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Effect of the Adsorbent dosage, Initial Dye Concentration and Contact time on Methyl Orange Dye Removal by Napier Grass Stem treated with Hexadecyl trimethyl ammonium bromide (CTAB)

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DECLARATION

I declare that this thesis entitled Effect of the Adsorbent dosage, Initial Dye Concentration and Contact time on Methyl Orange Dye Removal by Napier Grass Stem treated with Hexadecyltrimethylammonium bromide (CTAB) is the result of my own research except as cited in the references.

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Kesan dos Penyerap, Kepekatan Pewarna Awal dan Masa Hubungan pada Pembuangan Pewarna Methyl Orange oleh Napier Grass Stem dirawat dengan Hexadecyl trimethyl ammonium bromide (CTAB)

ABSTRAK

Penggunaan rumput Napier yang murah dan mesra alam telah dicadangkan dalam kajian semasa sebagai pengganti teknik mahal yang kini digunakan untuk menyerap pewarna metil oren dari larutan berair. Analisis FTIR digunakan untuk mengkaji sifat rumput Napier yang diubah suai sebelum dan selepas penyerapan. Untuk menentukan keadaan eksperimen yang ideal, pelbagai faktor, termasuk dos penyerap, kepekatan awal pewarna, dan hubungan masa, telah diperiksa. Parameter yang ideal untuk penyingkiran pewarna ialah 1 g dos pennyerap selama 120 minit pada kepekatan pewarna 50 mg/L. Batang rumput Napier dirawat dengan CTAB untuk meningkatkan keupayaannya untuk menyerap pewarna Methyl Orange.

Kata kunci: Rumput Napier, pewarna Metil oren, CTAB,

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ABSTRACT

The use of the inexpensive and environmentally friendly adsorbent Napier grass has been suggested in the current study as a substitute for the expensive techniques now in use for adsorbing methyl orange dye from aqueous solution. FTIR analysis was used to examine the properties of modified Napier grass both before and after adsorption. To determine the ideal experimental circumstances, a variety of factors, including adsorbent dosage, initial dye concentration, and contact time, were examined. The ideal parameters for dye removal are 1 g of adsorbent dosed for 120 minutes at a dye concentration of 50 mg/L. Napier grass stem were treated with CTAB to enhance its ability to adsorb the Methyl Orange dye.

Keywords: Napier grass, Methyl orange dye, CTAB.

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LIST OF ABBREVIATION

FTIR	Fourier Transform infrared spectroscopy
SEM	Scanning Electron Microscopy
MO	Methyl Orange
C14H14N3NaO3S	Methyl Orange
CTAB	Hexadecyl trimethyl bromide
NG 1	Napier grass stem before adsorption of methyl orange
NG 2	Napier grass stem after adsorption of methyl orange
$C0$	Initial dye concentration
Ce	Equilibrium dye concentration

LIST OF SYMBOLS

%	Percentage
m	Meter
°C	Celsius
mol	Mole
Min	Minute
g	Gram
L	Liter
mL	Millilitre
nm	Nanometre
$C0$	Initial concentration
Ce	Final concentration

CHAPTER 1

INTRODUCTION

1.1 Research Background

Synthetic complex organic dyes have been increasingly popular in the textile industry as coloring agents. According to Lakshmi (1987), dye is carcinogenic, damages reproductive organs, and causes toxicity and neurotoxicity. As a result, water and wastewater must necessarily be free of dyes. Avoid encountering the solution or solid methyl orange (MO) on your skin as it is considered hazardous if ingested or inhaled. While certain methods for treating textile waste, such ion pair extractions, and electrochemical procedures, are relatively new, others have long been employed in the sector. Adsorption has been found to be superior to other water recycling techniques in terms of starting cost, usability, design simplicity, and insensitivity to toxic substances. This study is based on removing methyl orange dye which is the anionic dye by using agricultural waste as a material to adsorb dye from an aqueous.

Chemicals called dyes give materials like paper, leather, and textiles their colour so that exposure to heat, light, and other environmental factors such as washing won't readily alter the colour. Pigments are finely ground substances mixed with other materials or dispersed in a liquid, like paint or ink. This is not the same as dyes. Most dyes are carbon-containing chemical molecules. In contrast, pigments might be inorganic substances. In general, pigments provide colours that are brighter and can also be dyes that are insoluble in the used media.

Common anionic azo dye methyl orange (MO) must be handled in a non-toxic manner before it can be released into the environment since it is detrimental to organisms and the environment. Azo dyes, such as methyl orange, have aromatic and -N = N-groups in their molecules, which makes them harmful to both the environment and living creatures. In addition, these groups are teratogenic, extremely toxic, and carcinogenic. In this experiment, MO is used as a simulated pollutant. Given its molecular weight and structure, its molecular diameter is estimated to be between 6 and 8 nm. Therefore, it is crucial to remove the methyl orange dye from the aqueous. Based on my research study, the dye been removed using a few types of agricultural waste. Removal of Methyl from Aqueous Solution with Finger-Citron-Residue-Based Activated Carbon. (Gong et al.). Adsorptive removal of methyl orange dye from aqueous solution using populous leaves (Shah et al.).

Adsorption is the process by which molecules, atoms, or ions stick to a surface. The adsorbate is the material that has been adsorbed onto the surface. The adsorbent is the material that has a surface. Since energy is released when the adsorbate adheres to the adsorbent, adsorption is an exothermic process. Temperature and surface area have a major influence on the process's pace. Low temperatures promote adsorption because particles with lower thermal energy have lower kinetic energy and are more likely to stick to surfaces via the creation of covalent bonds, hydrogen bonds, or other intermolecular forces. (Helmenstine, 2021).

Planting Napier grass (NG), also known as Pennisetum purpureum, has been encouraged as a substitute for animal feed. It attracted attention due to its quick development without an abundance of nutrients, strong resistance to disease, flexibility, high yield of production, and ease of replication. (Obi Reddy, Uma Maheswari, Shukla, & Muzenda, 2014). NG has a high cellulose content, ranging from 35 to 50%. This substance has therefore been the main justification for supplementation as a potential sustainable alternative supply of precursors for the production of biosorbent. (Lu et al., 2014).

The use of NGS-based biosorbent for dye removal has not been documented. Here, we demonstrate for the first time the effectiveness of Methyl Orange dye in an aqueous solution via an adsorption technique on treated Napier grass stems. Furthermore, the impact of independent variables on adsorption capacity was ascertained, such as contact time, initial dye concentration, and biosorbent dosage.

1.2 Problem statement

Due of its inertness and potential health effects, dye poisoning of water sources has become a global problem. Among the many organic dyes that are anionic, cationic, and nonanoic are azo dyes, a broad class of synthetic dyes with azo groups (-N=N-). Azo dyes are extremely poisonous, carcinogenic, and teratogenic, as well as detrimental to the environment and biological creatures, due to the presence of aromatic rings and -N=N groups in their structural makeup (Bai et al. 2020; Haque et al. 2021). Up to 20% of the vast amounts of azo dyes used in the textile industry are ultimately released as effluent, which causes severe toxicity and mutagenicity in aquatic life and humans (Mahmood et al. 2016).

A classic and frequent azo anionic dye is methyl orange, also known as (MO) dimethylaminoazobenzenesulfonate. This water soluble organic synthetic dye has a bright orange colour and excellent colorability when dissolved in water. Aromatic and -N=N- groups, which are exceedingly toxic, carcinogenic, and teratogenic as well as harmful to the environment and living organisms, are present in the molecules of azo dyes like methyl orange. Methyl orange (MO) must be handled gently before being released into the environment since it is detrimental to biological systems and the environment (Wu et al., 2021). It is difficult to remove MO from aqueous solutions using current water treatment techniques since it is soluble in water and does not degrade easily. Furthermore, if improperly handled, MO lingers in the environment and poses a threat to living things.

1.3 Objectives

i. To determine the optimum value of adsorbent dosage, initial dye concentration and contact time for methyl orange dye removal.
ii. To characterise the chemical properties of treated Napier grass stem adsorbents using Fourier-Transform Infrared Spectroscopy (FTIR).
iii. To characterise the morphology of Napier grass stem treated with CTAB using scanning electron microscopy (SEM)

1.4 Scope of study

The study is primarily focusing on the ability of the Napier grass stem as a biosorbent to remove an anionic dye which is methyl orange in aqueous state. This experiment was conducted to study the effects of absorbent dosage, initial dye concentration, and contact time on adsorption of methyl orange by using biosorbent derived from Napier grass stem treated with CTAB. The percentage of removing dye was employed to evaluate the efficiency of Napier grass stem as adsorbent for removing methyl orange dye in aqueous solution.

1.5 Significance of study

This project aims to investigate how different operating parameters affect the dye removal process with a biosorbent made from treated Napier grass stems. Because it can be used to identify the ideal conditions for methyl orange dye removal from aqueous solutions, the investigation of the effects of operational factors on methyl orange dye using biosorbent formed from Napier grass is significant. The selection of methyl orange is based on its wide applications in the chemical, food, textile, printing, and pharmaceutical industries, as well as its negative effects on people, animals, and the environment due to its high toxicity, carcinogenicity, and teratogenicity. The goal of the study is to use biosorbent made from Napier grass stem to investigate the effects of operational parameters on the absorbance value of methyl orange dye from aqueous solutions, including adsorbent dosage, initial dye concentration, and contact time.

CHAPTER 2

LITERATURE REVIEW

2.1 Napier grass as adsorbent

Figure 2.1: Napier grass stem

Source: (Napier Grass: A Sustainable Solution for Agriculture and Environment | SocialDhara, 2023)

The *Pennisetum purpureum* schum species, popularly known as "elephant grass" or "Napier grass," is a member of the Poaceae family. Napier grass is a native of Africa, and it was brought to South America, Asia, and Australia centuries ago as animal forage. This grass has strong, fibrous internodes and is perennial. A single clump plant may typically grow to a height of 4 m and can generate up to 50 tillers. Napier grass is a natural, quickly expanding plant that just needs a small nutrient supplement. With an annual dry mass production of up to 40 tonnes per hectare, it can be harvested after 3.4 months after planting and again every 7-8 weeks for up to 5 years. (Woodard,1993).

