Progress in Engineering Application and Technology Vol. 3 No. 2 (2022) 001–013
© Universiti Tun Hussein Onn Malaysia Publisher's Office

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

The Effect of Modification on Adsorption Performance of Banana Fiber (*Musa Sapientum*) in Treating Wastewater: A Systematic Review

Nur Farah Aina Rosli[1], **Mas Rahayu Jalil**[1]*

[1]Department of Chemical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2022.03.02.001
Received 27 January 2022; Accepted 20 July 2022; Available online 10 December 2022

Abstract: The utilization of banana fiber as biosorbent was expanded as a feedstock in wastewater treatment. The modification of banana fiber as biosorbent for efficient adsorption has gained interests among researchers due to the materials are inexpensive, effective, environmentally friendly, and simple to deploy. However, it still has a number of limitations due to low exchange or sorption capacity, and lack of physical stability. Therefore, in this study, the effect of modification of banana fiber as biosorbent in treating wastewater were analysed in terms of qualitative analysis via systematic review. 22 studies related to the effect of modification on banana fiber as biosorbent were identified via PRISMA method. Based on the findings, chemical modification on banana fiber has improved the surface area and adsorption capacity which resulted to the higher percentage removal of color and metal ions. The study also found that the effect of chemical modification can improve the stability of the banana fiber as biosorbent by applying wide range of pH from 1 to 12 resulted on higher percentage of removal of color and cationic metal. The effective range of pH which physically stable was in the range of 2 to 10. The removal efficiency of modified banana fiber can increase the proportion of active sites present on the surface of adsorbent and improved the ability of banana fiber in adsorbing color and toxic metal ion at low dosage. Overall, the findings obtained provide comprehensive information and act as reference on improving the adsorption performance at wide range of working pH and lower adsorbent dosage for further research on banana fiber as biosorbent.

Keywords: Banana Fiber, Adsorption, Colour, Metal

1. Introduction

Pollution from wastewater creates many issues with turbidity, pH, BOD, COD, color and any other problem. Wastewater contained dissolved chemicals, solid that has been deposited and microorganisms which have been adversely affected the quality of the receiving water bodies. [1]

*Corresponding author: mrahayu@uthm.edu.my

Several methods have been used to treat wastewater including coagulation, adsorption, filtering, screening and many others. Adsorption process is one of the most effective methods for eliminating organic and inorganic contaminants from waterways system. Activated carbon is commonly used as absorbent for the adsorption process in the conventional method. Nowadays, many researchers looked at the potential of employing affordable materials as replacement to activated carbon. Any inexpensive material with high cellulose content and low inorganic percentage can be used as raw material. [2] Banana fiber is the most preferred sorbent material for the removal of color and heavy metal from wastewater due to its extensive availability and more economic. A few studies have been reported that even though these materials can be as adsorbent, but it still have a number of limitations due to low exchange or sorption capacity and lack of physical stability. Thus, modifications on surface of banana fiber need to be undergoing to alter the sorption capacity by activating the functional group of banana fiber. The physical stability of banana fiber can be improved by increasing it porosity in which the porosity and pore size is the most important factor in absorbent. The pH and absorbent dosage also affect the performance of adsorption process.

In order to achieve good adsorption performance, the working pH and adsorbent dosage was analyzed. This scenario has led several researchers to investigate on the effect of modification on banana fiber for efficient adsorption performance for removal of color and heavy metal. Therefore, it is our interest to investigate the optimum range of pH and adsorbent dosage which contribute to the increase of adsorption performance of banana fiber as biosorbent via PRISMA method. Thus, in this study, the systematic review and quality analysis were conducted in order to identify the effect of modification on banana fiber for efficient adsorption performance and to determine the optimum range of pH and adsorbent dosage for efficient adsorption performance after applying modification on banana fiber.

2. Materials and Methods

The methodology for carrying out a systematic review is presented in this section. The guidelines, along with the search and analysis of the literature, are clarified. Preferred reporting items for systematic analysis and quality analysis (PRISMA) statements have been used. The approach involves a range of stage such as literature retrieval and review process steps. These stages contain identification, screening and eligibility, data abstraction and analysis.

2.1 Criteria for study selection

PRISMA specifies the eligibility and dismissal conditions. Only articles with certain standards have been eligible for the review process. First criteria would be journal papers and case studies mainly since they include a rather more comprehensive and complete research report. Next, the manuscripts must be in English only to facilitate data extraction and synthesis [3] The third criteria are manuscripts relevant to banana fiber, biosorbent and wastewater are selected just to tackle the objective. These criteria are displayed in Table 1.

