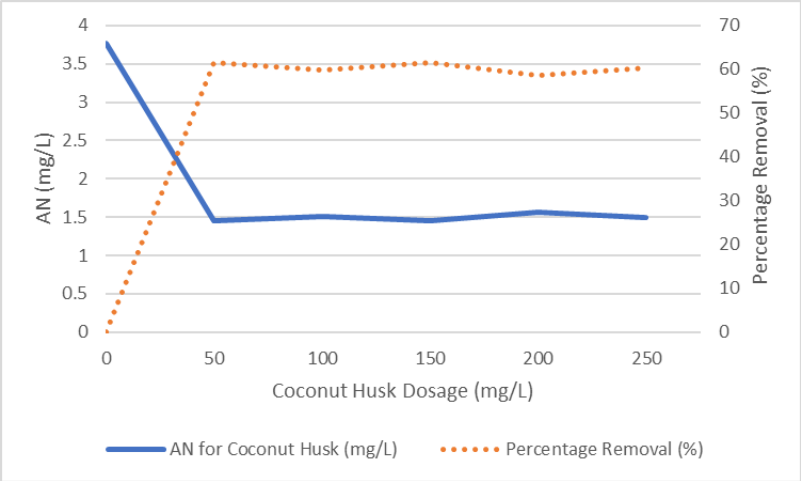

Figure 10. Result of coconut husk as a natural coagulant in different dosages of ammonia-nitrogen for water sample.

The effects of coconut husk and aloe vera with various dosages on ammonia-nitrogen were shown in Figure 9 and Figure 10, as the ammonia-nitrogen value indicates the reduction level in the water sample after the jar test experiment. It can be denoted that a high concentration of ammonia-nitrogen in the water indicates that the water is polluted and later can harm the aquatic life in the ecosystem [21]. Moreover, direct consumption of water containing excessive ammonia-nitrogen levels can be poisonous and cause risk to the human body. Figures 9 and Figure 10 manifestation the effect of aloe vera and coconut husk as natural coagulants on ammonia-nitrogen for the water sample. The best value of ammonia-nitrogen is shown for an aloe vera sample of 40 g/L with a percentage removal of 71.62%. Coconut husk also has the potential to decrease the ammonia-nitrogen in the water samples, where the highest percentage removal was 61.54% for 50 mg/L and 150 mg/L of coconut husk as natural coagulants.

According to [9], oxygen is less available for microbes to break down when the BOD value is high in water. Figure 11 and Figure 12 show the result of BOD for various dosages of aloe vera and coconut husk as natural coagulants. The result shows that aloe vera with a dosage of 30 mg/L has been most effective in reducing the value of BOD, with the percentage of removal being the utmost, at 97.80 %. Thus, compared with WQI standards, it can be categorized as Class I. Meanwhile, coconut husk with a dosage of 100 mg/L showed a significant reduction of 75% percentage removal for BOD.

In line with the results displayed by both bio-coagulants in the jar test experiment, the BOD value can be improved adequately. The aloe vera coagulant reduced the BOD value significantly and achieved Class I for the WQI standard [22]. Therefore, the adaptation of bio-coagulants can promisingly be considered for the coagulation of water treatment instead of using conventional methods [23].

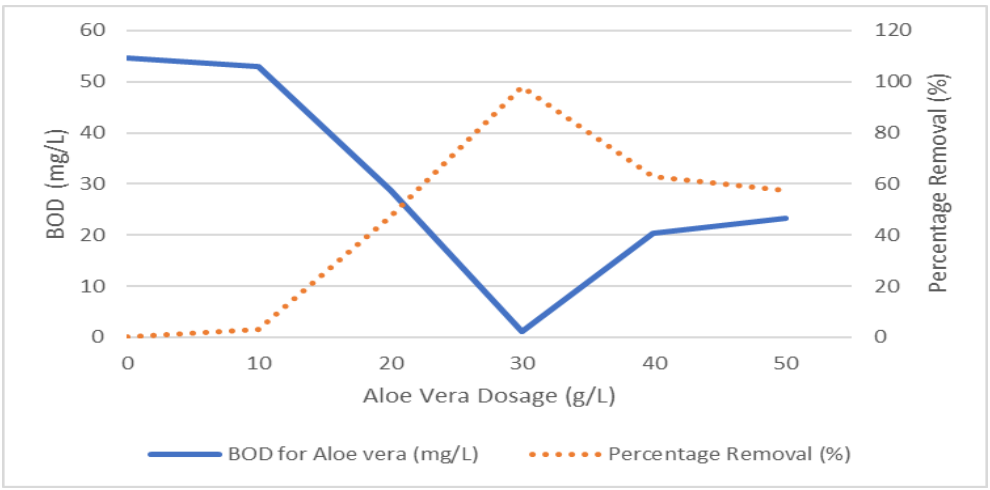

Figure 11. The result of BOD for various dosages of aloe vera as natural coagulants.