Table 2.1 : Comparison of chemical composition of Napier grass fibre with other perennial grasses

(Source: Reddy, K. 2012)

Grass fibre	Dry matter yield (ton/hec)	Attractive (%)	cellulose	Lignin (%)	Ash (%)	Hemicellulose/ pentosan (%)
Alfa	0.4-2	6.59	4.76	17.71	5.12	22.15
bamboo	4	2.3	26-43	21-31	1.7-4.8	15-26
Giant reed	32-37	4.55-6.34	29.18-32.03	20.92-21.31	4.77-6.14	28.48-32.03
mischantus	12	3.1	42.2	19.9	0.7	30.3
Reed cannery	5.38	1.1	28.0	14	8	22.0
Switch	10-12	1.6	43.4	21.8	1.5	35.9
Napier grass	40	3.1	44.2	18.3	3.7	30.5

2.2 Composition of Napier grass

The table 1 outlines the chemical make-up of the fibres of Napier grass (3.1% extractives, 44.2% -cellulose, 30.5% hemicelluloses, 18.3% lignin, and 3.7% ash). Table 1 compares the Napier grass fibres' dry matter output and chemical makeup to those of a few other perennial cellulosic grasses. Naturally occurring in plants and trees, cellulose is a material that is both biodegradable and good to the environment. The several active hydroxyl groups present in cellulose molecules allow for easy chemical modification of the material by the addition of other functional groups to the hydroxyl group. O., Dw. Connell, 2008. Cellulose is a good candidate for surface modification to turn it into an adsorbent because to its porosity, large surface area, and hydroxyl group content.

2.3 Other applications of Napier grass

Napier grass (Pennisetum purpureum Schumach.), which is native to Sub-Saharan Africa, spreads swiftly and is widely planted in tropical and subtropical regions across the globe. This adaptable fodder crop is mostly used in cut and carry livestock feeding schemes.

Research on the diversity and characterization of a small subset of Napier grasses has shown that these grasses contain a moderate amount of genetic variety and are useful as fodder crops due to their high biomass output and other desirable agronomic traits. High-quality feed and forage resources are essential for the sustainability of livestock production. One of the most significant tropical fodder crops is Napier grass, sometimes referred to as elephant or Uganda grass. (Farrell, Simons, & Hillocks, 2002). It is becoming more and more important in various agricultural systems and is extensively employed in cut and carry feeding systems. Napier grass is a preferred fodder due to its many advantageous qualities, which include its high yield per unit area, resilience to sporadic droughts, and excellent water usage efficiency. It will quickly recover and produce edible green shoots even after being repeatedly chopped. Cattle value chains stand to gain a great deal from increasing the knowledge-based utilisation and protection of the existing Napier grass resources. (Lowe, Thorpe, Teale, & Hanson, 2003).

2.4 Agricultural waste

Agricultural wastes have drawn more attention in recent years due to the potential for serious environmental issues. Nevertheless, they can also be used for several advantageous processes, such as chemical recovery, dye or chemical adsorption, and feedstock to produce energy. The four areas of this review are waste management and minimization, waste treatment, waste reuse and recycling, and agricultural waste characterisation. In Agricultural and Natural Fibres, the physical, chemical, and spectroscopic characteristics of the remnants of the indigenous marine plant Posidonia oceanica were investigated. They concluded that because P. oceanica's fibrous component has lower heating values between 13.6 and 15.7 mg/kg it can be used as a biofuel. Furthermore, it was shown that although the leaves had reduced heating values roughly 10 MJ/kg they still resembled a green waste and are not appropriate for energy recovery.

2.5 Agricultural waste as adsorbent

The water purification industry is considering the use of green adsorbents as a possible substitute for traditional synthetic adsorbents due to their abundance, low cost, and environmental friendliness. Recycled materials from various industries, such as forestry, agriculture, and biology, are referred to as "green adsorbents". Adsorption capacity, regeneration potential, high surface area, quick kinetics, and porous properties are all ideal characteristics of an effective adsorbent. When adsorbents are applied more widely beyond lab settings in water and wastewater treatment plants, these become extremely important. Because they are plentiful and inexpensive, some of the traditional green adsorbents such as clay, bentonite, zeolite, and montmorillonite are widely employed for the adsorption of pollutants from wastewater. (França et al., 2022)

Agricultural wastes are the unwanted solid byproducts of farming, such as discarded grain and animal dung. The cellulose content of agricultural waste materials is higher, indicating a possible capacity for contaminant biosorption. The other essential components of the biomass of agricultural waste materials are hemicellulose, lignin, extractives, lipids, proteins, simple sugars, water hydrocarbons, and starch. These compounds contain a range of functional groups that enable them to combine with other substances to create complexations and help remove pollutants from wastewater. It is difficult to decompose lignocellulosic materials due to their complex structure. (Sud, Mahajan, & Kaur, 2008).

2.6 Chemical treatment

A study by (Shahnaz, Patra, Sharma, & Selvaraju, 2020) used a chemically modified biosorbent derived from Acacia auriculiformis to remove hexavalent chromium. The plant material was treated with sulfuric acid and pyrolyzed at 400 °C after being processed similarly to the previously discussed biosorbents. After drying and mixing with ethylenediaminetetraacetic acid for two days at room temperature, the resultant powder was neutralised with a sodium bicarbonate and water mixture. It was then rinsed and dried. In comparison to the pristine biosorbent, which had a removal efficiency of 40.65%, the modified biosorbent obtained a greater efficiency of 57.51%. This rise was explained by the virgin biosorbent's complexation with chelating agents, which increased the quantity of functional groups that interacted with chromium ions, such as carboxyl and hydroxyl groups.

2.7 CTAB

One gramme of newly taken out of the oven NaOH-treated POF was mixed with one hundred millilitres of 14mmol·L− 1 CTAB solution for the CTAB treatment was additionally agitated on a mechanical platform shaker (Edmund Buhler GmbH) for a time of 24hata speed of 200rpm. Subsequently, the suspension was filtered, and the resulting material was repeatedly washed with distilled water to remove any further partially retained CTAB until $AgNO3$ (0.1mol·L−1) was added to the water and no white precipitate developed. The resulting biosorbent was sieved and stored in a bottle for later use after being dried for 24 hours at 60°C in an oven. (Ngaha, Njanja, Doungmo, Tamo Kamdem, & Tonle, 2019)

2.8 Dye

A certain visible spectrum wavelength is absorbed by dye, a coloured material. Its complex, comparatively stable, and resistant to degradation aromatic structure. The industries that use dyes the most are those in the pharmaceutical, textile, cosmetic, food, plastics, photography, and paper sectors. (Yang et al., 2018). In addition to having an aesthetic effect, dyes in water resources block sunlight from penetrating water bodies, which hinders photosynthetic activity and eventually destroys aquatic ecosystems. Furthermore, people's kidneys and central nervous systems are gravely harmed by the colours in water (Moawed & El-Shahat, 2016). Even very modest quantities of colour in water (less than 1 ppm for certain colours) are very apparent and unpleasant. Many dye metabolites are poisonous, teratogenic, and mutagenic to people and aquatic life because they contain aromatics, metals, and chlorides. In addition to being carcinogenic, dyes greatly endanger aquatic life. (Nawar & Doma, 1989).

In addition, dyes can be categorised as non-ionic, anionic, or cationic. Anthraquinone or azo chromophores are found in most anionic and non-ionic dyes. Azole dyes have one or more R 1-N-N-R 2 linkages in them. Aromatic amines can be produced through the enzymatic reduction of these bonds. Because to the presence of carboxyl, hydroxy, amino, or sulfonyl functional groups, they may also have amphoteric characteristics. (Ajmal, Majeed, Malik, Idriss, & Nadeem, 2014).

2.8.1 Synthetic dye

In contrast to natural dyes, synthetic dyes are more difficult to fully dissolve through photolysis, chemical and biological breakdown, and other common processes. The amount of dyes absorbed into the environment can be decreased using a variety of techniques, such as ion exchange, membrane processes, chemical sedimentation, electrochemical reduction, and absorption. (Ganzenko et al., 2018). Most colouring agents are synthetic chemical dyes. Over 100,000 synthetic organic dyes that are commercially accessible are extensively utilised in the food processing, pharmaceutical, textile, tanning, printing, paper, and plastic industries. (Tkaczyk, Mitrowska, & Posyniak, 2020). When these colours are discharged into wastewater, they endanger the ecosystem. To be more precise, they may cause severe photosynthetic degradation, impede development, enter the food chain, and ultimately raise the toxicity, mutagenicity, and carcinogenicity of food items. Neutralising synthetic dyes can be difficult due to their chemical stability. In this sense, removing these dyes using a variety of adsorbents is a useful wastewater cleanup technique. (Deniz & Kepekci, 2017).