Table 1: Eligibility and exclusion criteria

Criteria	Eligibility	Exclusion
Literature type	Journal articles	Review articles, proceeding, chapter in book, case study
Language	English	Non-English
Discipline	All	None
Focus of study	banana fiber, biosorbent, wastewater	Non-banana fiber/biosorbent, wastewater
Publication year	2010 to 2021 (The recent 11 years)	2009 and before

2.2 Search technique

The integrated systematic review should be implemented in order to provide a manuscript with qualitative, quantitative and mixed method. This systematic review technique is favoured since it offers a depth summary of the manuscript with diverse research methods. An integrative systematic review was used mainly using WoS and Scopus databases. The systematic review utilized comprises four steps. Initially, according to prior research, thesaurus and recommended keywords from Scopus, relevant keywords linked to banana fiber, biosorbent and wastewater were reported. Inside of query sections such as title, abstract and keyword, the extensive functionality of the databases allowed the customization and prioritization of certain terms over the others. The search strings for various databases are shown in Table 2.

Table 2: The search strings applied for systematic review

Journal database	Search string	Frequency of hits
Scopus	(TITLE-ABS-KEY("banana fiber" OR "banana peel" OR "banana stem fiber") AND TITLE-ABS-KEY ("bioadsorbent" OR "sorbent") AND TITLE-ABS-KEY ("surface modif*" OR "surface treatment" OR "chemical treatment" OR "graft*" OR "alkali treatment" OR "ester*" OR "binding groups") AND TITLE-ABS-KEY ("wastewater" OR "POME" OR "water treatment" OR "effluent" OR "heavy metal" OR "metal ions" OR "color" OR "dyes"))	62
WoS	(TOPIC: ("banana fiber" OR "banana peel" OR "banana stem fiber") AND TOPIC: ("bioadsorbent" OR "sorbent") AND TOPIC: ("surface modif*" OR "surface treatment" OR "chemical treatment" OR "graft*" OR "alkali treatment" OR "ester*" OR "binding groups") AND TOPIC: ("wastewater" OR "POME" OR "water treatment" OR "effluent" OR "heavy metal" OR "metal ions" OR "color" OR "dyes"))	25

The search strings from both databases suited 87 and the manuscripts are accessed eventually. The identification stage eliminated 23 duplicate manuscripts. 18 manuscripts were omitted during the screening stage, and other 24 manuscripts were excluded during the eligibility process. Finally, 22 manuscripts were remained and related to banana fiber, biosorbent and wastewater were firmly oriented on quality manuscripts to resolve the objective.

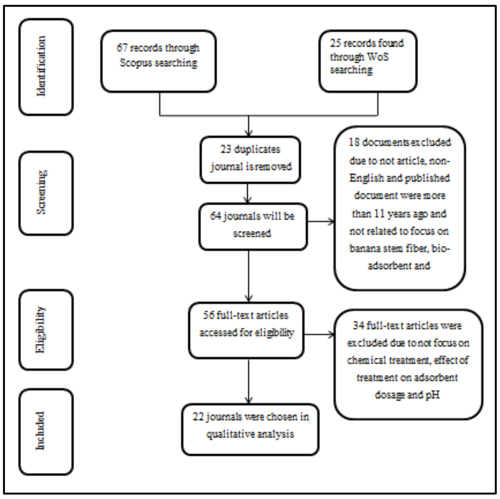

Figure 1: The flow process of the systematic study

3. Results and Discussion

In this section, 22 studies were included for content analysis. The content analysis was focused on the morphology and characteristics of banana fiber. The discussion was divided according to following sections. Firstly, the effect of modification of banana fiber on adsorption performance was studied in term of removal of color and heavy metal. Next, the effect of modification on banana fiber was studied in term of factor that influences adsorption which was pH and adsorbent dosage. The optimum value for each factor can be analyzed in order to optimize the adsorption performance in removing the adsorbates. The trend of adsorption capacity or percentage removal of adsorbates was observed by comparing the untreated banana fiber with treated banana fiber. Lastly, the effect of modification on banana fiber can be analyzed and the suitable modification can be proposed for efficient adsorption process in wastewater treatment.

3.1 Effect of modification on morphology/characteristic of banana fiber

In this section, the effect of modification on morphological/characteristic of banana fiber was analyzed in term of surface area, functional groups and adsorption performance. The changes in surface area and functional group were summarized in Table 3.

Table 3: The effect of modification on the surface area of banana fiber as biosorbent

.

Bio sorbent	Type of modification	Surface area (m^2 /g)	Percentage of removal (%)	Trend	Morphology changes		Functional group	Autho r(s)
					Before modified	After modified		
Natural banana fiber	-	24.2572	34	Increase	Smooth and non-porous were appeared in irregular shape	Surface of banana fiber has more irregular and porous structure	The modified banana fiber has introduces specific functional group on surface that improve the hydrophobicity which is carboxyl and amine groups.	[4]
Methylated banana fiber	Alkali treatment	168.3648	42					
Banana peel activated carbon	Activation and carbonization	875.2914	95.6					
Banana peel activated carbon	Activation and carbonization	1396.60	85	Increase	n/a	Pores size and irregularity of surface improved porous structure with higher surface area	Chemical modification using activation and carbonization and binding oxygen on banana fiber has formed oxygen functional group that change surface properties and enhance the binding	[6]
Banana peel activated carbon oxidized	Binding group enhancement (Oxidation)	1238.47	96					