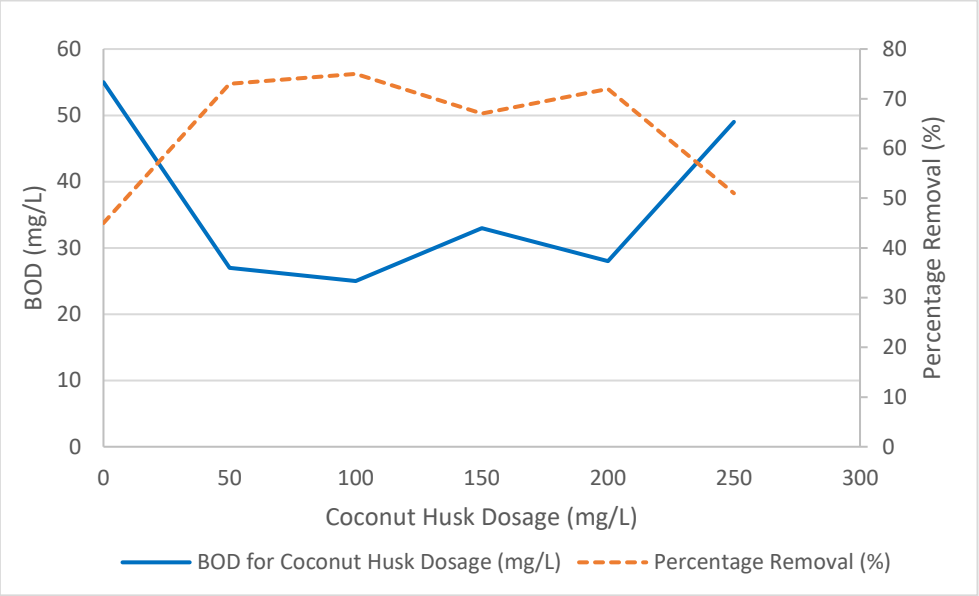

Figure 12. Result of BOD for various dosages of coconut husk as natural coagulants

Figure 13 shows that after the fifth day of the jar test experiment, turbidity removal achieved the highest for coconut husk as the natural coagulant. It shows that the most effective dosage was 150 mg/L of coconut husk, with a 78.96 % removal rate for turbidity. It can be denoted that 100 mg/L of coconut husk has shown great potential in removing the turbidity, with 75.73% of the percentage removal in the water sample.

Figure 14 indicates the effect of various dosages of aloe vera as a natural coagulant in turbidity removal. For this result, turbidity readings were observed after five days of the jar test experiment. Based on the observation, aloe vera effectively decreases the turbidity value in the water samples. The highest removal efficiency was 67.98% for a 40 g/L dosage of aloe vera as a bio-coagulant.

In this experiment, the bio-coagulant of the fabricated coconut husk was in the form of particles compared to the aloe vera in liquid form. Therefore, it can be emphasized that during the coagulation process for the water samples in the jar test, the particles of coconut husk react more effectively [24].

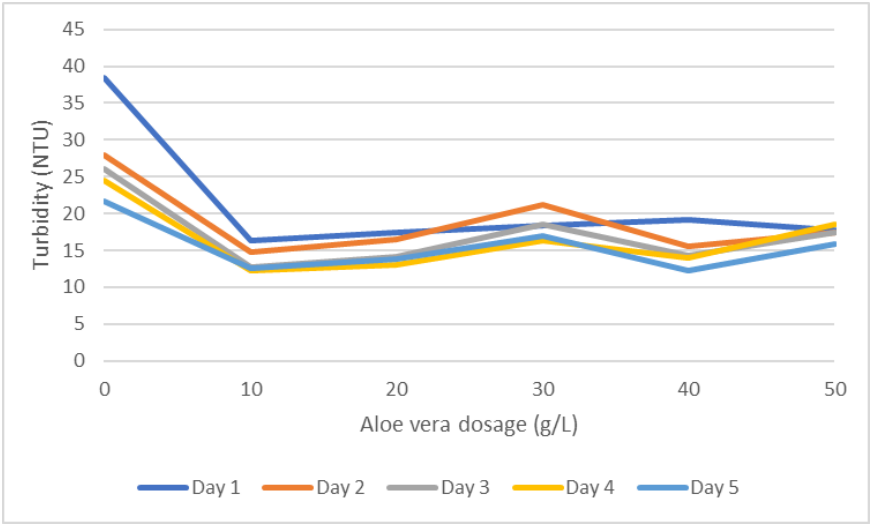

Figure 13. Result of turbidity for aloe vera as natural coagulant.