2.8.2 Azo dye

Azo compounds account for most dye production (more than 60%), and their significance is expected to increase going forward. The culinary, pharmaceutical, cosmetic, paper, textile, and leather sectors all make substantial use of azo dyes. The food additive industry uses over 65% of azo colours in soft drinks, jam, candies, and pickles. The most often utilised food azo dyes include E102 Tartrazine, E110 Sunset Yellow, E122 Carmoisine, E123 Amaranth, E124 Ponceau 4R, E129 Allura Red AC, E133 Brilliant Blue, and E155 HT Brown. (Kaya, Cetinkaya, & Ozkan, 2021). Azole dyes are widely used because of their chemical adaptability, which produces a wide range of vivid hues. They also don't taste bad or smell bad, are inexpensive, easily available, reliable, and constant. Food azo dyes, however, might be harmful to your health. Consuming artificial dyes may be safe if done so in amounts below the Allowable Daily Intake (ADI). Larger dosages, meanwhile, might have negative health impacts, especially for young children. Several potential hazards have been documented, including cytotoxicity, genotoxicity/cancer, allergy, asthma, attention deficit hyperactivity disorder (ADHD), and anxiety. Azo dyes don't break down much in aerobic environments, making them comparatively durable. (Selvaraj, Swarna Karthika, Mansiya, & Alagar, 2021)

2.8.3 Methyl orange dye

Among the main pollutants released by the food, printing, textile, and pharmaceutical industries are dyes like methyl orange, which contaminate water supplies and make wastewater treatment challenging potentially in extremely little amounts, these colours are harmful in the environment and can potentially cause cancer in people. (Yuan, Huang, Guo, Yang, & Yu, 2011). Methyl orange is difficult to remove from wastewater because it is persistent in aqueous solutions and has a low biodegradability. Methyl orange cannot be effectively removed by conventional water treatment methods as coagulation, filtration, oxidation, sedimentation, biological digestion, and adsorption using activated charcoal. (Zheng et al., 2018). Methyl orange is removed from wastewater using clays such illite, kaolinite, smectite, and montmorillonite.

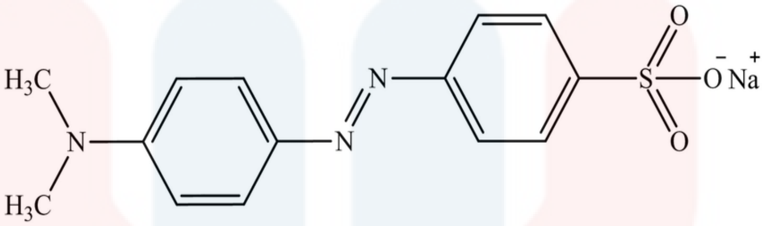


Figure 2.2: The chemical structure of Methyl Orange

Source: (Dakhil, Gaaz, Al-Amiery, Takriff, & Kadhum, 2019)

MO was selected as the study's target substance because to its wide applications in the textile, printing, paper, food, pharmaceutical, and chemical industries as well as its negative effects on people, animals, and the environment (Alseddig et al. 2017). Dimethylaminoazobenzenesulfonate, or (MO) methyl orange, is a common and traditional azo anionic dye. This water-soluble organic synthetic dye has a strong orange colour and excellent colourability when dissolved in water. The molecules of azo dyes, such as methyl orange, contain amino and -N=N- groups, which are extremely poisonous, carcinogenic, and teratogenic as well as harmful to the environment and organisms (Bai, Y. N. et al., 2020). The simulated pollutant used in this study, MO, has a molecular diameter estimated to be between 6 and 8 nm based on its molecular weight and structure.

Figure 2.3: Methyl Orange

Source: (Bai, Y. N. et al., 2020)

Table 2.2: physical and chemical properties of Methyl Orange dye

Source: (Khan et al., 2022)

Molecular formula	C14H14N3NaO3S
Boiling point	> 300 °C, density 1.28 g/cm^3
Solubility	500parts water and insoluble in alcohol**.**
Physical state	orange-red solid that has no odour (odourless)
Charge anionic dye	Negative charge.
Molecular mass	327.34 g/mol
CA Index name	4-[4-(Dimethyl amino)phenylazo]benzenesulfonic acid sodium salt
Generic	Acid orange 52
Colour index number	13025
Dye class	Azo dye
pH range	3.1 to 4.4
Maximum wavelength	464 nm
Stability	Stable under ordinary condition
Biological application	Decolorization using *Pseudomonas aeruginosa*
Industrial Applications	- Textiles - Dyeing - Leather - Paper

Table 2.3: Previous research of Methyl Orange dye removal

Biosorbent	**Capacity (mg g)**	**References**
Eggshell	25	(Haqiqi & Hikmawati, 2019)
Coconut shell	0.247	(Yusmaniar, Erdawati, Ghifari, & Ubit, 2020)
Mandarin peel	2.52	(Park, Kim, Lee, & Chon, 2021)
corncob	6.09	(Salih, Abdul Kareem, & Anwer, 2022)
Coffee waste/cetyltrimethylammonium bromide	58.82	(Lafi & Hafiane, 2016)

2.9 The effect of synthetic dye to environment.

The dyes' bioaccumulation in soil and sediments and subsequent transit to public water supply systems can be attributed to their propensity to be resistant in anaerobic conditions, especially in traditional treatment facilities (Vikrant et al., 2018). As shown by the decline in azo-type compounds that produce dangerous aromatic amines, they can partially degrade or transform in the presence of anoxic sediments even though most of them are resistant to environmental change (Ito, Adachi, Yamanashi, & Shimada, 2016). Another possibility is to combine dyes with intermediate synthetic compounds or the products of their breakdown to produce other molecules that are potentially mutagenic and carcinogenic (Vikrant et al., 2018).

The refractory and xenobiotic properties of the dyes have an impact on the structure and functionality of ecosystems, as noted by Rawat, Misra, and Sharma (2016). Chronic exposures have been shown to have significant effects on human health and the aquatic biota (Ito et al., 2016). This is especially true with complex metal dyes. Because of its resistance, this type of dyes is commonly utilised in the textile sector, and they have half-lives of two to thirteen years. (Lellis, Fávaro-Polonio, Pamphile, & Polonio, 2019)

2.10 The method of treatment for dye effluents

Before dumping textile dyeing effluent into adjacent surface water bodies, it should be treated because it degraded the quality of the surface water. Adsorption, precipitation, ozonization, oxidation, and coagulation-flocculation are just a few of the treatment methods that have been developed recently to deal with effluents. (El-Fadaly, El-defrawy, F.El-Zawawy, & D.Makia, 1999). Physical and chemical procedures such as adsorption, flocculation, coagulation, precipitation, ozonization, irradiation, etc. are used to treat textile dyeing effluents. One of the best chemical techniques for eliminating pigments and dyes from textile dyeing effluents is coagulation. In textile dyeing wastewater treatment, chemical coagulation refers to the addition of chemicals to alter the suspended and dissolved solids' physical state and promote sedimentation-based sedimentation.

2.11 Adsorption

The adherence of a gaseous, liquid, or solid substrate to the surface of a liquid or solid known as an adsorbent or sorbent mediates adsorption processes. There are various adsorption systems, including liquid-gas and liquid-liquid. An emulsion, micelle, or film forms as the interfacial layer when a liquid substance acts as an adsorbent. Since the adsorbent in the other system is a solid, the interfacial layer model is the approved mechanism for the adsorption process. Other systems include solid-liquid or solid-gas systems. The interfacial layer describes the equilibrium that exists between the adsorbent and bulk phase. In the first zone, the sorbent's surface is linked to the substrate, while in the second, the sorbent's surface layer is present. There are two primary ideas that explain the interfacial layer mechanism. (Dąbrowski, 2001). Physical adsorption, also known as physisorption, is a type of bonding in which there are no chemical structural changes for either the sorbent or the substrate. It is based on a weak Van der Waals force. Chemical Adsorption: Also referred to as Chemisorption, this process creates chemical bonds between an adsorbent and a substrate by rearranging their respective electron densities. These bonds can be either covalent or ionic in nature.

2.12 Factor affecting adsorption.

The nature of the adsorbent its size, shape, polarity, presence of effective groups, molecular weight, and solubility affects the interaction between the adsorbed particles and the adsorbent surface. One component of the solution will selectively adsorb without the other when there are multiple components present in the adsorption solution. Adsorbents with higher molecular weights have a greater chance of interacting with surfaces in multiple sites, which facilitates adsorption. Additionally, adsorbents with multiple aromatic rings in their composition are better able to increase their adsorption efficiency on a variety of adsorbent surfaces. (Natarajan, Mohan, Martinez, Meltz, & Herman, 2000). Their distribution on the surface in terms of the nature of regularity or homogeneity and lack thereof since the adsorption efficiency depends on the physical and chemical characteristics and particle size of the adsorbent material, therefore the adsorption rate increases with the decrease in particle size. Therefore, in order to improve the diffusion step, smaller particles must be added to the material's surface. It's also critical to remember that another essential element of the adsorption process is the size distribution of the pores in the particles, which enables the effective migration of pollutants to the adsorption site. (Alfatlawi, Aljamali, & Obaid, 2015).

2.12 Parameters affecting adsorption.

The extent of solute adsorption typically increases as adsorbent concentration rises because higher adsorbent concentrations lead to more active exchangeable adsorption sites. Nevertheless, following an increase in adsorbent concentration, interference from the interaction of an adsorbent's active sites may result in a decrease in the total solute adsorption per unit weight of an adsorbent. (Esposito, Pagnanelli, Lodi, Solisio, & Vegliò, 2001). The amount of La adsorption was not enhanced in a study by (Wu, Zhao, Zhang, Wu, & Yang, 2010) when the dose of Fe3O4@Ca-Alg beads was increased from 0.1 to 0.3g/50mL. Furthermore, at doses of 0.2 and 2.5 g/L, respectively, neem sawdust (Das, Jaya Sre Varshini, & Das, 2014)and S. fluitans studied by (Palmieri, Volesky, & Garcia, 2002) shown excellent la adsorption (>90%).Similarly, the studies by (Kütahyali, Sert, Çetinkaya, Inan, & Eral, 2010) changed the dose of a biosorbent (Pinus brizanthaleaf) from 0.05 to 0.45 g and discovered that removal rose as the dose increased. On the other hand, (Torab-Mostaedi, Asadollahzadeh, Hemmati, & Khosravi, 2015)discovered that the removal of La ions diminishes with a certain rise in dosage because all of the La ions bind to the adsorbent. Therefore, to achieve effective removal, it is important to optimise the dose of an adsorbent.

The contact time has a significant effect on the adsorption process. Furthermore, the adsorption kinetics and the economic efficiency of the operation could be impacted by contact time. As a result, contact time is another factor that affects adsorption process performance. (Haldorai et al., 2015) investigated the adsorption of LaonFe3O4/chitosan nanocomposite after a 60-minute contact time, they achieved 86% removal. La removal was notably decreased by extending the contact time from 60 to 150 minutes. The desorption of La was the reason for the reduced migration (Haldorai et al., 2015) La adsorption on DGA-g-PAA reached saturation in 120 minutes in another investigation (Zhou et al., 2016).