							sites	
Banana fiber	Activation and carbonization	256.635	95	n/a	n/a	Pore size irregularity of surface has improved porosity structure.	n/a	[16]
CoFe2O4-modified biochar banana pseudostem	Polymer grafting banana fiber	701.9	n/a	n/a	A regular structure with discrete net fibrils	A visible separation of fibrils in the case of chemical modified banana fiber	Modified banana fiber has form oxygenated functional group	[18]
Banana peels	Natural banana fiber Physical treatment banana fiber	19.36 20.6–23.5	43 50	Increase	n/a	n/a	n/a	[21]
Banana peels NaOH treatment Chemically-modified banana fiber	Natural banana fiber Alkali modified treatment Activation and carbonization	23.5 168.3648 875.2914	40 60 86	Increase	Relatively smooth	Large number of irregular micropores on surface	The modification of banana fiber has the number of functional groups which can enhance the binding capacity.	[5]
Banana fiber	Physical treatment	n/a	90	n/a	n/a	n/a	Has hydroxyl group	[20]
Banana fiber	Chemically-modified banana fiber	n/a	93	n/a	n/a	More porous and irregular in shape	Has carboxyl, hydroxyl and amine groups that helps improve hydrogen bonding	[12]

From Table 1, the modified banana fiber shows an increment in surface area. Some studies conducted by [6],[5] and [4] shows that the surface area of banana fibers have increased when applying modification on it. The surface area of banana fiber increased from 24.2572m^2/g to 875.2914 m^2/g via activation and carbonization process [6]. [4] shows higher in surface area of banana fiber when modification applied on it, 1396.60m^2/g for alkaline treatment and 1238.47m^2/g for binding group enhancement treatment. A study from [5] shows that percentage of removal increased from 40% to 86% with the increasing of surface area of banana fiber from 23.5m^2/g to 875.2914 m^2/g. The increases in surface area of banana fiber is due to the treatment with chemical has changed the surface morphology of banana fiber. [6] reported that the surface of chemical modified banana fiber has more irregular and porous structure than natural banana fiber.

In another study, [21] revealed that the surface of chemical modified banana fiber is smothering than natural banana fiber and there is a visible separation of fibrils in the case of chemical modified banana fiber. The roughness of surface of banana fiber is due to the removal of hemicellulose and lignin [21]. The morphology of biosorbent from banana fiber generally possess heterogeneous and have microporous structures. Surface modification using chemical treatment aids in the removal of lignin from the biomass and enhancing the roughness of the base cellulose. Other than that, the surface modification also gives a more porous adsorbent, adjusts the functional group, effects on the solution chemistry and improves the inherent affinity of banana fiber. The modification of banana fiber has altered the chemical functional group which can help to increase the removal uptake, sorbates selectivity, stability, good diffusion and hydrodynamic behavior. The functional group can enhance the specific surface area of banana fiber whereas it attributes to their porous nature. The incorporation of functional groups is known to clog particle pores and the development of multi-functional surfaces appears to increase the surface area.

From the Table 3, it shows that the modification of banana fiber through chemical modification which is activation and carbonization shows significant changes on surface area. This is due to a major transformation in the cellular structure of banana fibre. The use of reagents such as KOH or ZnCl2 allows them to interact with carbon atoms and catalyse dehydrogenation and oxidation processes, resulting in increased tar evolution and porosity development. During the pyrolysis process, the pore size increased and the structure deformed. Meanwhile, alkali treatment in chemical modification has disrupted the network structure of banana fibres, increasing surface roughness and destroying hydrogen bonding [6]. As lignin, hemicellulose, and waxes are removed from the fibre during alkali treatment, the fibre density is increased Overall, most of researchers reported the similar hypothesis which is increases in surface area of banana fiber resulted to the higher adsorption capacity and changes in morphology can enhance the functional group of banana fiber. Therefore, it proved that the mechanism from chemical modified has caused the banana fiber to be improved the adsorption performance.

3.2 The effect of chemical modification on adsorption performance of banana fiber

The effect of chemical modification was discussed in this section for both color and metal ions removal. The adsorption performance of banana fiber as biosorbent was analyzed through percentage removal of color and metal ions. Figure 2 and Figure 3 shows the maximum removal of color and heavy metal when using modified banana fiber.