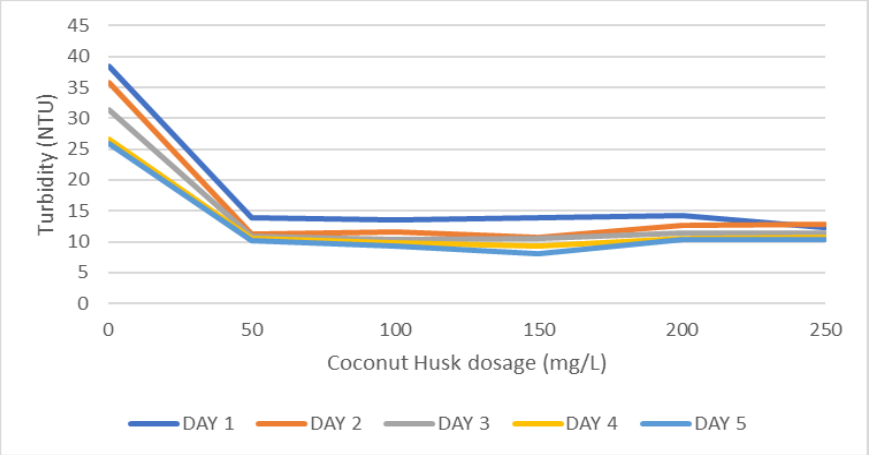

Figure 14. Result of turbidity for coconut husk as natural coagulant.

This coagulant enhances the flocculation processes and colloids with the pollutants in the water samples and later precipitates at the bottom of the beakers [25, 26]. This scenario contrasts with the aloe vera gel, which was in the liquid form by which less reaction was shown when those coagulants mixed and countered with the pollutant particles as this liquid aloe vera needed to perform floc particles combined with the pollutants in the samples.

CONCLUSION

Aloe vera and coconut husk have great potential to substitute chemical coagulants in water treatment. A significant reduction is shown in total suspended solids (TSS), ammonia-nitrogen, biochemical oxygen demand (BOD) and turbidity. Thus, it was found that turbidity removal was most effective on the fifth day after the jar test experiment for an aloe vera dosage of 40 g/L. Its turbidity removal was from 38.4 NTU to 12.4 NTU, with a percentage removal of 67.97%. At the same time, coconut husk with a dosage of 150 mg/L reduced the turbidity from 38.4 NTU to 8.08 NTU with a turbidity removal percentage of 78.96%. Moreover, no changes in parameters were detected in the control samples. Therefore, this study demonstrated that the usage of chemicals can be limited as bio-coagulants have the potential to be introduced in water treatment. Moreover, from the observations, the quality of water samples can be enhanced by using these natural coagulants as best management practices for greener technology in the water treatment plant for the future.

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REFERENCES

1. Prakasha, D. and Veeresha, P. (2020) Analysis of lakes pollution model with Mittag-Leffler kernel. *Journal of Ocean Engineering and Science*, **5(4)**, 310–322. https://doi.org/10.1016/j.joes.2020.01.004.

2. Hassan, R. A., Kasmuri, N., Ahmad, R., Santiagoo, R. and Ramasamy, S. (2021) Enhancement of water quality using natural coagulant in Shah Alam Lakes, Malaysia. *IOP Conference Series: Earth and Environmental Science*, **646(1)**, 012051. https://doi.org/10.1088/1755-1315/646/1/012051.

3. Mardani, S., Aghabalaei, V., Tabeshnia, M. and Baghdadi, M. (2021) Modification of conventional coagulation-flocculation process with graphene oxide and magnetite nanoparticles for turbidity removal from surface water. *Desalination and Water Treatment*, **229**, 206–216. https://doi.org/10.5004/dwt.2021.27393.

4. Jinna, A., Anu, M. R., Krishnan, N., Sanal, V. and Das, L. (2019) Comparative Study of Efficiency of Local Plants in Water Treatment. *International Research Journal of Engineering and Technology (IRJET)*, 4046-4052.

5. Sibiya, N. P, Rathilal, S. and Kweinor Tetteh, E. (2021) Coagulation Treatment of Wastewater: Kinetics and Natural Coagulant Evaluation. *Molecules*, **26(3)**, 698. https://doi.org/10.3390/molecules26030698.

6. Ghernaout, D., Elboughdiri, N., Ghareba, S. and Salih, A. (2020) Coagulation Process for Removing Algae and Algal Organic Matter—An Overview.

OALib, **07(04)**, 1–21. https://doi.org/10.4236/oalib. 1106272.

7. Gautam, S. and Saini, G. (2020) Use of natural coagulants for industrial wastewater treatment. Department of Civil Engineering, School of Engineering and Technology, Sharda University, Uttar Pradesh, India.

8. Nimesha, S., Hewawasam, C., Jayasanka, D. J., Mueakami, Y., Araki, N. and Maharajan, N. (2021) Effectiveness of natural coagulants in water and wastewater treatment. *Global Journal of Environmental Science and Management*, 101-116.