The initial dye concentration in the solution is crucial in batch biosorption operations because it acts as a catalyst to break down the mass transfer resistance between the solution and solid phases. With a fixed biosorbent dose of 2.5 g/L and varying initial concentrations (10–40 mg L 1). The outcome shows that for both dyes, an increase in the initial dye concentration causes an increase in ALP biosorption. The theory that suggests that the MG and CV dye molecules must first experience the boundary layer effect, then diffuse from the boundary layer film onto the biosorbent surface, and finally diffuse into the porous structure of the biosorbent the studies by (Senthilkumaar, Varadarajan, Porkodi, & Subbhuraam, 2005) could explain this observation. When the concentration increased from 10 to 40 mg L 1, the sorbed amount increased for MG from 3.23 to 11.70 mg g 1 and for CV from 3.55 to 13.75 mg g 1 at equilibrium.

CHAPTER 3

MATERIALS AND METHODS

3.1 Apparatus and Equipment

The apparatus that was used are conical flask (250 ml), volumetric flask (100 ml and 500 ml), beaker (250 ml, 1000 ml), scott bottle (1000 ml), measuring cylinder (5 ml, 10 ml, 500 ml), micropipette (50 microlite, 100 microlite), blender, sieve, spatula, dropper, cuvette tube, aluminium foil. oven, airtight zipper bag

Equipment that was used are weighing scale, orbital shaker, Fourier-Transform Infrared Spectroscopy (FTIR), Genesys visible spectrophotometer and Scanning electron microscope.

3.2 Chemical and Reagents

Chemical and Reagents used in these experiments are Methyl Orange (MO), and hexadecyl trimethyl ammonium bromide (CTAB).

3.3 Methods

3.3.1 Preparation of treated Napier grass stem powder.

The Napier grass utilised in this study was harvested from a farm in Kota Bharu, Kelantan. A simple process that needed little energy and chemical input was used to create biosorbent. To put it briefly, the stem of Napier grass was chopped, mixed, and sieved to create a fine powder. The oven was preheated to 70°C for drying. After that, distilled water was used to thoroughly wash the Napier grass until the filtrate became neutral. The residue was dried for 24 hours at 70°C, and then sieved. Consequently, biosorbent which comes from the stem of Napier grass was created.

3.3.2 Preparation of Dye Stock Solution (Methyl Orange)

To prepare dye stock solution of 1000 mg/L, 0.5 g of Methyl Orange dye was accurately weighed and dissolved in 500 mL using distilled water and the desired experimental concentration were obtained by further dilution. Then, the serial dilutions were made by diluting the Methyl Orange stock solution in accurate proportions using distilled water. For the construction of calibration curve, a few series of Methyl Orange concentrations were prepared in the range of by diluting the prepared stock solution with distilled water. Next, various concentrations of Methyl Orange were measured by using spectrophotometer at 464 nm wavelength.

3.4 Chemical treatment with CTAB

2.5 g of CTAB was dilute into 1500 ml of distilled water. 100 g of raw Napier grass stem powder was soaked with the CTAB solution. The Napier grass stem powder been soaked for 24 hours. Then it was filtered and dried in the oven to remove the moisture.

3.5 Effect of adsorbent dosage

The optimum initial dye concentration obtained from previous parameter in section 3.3.3 was used for the subsequent studies. The concentration of dye which is 50 mg/L and the volume of dye which is 100.0 mL were kept constant. The study of Methyl Orange dye removal by modified Napier grass powder from aqueous solutions was performed using the adsorbent with different dosages i.e. 0.5 g, 1.0 g, and 2.0 g. the mixtures were agitated for 30 minutes at 150 rpm in the orbital shaker. Then the samples were filtered, and the filtrates were measure by spectrophotometer at 464 nm.

3.6 Effect initial dye concentration.

The effect of initial dye concentration was studied at concentration of Methyl Orange of 50, 100, 200 mg/L. A mixture of 100 mL of 100 mg/L Methyl Orange solution and different concentrations with 0.5 g of modified Napier grass powder were agitated for 30 minutes at 150 rpm under room temperature. After 30 minutes the samples were filtered using filter paper. The filtrates were measured using spectrophotometer at 464 nm wavelength. The filtrates were measured for 3 times in the spectrophotometer to obtain the average reading. After that, the percentage removal of Methyl Orange dye was calculated.

3.7 Effect of contact time.

The effect of contact time was studied using the optimum parameters such as initial dye concentration (50 mg/L) and adsorbent dosage (1.0 g). All these parameters were kept constant throughout this study. Then, the contact time was studied in 30 minutes, 1 hour and 2 hours. The mixtures were agitated at 150 rpm in the orbital shaker. After that, the samples were filtered, and the filtrates were measured using spectrophotometer at 464 nm.

3.8 Spectrophotometer and calibration curve

Following adsorption, the sample is filtered, and a UV spectrophotometer is used to measure the solution sample. The wavelength of 464 nm is used to determine the maximum wavelength of the dye solution following adsorption. A calibration curve is used to determine the methyl orange dye concentration. Using a UV spectrophotometer, readings are taken three times. Equation 3.2 is used to determine the percentage of dye elimination.

$$\%\ \text{adsorption}\ \frac{(C_0-Ce)}{C_0} \times 100$$

Where C0 and Ce are the initial and equilibrium dye concentration (mg L-1), respectively.

3.9 Absorption process

By adjusting the parameters that influence the adsorption of methyl orange on Napier grass stem powder, adsorption operations are carried out in a laboratory shaker under incubation. By using 100 ml of methyl orange solution, the effects of the adsorbent dosage, initial dye concentration, and contact time are investigated. The dosage of the absorbent is adjusted between 0.5 g, 1 g, and 2 g while holding all other parameters constant. There are three different initial concentrations: 50, 100, and 200 mg/l. The contact time is now 60, 120, and 30 minutes. The adsorbent was separated from the adsorbate solution by filtering it after the predetermined amount of time had passed. After adsorption, the solution was filtered using filter paper. After filtering, the solution's concentration was measured at 464 nm using a spectrophotometer that had previously been calibrated.

3.10 Spectrophotometer

I can confirm and make sure that the dye has been successfully removed using a variety of techniques after running the methyl orange removal utilising a biosorbent made from Napier grass. Spectrophotometric examination. One frequent method for determining the concentration of a particular material in a solution, such as dyes, is spectrophotometry. The absorbance of the dye solution is measured using spectrophotometers both before and after the adsorption process. A successful adsorption of dye is indicated by a considerable decrease in the absorbance of the solution. We can ascertain if the dye has been eliminated or whether its concentration has dramatically dropped by comparing the chromatograms of the dye solution before and after adsorption.

3.11 Characterisation of treated Napier grass powder using Fourier-transform Infrared Spectroscopy (FTIR)

The Fourier transform infrared (FTIR) spectroscopy approach can be used to detect changes in the overall composition of biomolecules by detecting changes in their functional groups. FTIR is used to measure how much molecules that are impacted by a particular wavelength of infrared light vibrate and rotate. By recognising structural differences in molecule binding, details on the presence of their interactions can be extracted. The most often used FTIR-based techniques for characterisation are micro-spectroscopy FTIR, attenuated total reflectance (ATR–FTIR), and transmittance FTIR.

3.12 Scanning Electron Microscope.

Scanning electron microscopy (SEM) is a powerful technique used to characterize the surface morphology and composition of materials at high magnification. It works by focusing a beam of high-energy electrons onto a sample, and then collecting the resulting secondary electrons, backscattered electrons, and characteristic X-rays. These signals can be used to create images of the sample's surface, as well as to determine its elemental composition.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Calibration curve of Methyl Orange

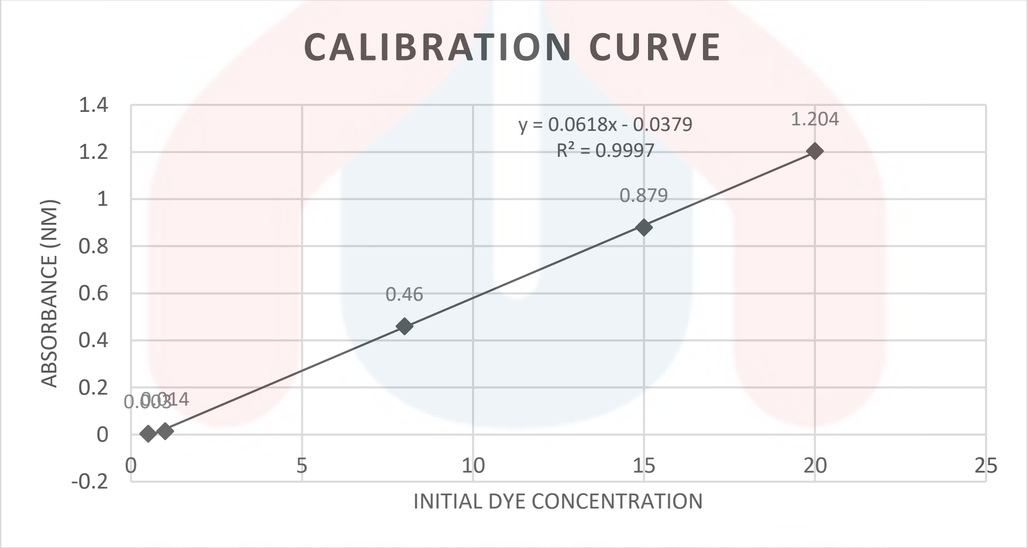


Figure 4.1: Calibration curve of Methyl Orange using 464 nm

To create a linear calibration curve, a few series of Methyl Orange solutions at various concentrations (1 mg/L – 20 mg/L) were generated from a 1000 mg/L stock solution of Methyl Orange dye. The calibration curve's objective is to ascertain the Methyl Orange dye's ultimate concentration following adsorption with modified Napier grass powder. Figure 4.2 displays the MO calibration curve. You may find the calibration curve data in the appendix.