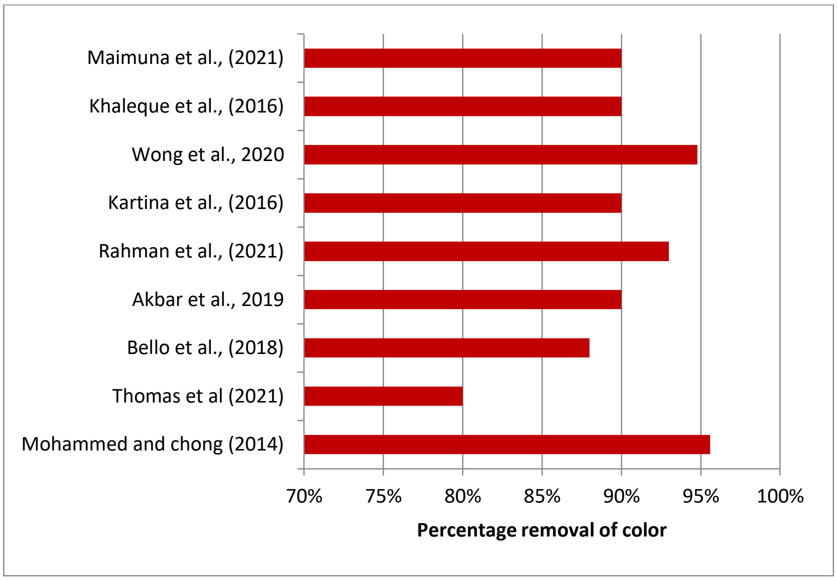

Figure 2: Maximum color removal by modified banana fiber as biosorbent

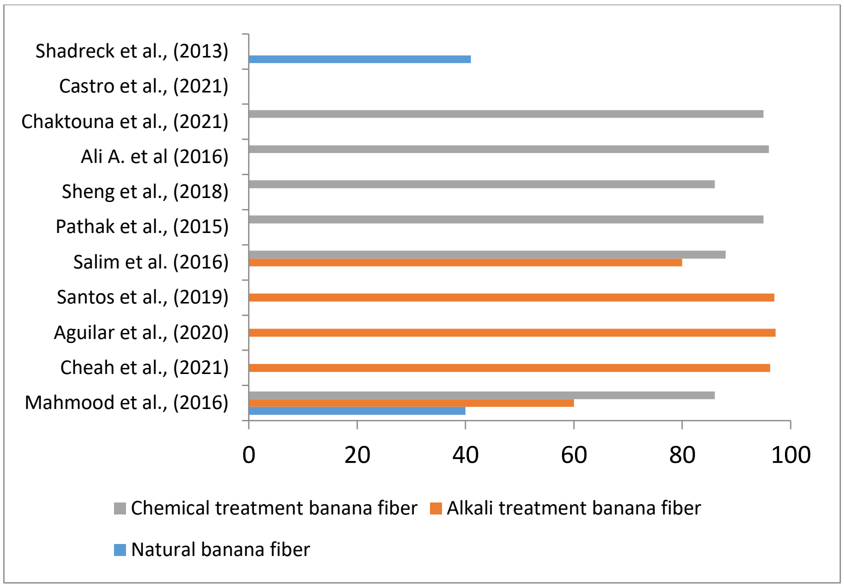

Figure 3: Maximum of cationic metal removal by modified banana fiber as biosorbent

From the studies, the modification of banana fiber using chemical treatment shows positive effect on removing color and heavy metals. The percentage removal of color is ranging from 80 to 95.6% as shown in Figure 3. [6] investigated that the modification of surface of banana fiber has increased the performance of adsorption. The modification through activation and carbonization has been used in treating color in POME and resulting 95.60 % of color removal. Besides, other studies from [7] shows higher color uptake at 95.00 % by applying chemical modification. The chemical modification by using alkali treament shows positive effect on removal of color whereas 88.00 to 90.00 % of color has been removed due to higher specific surface area (Bello et al., (2018); [12]. A distinct result was observed for modified banana fiber via xanthanation where maximum color removal is 80.00 % slightly lower compared to other biosorbents [8].

In Figure 4, modified banana fiber via physical and chemical activation has removed 86 % of cationic metal. The highest uptake to remove cationic metal is 97.24 % by using alkaline modified banana fiber. The range of maximum removal of cationic metal for alkaline modified banana fiber was from 60.00 to 97.24 %. [20] and [9] shows maximum removal for cationic metal is below 90.00 % in which 86.00 % and 88.00 % respectively. Other studies exceeded 90.00 % of maximum removal of cationic metals.

The color and cationic metal removal efficiency can be influenced by the biosorbent surface morphology as it served functional group that act as active/binding site in adsorption process. The porosity and irregularity of banana fiber as biosorbent are vital in enhancing the adsorption performance of biosorbent. High porosity improved their specific surface area in which providing more active sites for ion binding. The chemical modification also introduced new functional group onto the surface of biosorbent by destroying their original structure. The surface charge of biosorbent also related to the adsorption performance of biosorbent [10] Therefore, the performance of biosorbent is depending on the chemical and physical properties of the adsorbent surface. An ideal adsorbent should have a high affinity for the required sorbate and a broad surface area, resulting in active or binding sites, among other desirable properties.

3.3 Optimization of operational parameter on adsorption performance

In this section, the study was conducted to determine the wide range of the pH, and adsorbent dosage. The optimum condition for pH and adsorbent dosage were obtained to determine the effectiveness of banana fiber in color and metal ion removal and improve its stability.