9. Kasmuri, N., Shokree, N. S. A., Zaini, N., Ismail, N., Miskon, M. F., Ramli, N. H. and Nayono, S. E. (2023) Treatment of Wastewater by Moringa Oleifera and Maize Seeds as Plant-Based Coagulant. *IOP Conference Series: Earth and Environmental Science*, **1140(1)**, 012010–012010. https://doi.org/10.1088/1755-1315/1140/1/012010.

10. Benalia, A., Derbal, K., Khalfaoui, A., Bouchareb, R., Panico, A., Gisonni, C., Crispino, G., Pirozzi, F. and Pizzi, A. (2021) Use of Aloe vera as an Organic Coagulant for Improving Drinking Water Quality. *Water*, **13(15)**, 2024. https://doi.org/10.3390/w13152024.

11. Baird, R. B., Eaton, A. D. and Rice, E. W. (2017) Standard Methods for the Examination of Water and Wastewater, 23rd Edition. *American Water Works Association*.

12. DOE (2006) Interim National Water Quality Standards for Malaysia in *Wepa*, 1-5.

13. HORIBA (2018) Instruction Manual Dissolved Oxygen Meter LAQUAact-DO110 LAQUAact-DO120 Portable pH Water Quality Meter. HORIBA Advanced Techno Co., Ltd.

14. HACH (2007) DR 2800 Spectrophotometer. Germany: HACH.

15. Putra, R. S., Putri, C. I. and Tyagustin, N. S. (2021) The combination of the electro-flotation-biocoagulation process using aloe Vera for river water treatment. *IOP Conference Series: Materials Science and Engineering*, **1087(1),** 012047. https://doi.org/10.1088/1757-899x/1087/1/012047.

16. Sheba, M. C., Parvin, R. S., Vinubala, P. and Lakshmi, R. P. (2019) Assessment of Natural Coagulants for the Treatment of Wastewater from Metalwork Industry. http://dx.doi.org/10.1729/Journal.20659.

17. National Water Quality Standards and Water Quality Index – Department of Environment - NWQS. (2022) Doe.gov.my. https://www.doe.gov.my/en/national-river-water-quality-standards-and-river-water-quality-index/.

18. Pakharuddin, N. H., Fazly, M. N., Ahmad Sukari, S. H., Tho, K. and Zamri, H. (2021) Water treatment process using conventional and advanced methods: A comparative study of Malaysia and selected countries. *IOP Conference Series: Earth and Environmental Science*.

19. Amruta, G. and Munavalli, G. R. (2017) Use of Aloe Vera as Coagulant Aid in Turbidity Removal. *International Journal of Engineering Research and Technology*, **10**.

20. Azman, A. S. and Bain, N. F. (2022) Study on Aloe Vera, Cactus, and Banana Stem as Bio-coagulant in Removal of Turbidity. *Penyelidikan dan Inovasi Hijau.*

21. Purwono, Rezagama, A., Hibbaan, M. and Arief Budihardjo, M. (2017) Ammonia-nitrogen (NH_3-N) and Ammonium-Nitrogen (NH_4^+-N) Equilibrium on the process of removing nitrogen by tubular plastic media. *Journal of Materials and Environmental Sciences*, **8**, 4915–4922.

22. Katubi, K. M., Amari, A., Harharah, H. N., Eldirderi, M. M., Tahoon, M. A. and Ben Rebah, F. (2021) Aloe vera as Promising Material for Water Treatment: A Review. *Processes*, **9(5)**, 782. https://doi.org/10.3390/pr9050782

23. Deswal. S. (2022) Comparative Studies of Aloe Vera Powder and Alum to Remove Turbidity in Raw Water. *IEOM Society International*.

24. Hanafiah, S. F., Salleh, N. F., Ghafar, N. A., Shukri, N. M., Kamarudin, N. H., Hapani, M. and Jusoh, R. (2020) The efficiency of coconut husk as an agricultural adsorbent in removing chromium and nickel ions from aqueous solution. *IOP Conference Series: Earth and Environmental Science*, **596**, 012048. https://doi.org/10.1088/1755-1315/596/1/012048.

25. Dash, S., Borah, S., Singh, K. R. and Kalamdhad, A. S. (2020) Seasonal and Spatial Variation of DO and BOD for Assessment of the Water Quality of Brahmaputra River. *Lecture Notes in Civil Engineering*, 473–483. https://doi.org/10.1007/978-981-15-0990-2_37.

26. Sholihah, Q., Nur Ajeng Prilliab, D., Hanani, N., Kuncorod, W., Tri Juono, P. and Pambudi Tama Ishardita (2019) Analysis of Water Quality Based on BOD and COD Levels in Unisma Hospital *International Journal of Innovation, Creativity and Change*, **7(9)**, 42–48.