4.2 Control

Table 4.1: Absorbance reading for control.

Initial dye concentration	Contact time	Absorbance reading	(2)	(3)
50 mg/l	30 minutes	2.218	2.217	2.200
100 mg/l	30 minutes	2.320	2.307	2.306
200 mg/l	30 minutes	2.374	2.373	2.373

4.3 Adsorbent dosage

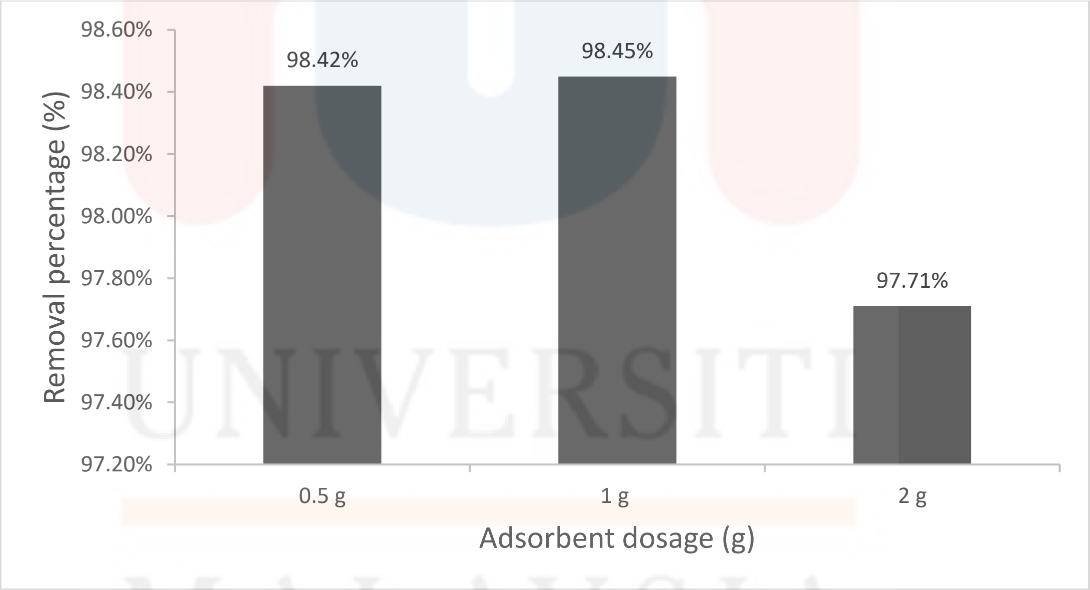


Figure 4.2: Effect of adsorbent dosage based on removal percentage of methyl orange dye.

The effect of adsorbent dosage has been studied at 3 different values which is 0.5 g, 1 g, and 2 g. figure below show that the effect of adsorbent dosage for removal of methyl orange dye. This figure indicates that the removal percentage of methyl orange decrease from 0.5 g, 1 g, 2 g. higher percentage removal of methyl orange was achieved for 1 g (98.45%) whereas 2 g gave lesser percentage removal or dye (97.71%). The result showed that the biosorption increase but then decreased when the adsorbent dosage at 2 g. A higher dosage of adsorbent results in partial aggregation rather than a proportionate increase in the active sites available for adsorption, which explains why the amounts of adsorbed dye tend to decrease in response to the adsorbent dose. Moreover, this state can be connected to the unsaturation of the sites responsible for the adsorption process. (Brini et al., 2021). This assertion is further supported by the removal ratios' comparatively upward tendency in relation to adsorbent dosage. That is, increasing the dosage of the adsorbent caused a certain rise of dye uptake, albeit not proportionate to the increase in quantity. (Doğar, Gürses, Açikyildiz, & Ozkan, 2010)

4.4 Initial dye concentration

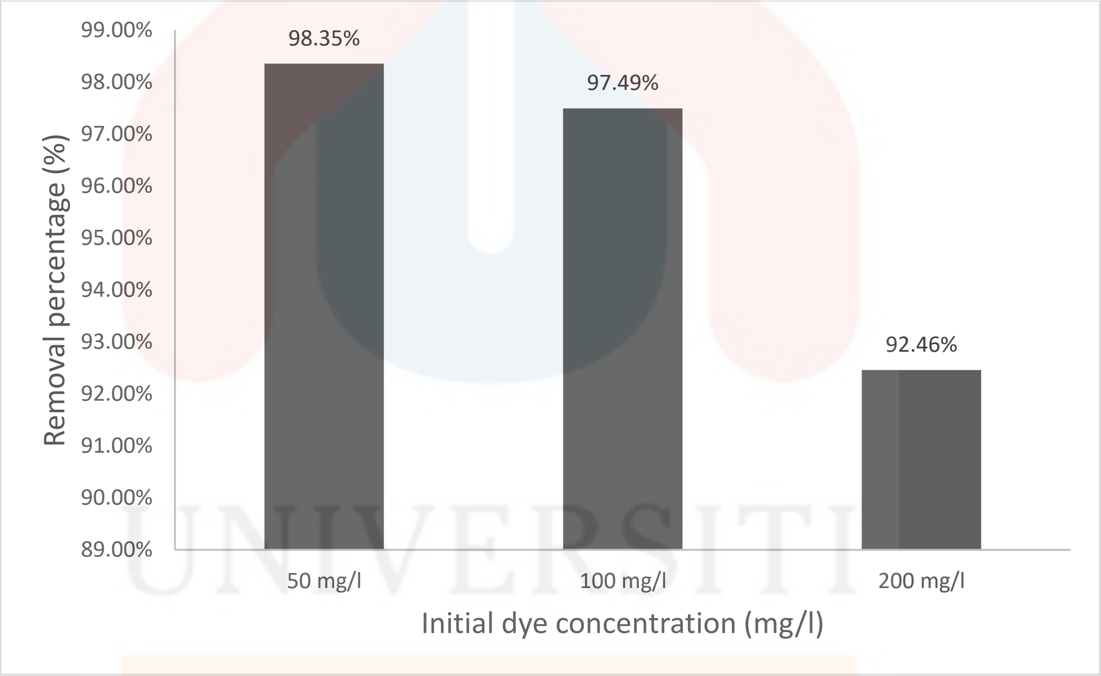


Figure 4.3: Effect of initial dye concentration based on removal percentage of methyl orange dye.

The parameter was investigated using 50 mg/L, 100 mg/L, 200 mg/L. figure above shows the graph were plotted for all the concentrations with percentage removal against constant contact time which is 30 minutes and 1 g of adsorbent dosage.

Based on figure, it shows that the biosorption decrease when the initial dye concentration increases. Furthermore, the maximal number of positively charged binding sites for adsorption was present, therefore the adsorption rate was initially fast independent of the initial concentration. The dye adsorption on the adsorbent surface was first driven by a strong force. Nonetheless, there was a reduction in the driving force and unsaturated locations. The adsorption rate was slowed as a result. (Bello & Banjo, 2012).

4.5 Contact time

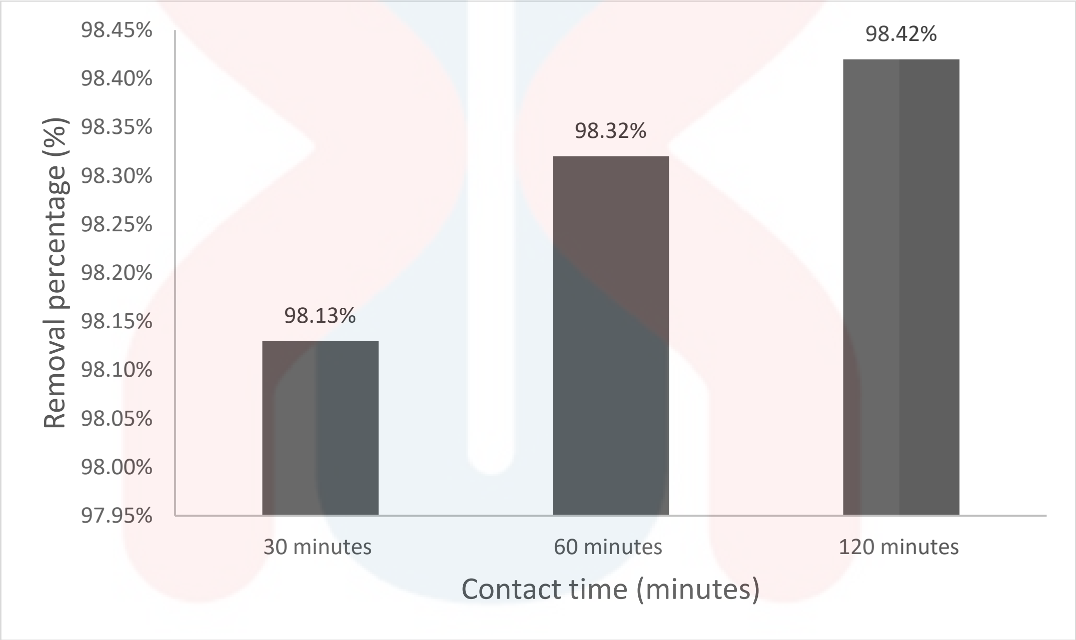


Figure 4.4: Effect of contact time based on removal percentage of Methyl orange dye.

The parameter was investigated using 1 g of adsorbent and 50 mg/l of initial dye concentration for different contact time which is 30 minutes, 60 minutes, and 180 minutes. figure below shows the graph were plotted for removal percentage against time.

Based on figure below, the removal percentage increase with increasing the time taken for the dye to adsorb. The contact time has a significant effect on the adsorption process. Additionally, contact time could alter the adsorption kinetics and the process's economic efficiency. Thus, in the adsorption process, contact time is another performance-determining element. (Srivastava, Sharma, & Sillanpää, 2015).