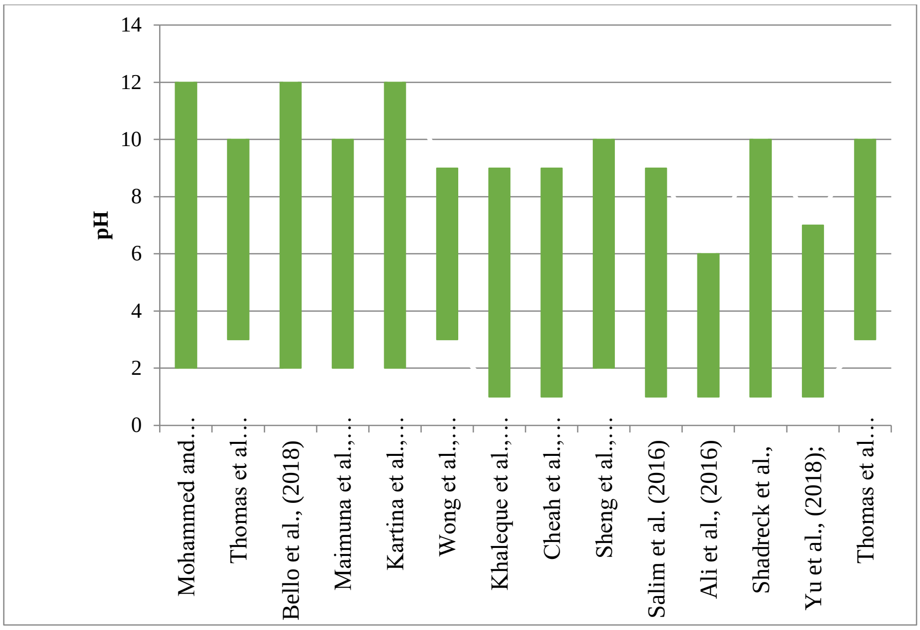

Figure 4: The range of working pH of chemically modified banana fiber

The pH of effluent can affect the adsorption performance of banana fiber. This is because adsorption performance is controlled by many factors that depend on the adsorbent characteristics including surface area, chemical content and interaction of sorbates to the surface of adsorbent. Figure 4 indicates the effect of chemical modification on working pH range of banana fiber as biosorbent. Based on Figure 4, the observation from the studies shows that the wide range of pH used in removal of heavy metal and color. [1] investigated the influence of pH on adsorbent performance to remove color. Modified banana fiber via activation and carbonization was used at pH ranging between 2 to 12. This can be seen in a study where the percentage of color removal increased from 52.00 % to 74.00 % as using wide pH range [6]. [8]revealed that the percentage of color is up to 80.00 % at pH range 3 to 10. The study shows significant differences on the effect of pH on adsorption performance by varying the pH value at 3, 5, 7, 9 and 11 in solution. The maximum color removal was observed at pH 3 where up to 94.79 % of color has been removed in the solution [7]

The metal ions adsorption amount increased significantly with the pH increase from 2 to 6 and varied a little with continuous increase until reach equilibrium at pH 9 [21]. Thus, the optimum pH range for modified banana fiber was from 6 to 9 while kept high adsorption performance toward metal ions. Most of the studies used pH ranging from 2 to 10. Other studies show data for chemically modified banana fiber only in which the percentage is around 86.00 % to 96.00 %. Some studies of removal heavy metal shows data for alkaline treatment banana fiber only in which the removal percentage shows a highest removal percentage is at 93.00 % to 97.00 % at pH range 2 to 9

The difference uptake for color and heavy metal removal is due to electrostatic interactions between the charged of adsorbent surface and charged of compounds. Increasing in solution pH increases the number of hydroxyl groups thus, increases the number of negatively charge sites and enlarges the attraction between cationic and adsorbent surface. In removal of cationic metal, pH is important parameter for metal adsorption due to its effect on the chemical speciation of the metal ion in sorbates and the ionization of functional group on surface of biosorbents. At the low pH value, biosorbent have produced minimal adsorption due to higher concentration of H+, which are preferentially adsorbed instead of metal ion meanwhile at higher pH, the adsorption is greater due to lower number of ion H^+ but a certain value it will decrease due to the presence of cation in the solution that competes with metal cation.

Generally, biosorbent with less sensitive to pH are desired in adsorption process due to stability. Stability of adsorbent is important factor that needed to be considered in adsorption process. In fact, adsorption of sorbate from solution to adsorbent is controlled by many factors that depend on adsorbent characteristics including surface area, chemical content, and interaction of sorbates to the surface of biosorbent. High performance of biosorbent should be able to show high removal in wide pH range. The improvement in effective pH range of the biosorbent is mainly ascribed to the adjustment of surface charge and functional group. Biosorbent can induce adsorption of particles with opposite charge. Thus, biosorbent was modified to possess charge opposite to the targeted particles.

From studies, it is reported that surface modification could improve the stability of the adsorbents. The percentage of removal adsorbates have seen to be increased with the wide range of pH for both color and cationic metal. This is due to increase of capable of linkage with the ions and the activation of functional groups on banana fiber. It can be highlighted that the pH is one of the most important factors controlling the adsorption of adsorbates onto adsorbent. This is because the pH may change the surface charge of an adsorbent, the degree of ionization of an adsorbate molecule and the extent of dissociation of functional groups on the active sites of an adsorbent.