4.6 Characteristics of Modified Napier grass powder

4.6.1 FTIR analysis

The characterization of treated Napier grass powder was examined using Fourier Transform Infrared Spectroscopy (FTIR). FTIR was carried out for the treated Napier grass powder before and after adsorption of methyl orange as shown in figure 4.1. To determine whether functional groups were present in the FTIR spectrum, the peaks of the treated Napier grass powder were examined both before and after adsorption. The FTIR spectrum was measured with the range of 500 – 4000 cm.

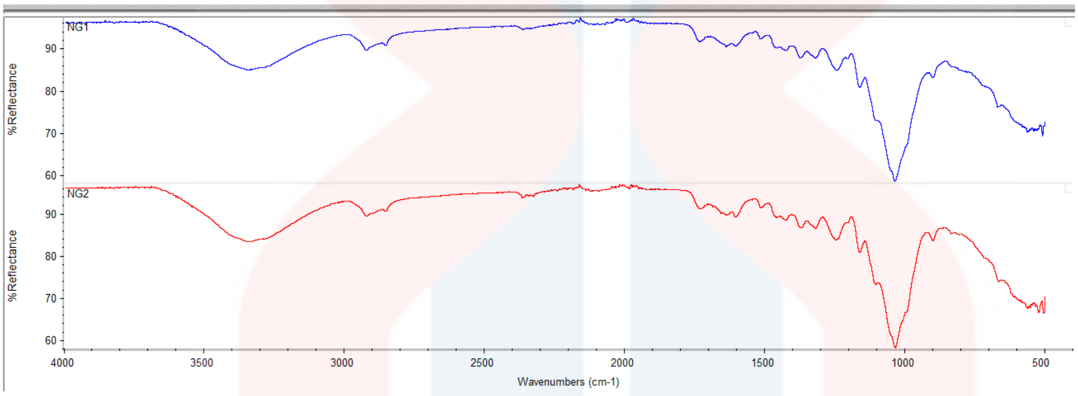


Figure 4.5: The spectrum of modified Napier grass powder before (blue line) and after adsorption (red line).

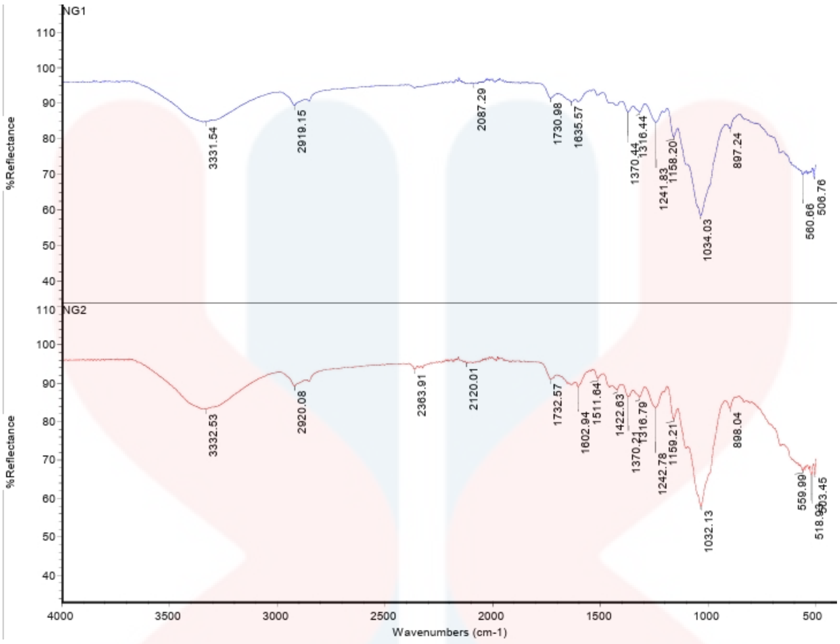
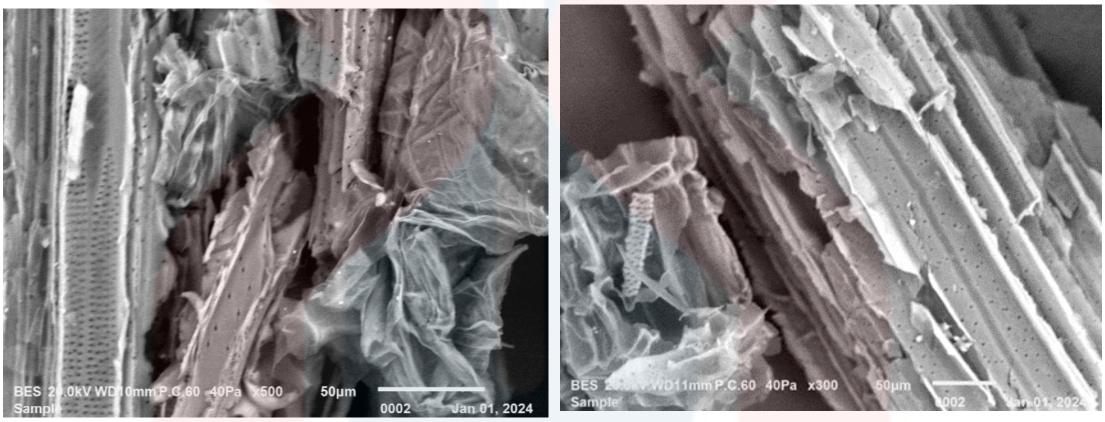


Figure 4.6: FTIR spectra with value and peaks

The peak at approximately 1600 cm-1 is probably caused by cellulose and lignin's C=O stretching vibrations. It is most likely the result of C-O stretching vibrations in cellulose and hemicellulose that cause the peak at about 1050 cm-1. The large peak in cellulose, hemicellulose, and lignin between 3000 and 3600 cm-1 is caused by O-H stretching vibrations. Following adsorption, the spectrum shows a little peak at about 1380 cm-1, which may be the result of methyl orange's N-O stretching vibrations. The peak at 3332.63 cm-1 is probably the result of O-H stretching vibrations in cellulose and hemicellulose, the two primary constituents of powdered Napier grass stem. The next peak, at 2900.08 cm-1, is associated with C-H stretching vibrations seen in cellulose and hemicellulose's aliphatic chains. The peak positions 1732.57 cm-1 and 1730.08 cm-1 are ascribed to the C=O stretching vibrations seen in hemicellulose and lignin. The C-O stretching vibrations in cellulose and hemicellulose are responsible for the peak 1241 cm-1. The C-O-C stretching vibrations in cellulose and hemicellulose have a wavelength of 1158 cm-1. This peak, at 1043 cm-1, is caused by bending vibrations in the C-H plane. Although their intensities differ slightly, the majority of the peaks found in NG 1 are also found in NG 2. This prove that the adsorption of methyl orange dye does not significantly alter the functional groups present in the Napier grass stem powder. New peaks appear at around 1540 cm-1 and 1380 cm-1. These peaks are characteristic of the azo (-N=N-) and aromatic C-N stretching vibrations in the methyl orange dye molecule. The peak at

3332.63 cm^-1 (O-H stretching) is slightly weaker in NG 2 compared to NG 1. This could be due to interaction of the dye molecules with the hydroxyl groups in the Napier grass stem powder. Inorganic phosphates: These are typically associated with minerals and salts, not with organic materials like plant biomass. While phosphorus can be present in organic phosphorus compounds, the FTIR fingerprint wouldn't likely show characteristic peaks for inorganic phosphates specifically.

4.6.2 Scanning electron microscope (SEM)



(a) (b)

Figure 4.7: (a) show the modified Napier grass stem powder before adsorption figure (b) show the treated Napier grass stem powder after adsorption.

Napier grass stem powder that has been treated with CTAB (Hexadecyl trimethyl ammonium bromide) and then adsorbed with methyl orange. CTAB is a cationic surfactant, which means it has a positively charged head group and a long hydrophobic tail. It is commonly used in detergents and cleaning products. Methyl orange is an azo dye that is commonly used as a pH indicator. It changes colour from orange to yellow in acidic solutions and from yellow to pink in basic solutions. shows the surface morphology of the Napier grass stem powder after it has been treated with CTAB and adsorbed with methyl orange. It's possible that the methyl orange molecules were adsorbed onto the CTAB molecules after the CTAB molecules adhered to the powder particle surface. This might alter the powder's surface characteristics, including its charge or wettability.

The surface in image (b) appears slightly rougher or more textured compared to image (a) This could be because the methyl orange in the first image might have filled in some of the gaps or pores on the surface, creating a smoother appearance. The current image also seems a bit brighter overall. This could be due to the absence of the orange dye, which might have absorbed some of the electrons in the scanning electron microscope (SEM) beam.

Before adsorption, the rougher texture in the pre-methyl orange image suggests a more exposed Napier grass stem powder surface. CTAB, while positively charged, might not fully coat the intricate network of cellulose fibres within the powder, leaving gaps and crevices visible under the SEM. After adsorption, Methyl orange, with its bulky aromatic structure, could act as a filler, smoothing out the surface by partially plugging the gaps and crevices. This could be due to physical adsorption. Methyl orange molecules simply adhering to the CTAB-coated surface through weak van der Waals forces. Electrostatic interactions where negatively charged methyl orange molecules attracted to the positively charged CTAB head groups, bridging the gaps between powder particles. (Shahida Hanum and Marlina, 2014).

4.6.3 Functional groups found in both samples.

Both sample Napier grass stem powder before and after adsorption of Methyl Orange dye removal has the same functional groups. Aliphatic phosphates. Like inorganic phosphates, phosphates are not common functional groups in plant biomass. If phosphorus is present, it's more likely to be in the form of phosphates or phosphonates. Primary aliphatic alcohols. These might be present in small amounts in the hemicellulose component of the Napier grass powder, but the FTIR peaks for O-H stretching would likely be dominated by the broader peak around 3332 cm-1 due to cellulose and hemicellulose combined. Aliphatic hydrocarbons. The C-H stretching peaks around 2900 cm-1 suggest the presence of aliphatic chains in both spectra. These are common in cellulose and hemicellulose. Cellulose and hemicellulose. These polysaccharides are the main components of plant biomass and contribute to the characteristic FTIR peaks observed in both samples.

Table 4.2: infrared spectroscopy adsorptions by frequency regions.

Source: (Libre text chemistry, 2014)

600-500	Strong	C – l	Bending	Halo compound
850-550	Strong	C – Cl	Stretching	Halo compound
1400-1000	Strong	C – F	Stretching	Fluro compound
3400-3300	Medium	C = O	Stretching	Aliphatic primary amine
3000-2800	Strong, broad	N – H	Stretching	Amine salt
2260-2190	Weak	CΞC	Stretching	Alkyne
1740-1720	Strong	C = C	Stretching	Aldehyde
1070-1030	Strong	S = O	Stretching	sulfoxide
1210-1163	Strong	C – O	Stretching	Ester
3000-2800	Strong, broad	N – H	Stretching	Amine salt
690-515	Strong	C – Br	Stretching	Halo compound

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

As a conclusion, this research proved that the Napier grass stem treated with hexadecyl trimethyl ammonium bromide has ability to remove methyl orange dye. The functional groups of the Napier grass stem treated with hexadecyl trimethyl ammonium bromide was identified by conducting physical characterisation using Fourier Transform Spectroscopy (FTIR). This research has proved that agricultural waste like Napier grass stem can be used as adsorbents for dyes removal. The removal of methyl orange dye was carried out using adsorption method, which is known as simple, ecofriendly cost-effective way.

First and foremost, all the percentage of dye removal increased with the increased in the dosage of adsorbent. It was found that 1 g adsorbent which is Napier grass stem powder was optimum for the removal of methyl orange dye. Next, for the effect of initial dye concentration, 50 mg/L was optimum initial dye concentration for methyl orange dye. The results showed that the lower the initial dye concentration, the higher the percentage of dye removal.

Then, for the final parameter, which is the effect of contact time, a graph was plotted with percentage removal of dye against time to identify the optimum pH value. It was observed that the maximum removal or methyl orange dye is 98.42% after 120 minutes. thus, the time which is 120 minutes was chosen as the optimum time for the removal methyl orange dye from aqueous solution using treated Napier grass stem.

5.2 Recommendations

There are some recommendations that can improve this study. Firstly, the physical characterization of raw Napier grass stem using Scanning Electron Microscopy (SEM) should be done. This is because, from the result I can observe the changes in morphology characterization before and after been treated with Hexadecyl trimethyl ammonium bromide. Apart from that, BET should be done also to know the surface area of the Napier grass stem powder.

So, for the techniques to separate the adsorbent from the solution it is better to use centrifugation rather than filtration. Centrifugation is mostly used to separate particulates from a liquid solution or slurry quickly and effectively. Because centrifugation techniques use powered machinery, the separation process is quicker and more effective.

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APPENDIX A

A.1: Calibration curve at 464 nm

Concentration (mg/L)	**Absorbance Reading**			**Average Reading**
	1	2	3	
0.5	0.005	0.003	0.003	0.004
1	0.17	0.15	0.014	0.011
8	0.463	0.461	0.460	0.461
15	0.878	0.879	0.879	0.879
20	1.205	1.205	1.204	1.205

A.2: Adsorption of Methyl Orange on different adsorbent dosage

Adsorbent dosage (g)	R1	R2	R3	Average reading	Percentage removal (%)
0.5	0.011	0.011	0.011	0.011	98.42%
1	0.010	0.009	0.009	0.009	98.45%
2	0.033	0.033	0.033	0.003	97.71%

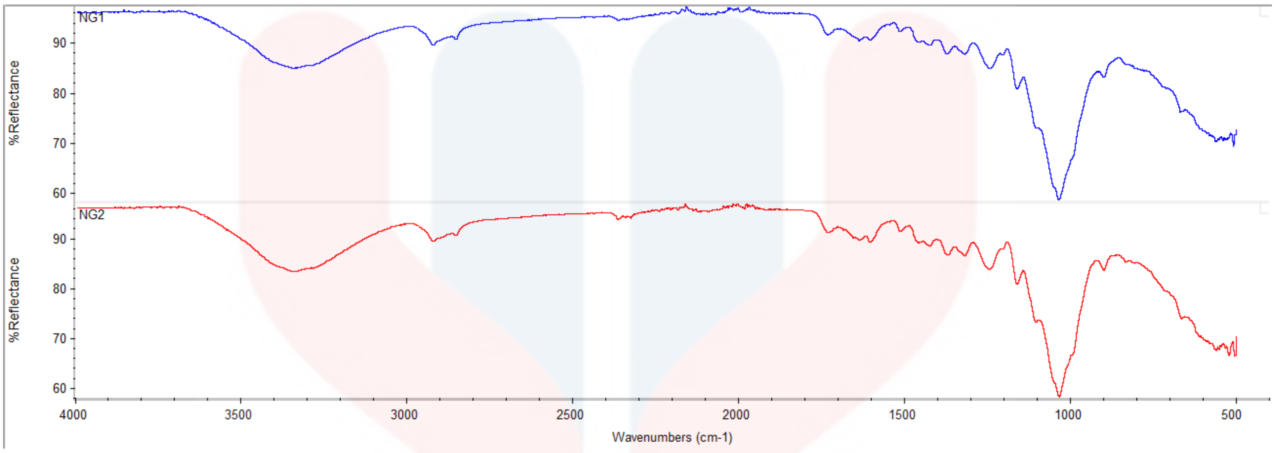
A.3: Adsorption of Methyl orange on different initial dye concentrations.

Initial dye concentration (mg/l)	R1	R2	R3	Average reading	Percentage removal (%)
50	0.013	0.012	0.012	0.012	98.35%
100	0.117	0.117	0.117	0.117	97.49%
200	0.894	0.891	0.892	0.892	92.46%

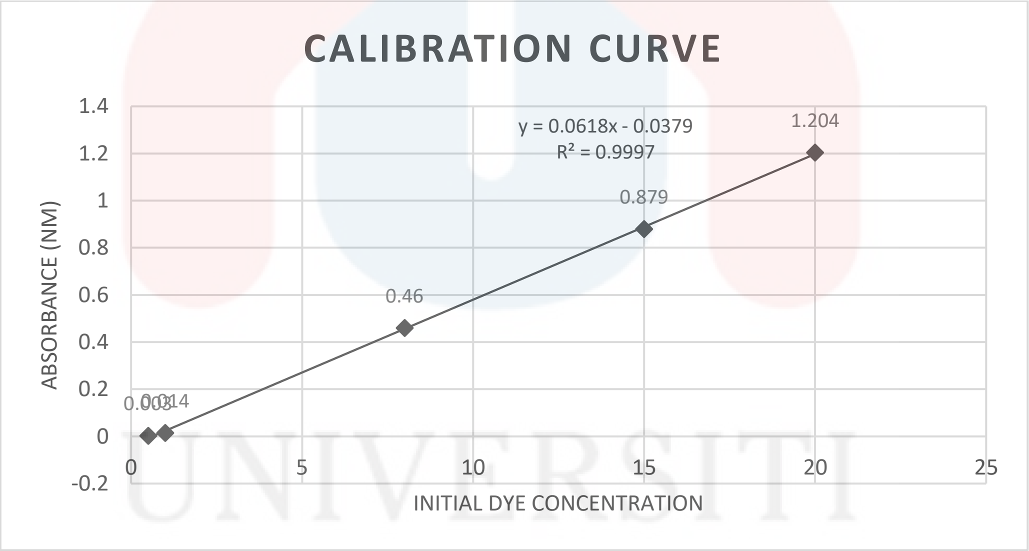
A4: Adsorption of Methyl Orange on different contact time

Contact time (minutes)	R1	R2	R3	Average reading	Percentage removal (%)
30 minutes	0.020	0.018	0.019	0.019	98.13%
60 minutes	0.014	0.012	0.013	0.013	98.32%
120 minutes	0.011	0.011	0.010	0.011	98.42%