3.4 Effect of adsorbent dosage on adsorption performance of banana fiber

In this section, the effect of chemical modified banana fiber on adsorbent dosage has been discussed. The usage of less amount of adsorbent dosage is favored in order to cut the cost of water treatment. The modification on banana fiber was studied in order to get lower adsorbent dosage used at high adsorption performance. Table 5 and 6 summarizes the adsorbent dosage used to remove color and heavy metals by comparing the unmodified and modified banana fiber.

Table 4: The effect ofadsorbent dosage on adsorption performance in removing heavy metal

Type of biosorbent	**Range of dosage** (g/ml)	**Dosage** (g/ml)	**Removal percentage (%)**	**Effect on optimum dosage**	**Author(s)**
Natural banana fiber	5 – 35	30	30	Removal of color is low up to 30% only when using 30g.	[6]
Alkali treatment banana fiber			42	Removal of color is 42% only	
Thermal treatment banana fiber			95.6	Removal of color achieves up to 95.6% with high dosage	
Physical treatment banana fiber	0.25 g -1	1	80	Removal of color up to 80% with low dosage	[8]
Thermally modified	0.2 – 1.4	1	90	Removal of color achieve at low dosage up to 90%	[11]
Chemically-modified	0.1 – 0.8	0.5	93	Removal of color up to 93% at lowest dosage	[12]
Chemically-modified	0.1 g -1.0	0.1	94.79	0.1g for removal color up to 94.79%	[7]
Chemically-modified	0.05 g - 0.2	0.1	90	0.1g for removal color up to 90%	[13]

Table 5: Effect of adsorbent dosage towards percentage removal of metal ions

Type of biosorbent	**Range of dosage**	**Dosage**	**Removal percentage (%)**	**Effect of adsorbent dosage**	**Author(s)**
Natural banana fiber	n/a	0.08 g	40	The removal of metal ion is 40% at 0.08g	[17]
Thermal treatment			86	The removal of metal ion is 86% at 0.08g	

banana fiber					
Natural banana fiber	0.02 – 0.5 g	0.4 g	39.9	The usage of natural banana fiber remove low amount of metal ions	[22]
Alkali treatment banana fiber			41.4		
Alkali treatment banana fiber	0.04 – 0.4 g/ml	0.08 g	85	The used of NaOH enhance the removal of color up to 85%	[4]
Chemically-modified banana fiber			96	The used of activation technique in chemical modification has removed meal ion up to 96%	
Alkali treatment banana fiber	0.1 – 0.9 g/ml	0.9 g	80	The removal of metal ion is 80 % at 0.9g	[9]
Thermal treatment banana fiber			88	Use of thermal increase oxygenated group that help to remove metal ion up to 88%	
Chemically-modified banana fiber			86	Used of modified banana fiber help to remove metal ion up to 86%	
Chemically-modified banana fiber	1 - 5 g/L	4 g	96	Polygrafting helps to remove metal ion up to 96%	[14]
Chemically-modified banana fiber	0.01 – 0.2 g/ml	0.1 g	96.26	Modification by using heat chemical activation help to remove color up to 96.26%	[15]

From the table 4, it was observed that increases in adsorbent dosage the percentage removal also increases. This trend can be seen in all 6 studies. [6] shows the percentage removal of color gradually increase as the adsorbent dosage increase from 5 g to 25 g but reach equilibrium at 30 g whereas maximum color removal is 95.60 %. Other studies used small range of adsorbent dosage. [8] used 0.25 to 1 g of adsorbent dosage in removing color. The optimum dosage used was 1 g in [8] and [11] whereas the maximum removal of color was 80.00 and 90.00 % respectively. The difference in maximum removal of color is due to the different type of chemical modification were used to modified banana fiber. The lowest dosage used in removing color is 0.1 g [7];[13]. [7] shows no changes in percentage removal after reaching equilibrium at dosage 0.1 g with 94.79 % of color can be removed. When adsorbent dosage increases the adsorption capacity also increases. The increase of adsorption performance is due to the introduction of more binding sites for adsorption.

The lowest dosage used in this study is found to be 0.5 g and the highest dosage is 30 g. from the Table 4, the highest removal of color is 95.60 % at the use of adsorbent dosage of 30 g. however, when compared with the second highest color removal percentage, he use of the adsorbent dosage was only 1 g. this indicates that the modification of banana fiber in [7] is better than in study conducted by [6]. Therefore, adsorbent dosage is not the only factor that affecting the adsorption performance, but also the characteristic of adsorbent itself. Since [7] using poly-grafting technique for chemical modified banana fiber in removing color, the efficiency of adsorption performance increase due to the structure and availability of active site on surface of banana fiber has increased. The adsorption performance was low due to the usage of natural banana fiber, which lack of active sites even though the dosage used is high

In table 5, the study indicates that the trend for metal ion removal shows the removal percentage shoot up to 88.00 % at 0.3 g but at 0.5 g to 0.7 g the removal percentage slowly drop and approaching equilibrium [9]. [14] shows that the percentage of removal adsorbates reach up to 96.00 % as adsorbent dosage increase from 0.1 to 0.4 g and no significant changes occurs after adding the adsorbent dosage more than 0.4 g . The lowest amount of adsorbent dosage was used is 0.01 where the percentage removal of metal ion is 51.00 % and at 0.1g the percentage removal reach up to 98.00 % [15].This shows that the banana fiber in [15] is most efficient compared to other studies. As shown in Figure 4, the lowest percentage removal of metal ion was 41.00 % at dosage 0.4 g [21]. Overall, the difference between adsorption performances is due to adsorbent dosage and surface modification of banana fiber. As seen in figure, the usage of chemically modified banana fiber will enhance the performance of banana fiber in adsorption of metal ions. Table 5 shows the effect of adsorbent dosage towards percentage removal of metal ions.