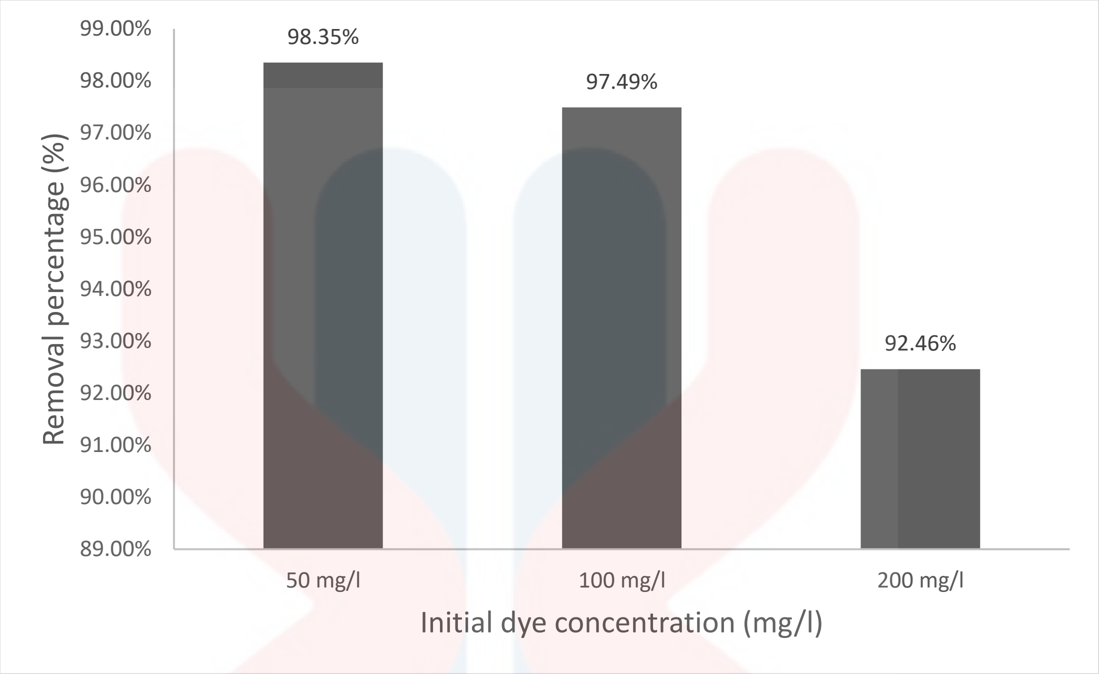
APPENDIX B



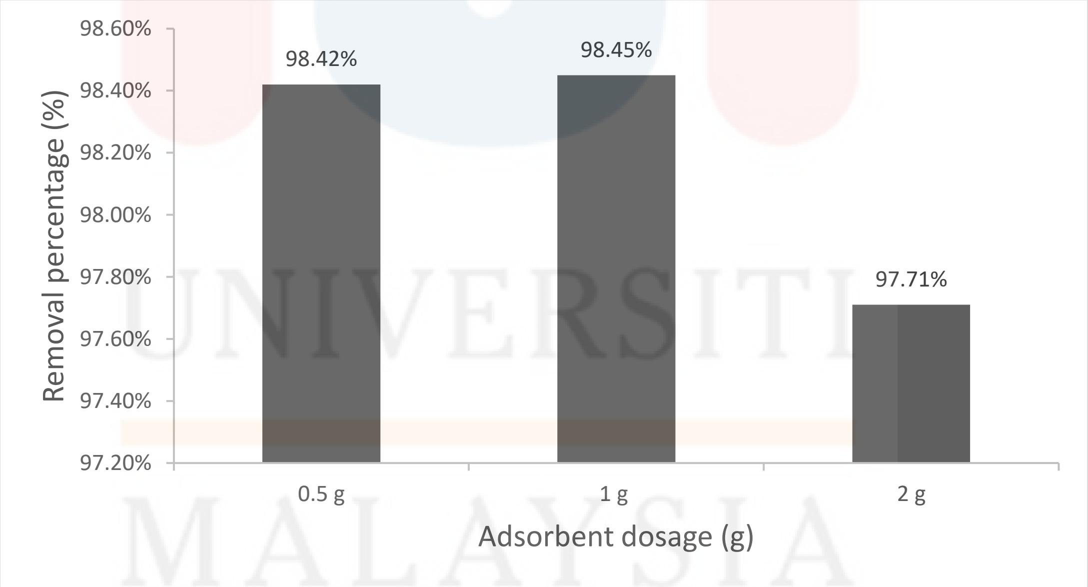
B1: the spectrum for Napier grass stem powder before and after adsorption of methyl orange



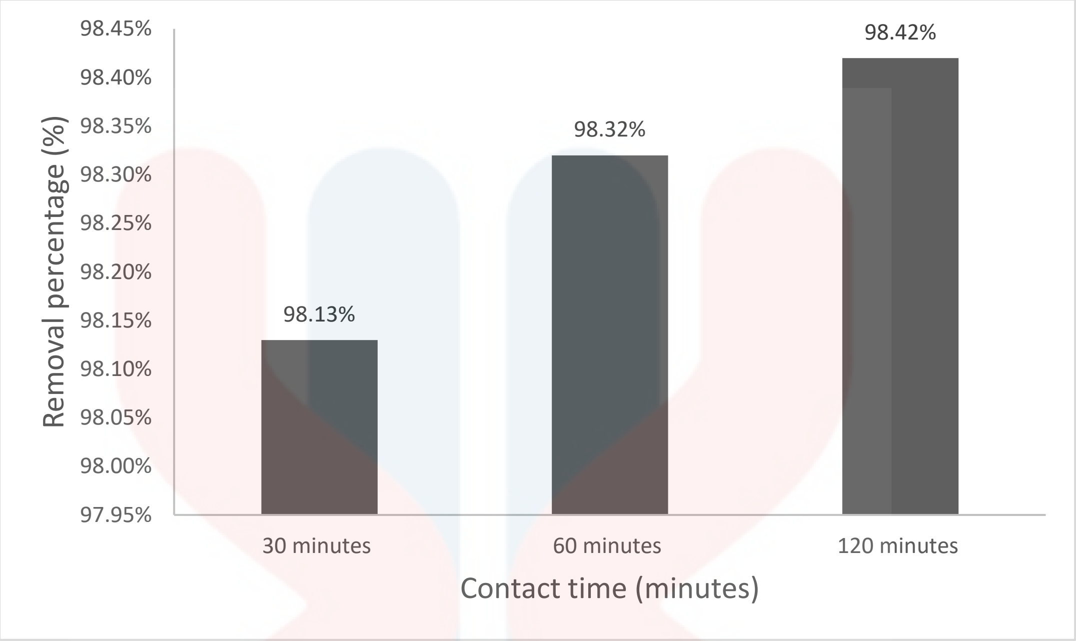
B2: the calibration curve of methyl orange dye at 464 nm



B3: removal percentage of adsorption of methyl orange on different initial dye concentration



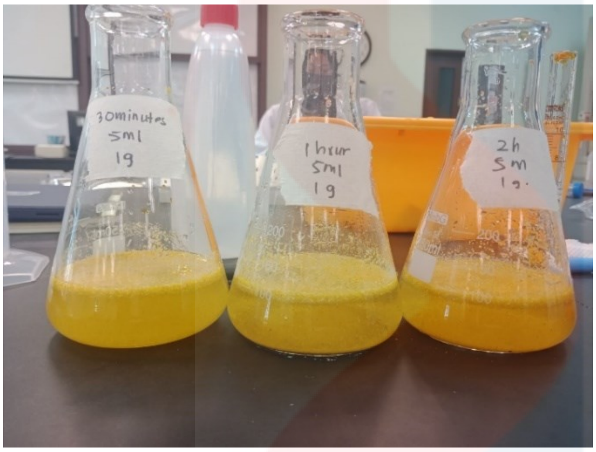
B4: removal percentage of adsorption of methyl orange on different adsorbent dosage



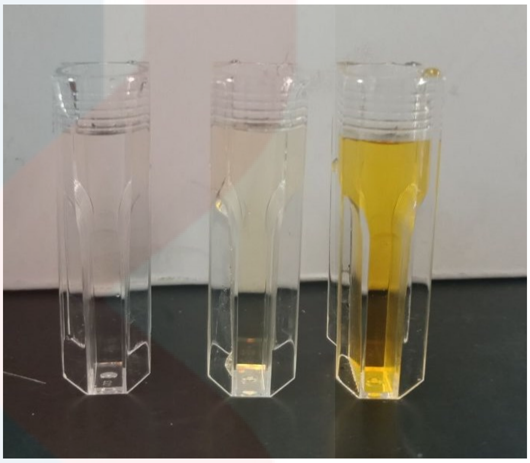
B5: removal percentage of adsorption of methyl orange on different contact time

APPENDIX C

C1: Effect of adsorbent dosage

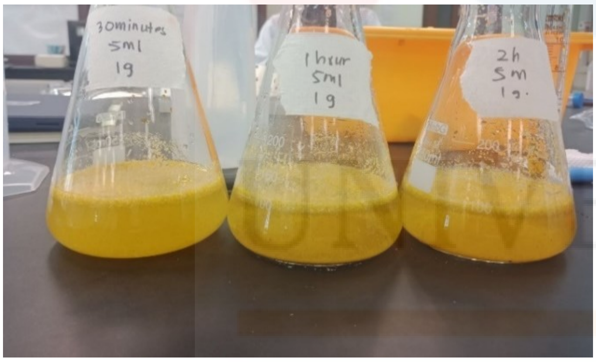


Before adsorption

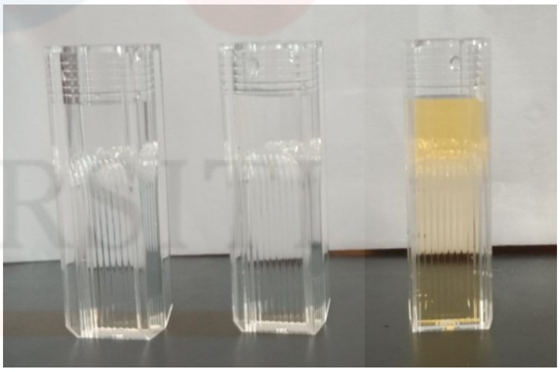


After adsorption

C2: Effect of initial dye concentration

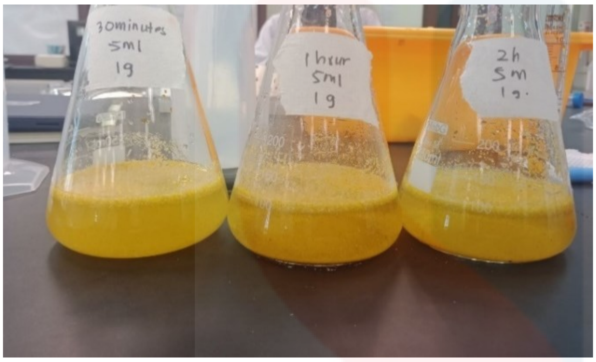


Before adsorption

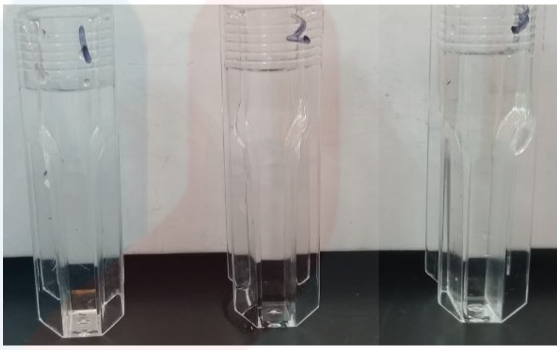


after adsorption

C3: Effect of contact time



Before adsorption



after adsorption