Theoretically, an increase in adsorbent dosage provides more active sites as well as functional groups for efficient adsorbate removal. However, the removal efficiency will reach equilibrium as at certain value as the adsorption capacity do not shows significant change in adsorbents activity. This happens due to the threshold limit of adsorption and higher saturation of adsorbates beyond the optimum dosage inhibits the process of adsorption caused by the clustering effect of molecules. The adsorption capacity for removal of color and heavy metal is higher when using chemically modified banana fiber compared to unmodified banana fiber and alkaline treatment banana fiber. This happens due to the active sites availability on surface of banana fiber. The variation in adsorption and adsorbent dosages could be related to the type of surface group responsible for the adsorption of metal ions from solution. The different in adsorption performance of banana fiber is due to selectivity towards ions and the surface area of banana fiber. This results also indicates that modified the structure of banana fiber can increase the proportion of active sites present on the surface of adsorbent and improved the ability of banana fiber in adsorbing color and toxic metal ions. These findings are relevant toward the appraisal of literature related to the analysis of adsorption efficiency is dependent on adsorbent dosage and modification of adsorbent.

4. Conclusion

This study emphasize on the effect of modification on banana fiber towards adsorption performance as biosorbent in treating wastewater. The results obtained from this study proved that the objectives were successfully achieved. 22 studies on the effect of modification on banana fiber as biosorbent on adsorption performance in treating wastewater were identified via PRISMA method. The chemical modification by activation and carbonization onto banana fiber are preferable to improve their characteristic and performance. Higher surface area on banana fiber as biosorbent resulted to the higher adsorption performance in removing color and metal ions. New surface functional group like oxygenated and amine group can also be introduced by applying surface modification on banana fiber. Hence, it can be correlated that the modification can improve the stability when biosorbent are being effective in wide range of pH and low of adsorbent dosage. The optimum pH and adsorbent dosage on adsorption performance of banana fiber were correlated via content analysis from systematic review. Overall, the findings obtained provide comprehensive information and act as reference on improving the adsorption performance at wide range of working pH and lower adsorbent dosage for further research on banana fiber as biosorbent.

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] M. Said, H. Abu Hasan, M. T. Mohd Nor, and A. W. Mohammad, “Removal of COD, TSS and colour from palm oil mill effluent (POME) using montmorillonite,” *Desalin. Water Treat.*, vol. 57, no. 23, pp. 10490–10497, 2016, doi: 10.1080/19443994.2015.1036778.

[2] D. Castro, N. M. Rosas-Laverde, M. B. Aldás, C. E. Almeida-Naranjo, V. H. Guerrero, and A.

I. Pruna, "Article chemical modification of agro-industrial waste-based bioadsorbents for enhanced removal of zn(Ii) ions from aqueous solutions," *Materials (Basel).*, vol. 14, no. 9, 2021, doi: 10.3390/ma14092134.

[3] M. Ahmadi, D., & Reza, "The use of technology in English language learning: A literature review.," *Int. J. Res. English Educ.*, vol. 3, no. 2, pp. 115-125., 2018.

[4] D. Yu, L. Wang, and M. Wu, "Simultaneous removal of dye and heavy metal by banana peels derived hierarchically porous carbons," *J. Taiwan Inst. Chem. Eng.*, vol. 93, pp. 543–553, 2018, doi: 10.1016/j.jtice.2018.08.038.

[5] M. Mahmood-ul-Hassan, V. Suthor, E. Rafique, and M. Yasin, "Removal of Cd, Cr, and Pb from aqueous solution by unmodified and modified agricultural wastes," *Environ. Monit. Assess.*, vol. 187, no. 2, 2015, doi: 10.1007/s10661-014-4258-8.

[6] R. R. Mohammed and M. F. Chong, "Treatment and decolorization of biologically treated Palm Oil Mill Effluent (POME) using banana peel as novel biosorbent," *J. Environ. Manage.*, vol. 132, pp. 237–249, 2014, doi: 10.1016/j.jenvman.2013.11.031.

[7] S. Wong *et al.*, "Effective removal of anionic textile dyes using adsorbent synthesized from coffee waste," *Sci. Rep.*, vol. 10, no. 1, pp. 1–13, 2020, doi: 10.1038/s41598-020-60021-6.

[8] B. Thomas, E. P. Shilpa, and L. K. Alexander, "Role of functional groups and morphology on the pH-dependent adsorption of a cationic dye using banana peel, orange peel, and neem leaf bio-adsorbents," *Emergent Mater.*, vol. 4, no. 5, pp. 1479–1487, 2021, doi: 10.1007/s42247-021-00237-y.

[9] R. Mohd Salim, A. J. Khan Chowdhury, R. Rayathulhan, K. Yunus, and M. Z. I. Sarkar, "Biosorption of Pb and Cu from aqueous solution using banana peel powder," *Desalin. Water Treat.*, vol. 57, no. 1, pp. 303–314, 2016, doi: 10.1080/19443994.2015.1091613.

[10] H. P. De Carvalho, J. Huang, M. Zhao, G. Liu, L. Dong, and X. Liu, "Improvement of Methylene Blue removal by electrocoagulation/banana peel adsorption coupling in a batch system," *Alexandria Eng. J.*, vol. 54, no. 3, pp. 777–786, 2015, doi: 10.1016/j.aej.2015.04.003.

[11] N. A. Akbar, S. Sabri, A. A. Abu Bakar, and N. S. Azizan, "Removal of colour using banana stem adsorbent in textile wastewater," *J. Phys. Conf. Ser.*, vol. 1349, no. 1, 2019, doi: 10.1088/1742-6596/1349/1/012091.

[12] M. Akter, F. B. A. Rahman, M. Z. Abedin, and S. M. F. Kabir, "Adsorption Characteristics of Banana Peel in the Removal of Dyes from Textile Effluent," *Textiles*, vol. 1, no. 2, pp. 361–375, 2021, doi: 10.3390/textiles1020018.

[13] A. Khaleque and D. K. Roy, "Removing Reactive Dyes from Textile Effluent Using Banana Fibre," *Int. J. Basic Appl. Sci.*, vol. 16, no. 01, pp. 14–20, 2016.

[14] A. Ali, K. Saeed, and F. Mabood, "Removal of chromium (VI) from aqueous medium using chemically modified banana peels as efficient low-cost adsorbent," *Alexandria Eng. J.*, vol. 55, no. 3, pp. 2933–2942, 2016, doi: 10.1016/j.aej.2016.05.011.

[15] C. Cheah, C. S. Yue, and A. S. Y. Ting, "Effects of Heat and Chemical Pretreatments of Banana Peels for Metal Removal in Single and Multimetal Systems," *Water. Air. Soil Pollut.*, vol. 232, no. 1, 2021, doi: 10.1007/s11270-020-04945-9.

[16] P. D. Pathak, S. A. Mandavgane, and B. D. Kulkarni, "Fruit peel waste as a novel low-cost bio adsorbent," *Rev. Chem. Eng.*, vol. 31, no. 4, pp. 361–381, 2015, doi: 10.1515/revce-2014-0041.

[17] Zhanwu Sheng, 1, 2 Yixiao Shen, 2, 3 Haofu Dai, 4 Siyi Pan, 1 Binling Ai, 2 Lili Zheng, 2 Xiaoyan Zheng and Z. Xu3, "Physicochemical Characterization of Raw and Modified Banana

Pseudostem Fibers and Their Adsorption Capacities for Heavy Metal Pb21 and Cd21 in Water," 2016, doi: 10.1002/pc.24140.

[18] H. Chakhtouna, H. Benzeid, N. Zari, A. el kacem Qaiss, and R. Bouhfid, "Functional CoFe2O4-modified biochar derived from banana pseudostem as an efficient adsorbent for the removal of amoxicillin from water," *Sep. Purif. Technol.*, vol. 266, no. January, p. 118592, 2021, doi: 10.1016/j.seppur.2021.118592.

[19] K. Bello, B. K. Sarojini, B. Narayana, A. Rao, and K. Byrappa, "A study on adsorption behavior of newly synthesized banana pseudo-stem derived superabsorbent hydrogels for cationic and anionic dye removal from effluents," *Carbohydr. Polym.*, vol. 181, pp. 605–615, 2018, doi: 10.1016/j.carbpol.2017.11.106.

[20] S. K. Abdul Karim, S. F. Lim, S. N. D. Chua, S. F. Salleh, and P. L. Law, "Banana Fibers as Sorbent for Removal of Acid Green Dye from Water," *J. Chem.*, vol. 2016, 2016, doi: 10.1155/2016/9648312.

[21] G. Annadurai, R. S. Juang, and D. J. Lee, "Use of cellulose-based wastes for adsorption of dyes from aqueous solutions," *J. Hazard. Mater.*, vol. 92, no. 3, pp. 263–274, 2002, doi: 10.1016/S0304-3894(02)00017-1.

[22] A. Murugesan, T. Vidhyadevi, S. D. Kirupha, L. Ravikumar, and S. Sivanesan, "Removal of chromium (VI) from aqueous solution using chemically modified corncorb-activated carbon: Equilibrium and kinetic studies," *Environ. Prog. Sustain. Energy*, vol. 32, no. 3, pp. 673–680, 2013, doi: 10.1002/ep.11684.