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Extraction of Chitosan and its Application on Removal of Dyes from Wasted Water

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Abstract

Chitosan is the most widespread bio polymer available in nature. Chitosan has economic value because of its biological activities, industrial and biomedical applications. In the present study, Chitosan polymer was obtained by deacetylation of Chitin, It was created by applying on alkaline Chemical like sodium hydroxide to the chitin shells of Shrimp. The chitosan Polymer was characterized by elemental and spectral analysis to confirm its structure. Chitosan based adsorbent has received a lot of attention for adsorption of dyes as the textile anionic Remazol red (RR) dye and malachite green dye from aqueous solution. Chitosan resulted in more efficient removal of (RR) dye (100%) than malachite green at certain condition. The kinetic study results were best fitted by pseudo-Second-order kinetic model.

Key Words:

Chitosan, adsorption, Remazol red (RR), Malachite green and kinetic models.

1. Introduction:

Chitosan, which makes up the majority of crustaceans' exoskeleton, is recognized as the most abundant and affordable biopolymer (Kurita K.2006) found in nature. Chitosan, poly-(1, 4)-2-amino-2-deoxy-b-D-glucose, is a high molecular weight polysaccharide that is biocompatible, biodegradable, heterogeneous, linear, cationic, and nontoxic (Zivanovic et al. 2007). Also, Chitosan contains about 6.9% nitrogen, which functions as a chelating agent as compared to other polysaccharides. For these reasons, it finds extensive applications in the pharmaceutical, medical, and agricultural industries (Geyse A. C. R. et al. 2017). In comparison to other polymers, it is thought that chitosan (Mina K. et al. 2021), has a significant role in the sorption of organic molecules such as proteins, metal ions, biphenyls, polychlorinated biphenyls, and phenols (Rabea EI 2011). This is due to the hydroxyl and amino groups in the polymer chains (Cestari A. R. et al. 2004), serving as the sites of electrostatic interaction and coordination (Attwood M.M.& Zola H. 1967).

Respectively, Chitosan (Saud et al. 2019). has a wide range of creative uses in water purification (SpoialăA. et al. 2021) that solve the problems of water pollution around the world (El-Harby et al. 2017). For example, chitosan-based hydrogels have been studied in detail due to their high capacity to adsorb water, (Mohammed F. et al2023) and contaminants, which makes them excellent for purifying and treating water (Diaconu2015). The bioavailability, biocompatibility, biodegradability, and environmental friendliness of these hydrogels are highly appreciated (Dhar B.R.2023). Chitosan-based hydrogels' synthesis procedures and structural properties are altered to boost their water filtering efficiency. It has been shown that incorporating nanomaterials like graphene, metal-organic frameworks, and nanoparticles into the hydrogels enhances their capacity to extract heavy metals, organic contaminants, and microorganisms from water sources (Zaldivar-Dίaz 2023).

Furthermore, due to its active amino (-NH2) and hydroxyl (-OH) groups, which are reactive adsorption (Mohammed F. et al. 2023), sites for a range of organic and inorganic water contaminants, chitosan has recently attracted a lot of attention for its potential uses in wastewater and water treatment technologies (Saud et al. 2019). These applications can enhance the material's adsorption capacity or adsorption kinetics, (Ratnamala, G., &Brajesh K. 2013) and effective adsorbents for wastewater filtration (Wan Ngaha et al. 2011), by increasing the sorbent's affinity and changing the sorption's selectivity (Tanhaei et al. 2016)

On the other hand, chitosan proves especially effective in absorbing negatively charged dyes in acidic conditions due to its protonated amine groups. Also, Chitosan has been used as a green cross linker by the formation of covalent bonds (Yang et al. 2016). According to Abd Malek et al. (2020), chitosan is a cationic polymer with hydroxyl and amine groups that serve as active adsorption (Murcia-Salvador A. er al.2019) sites to extract impurities and colors from water. and investigate the ability of chitosan to remove Remazol red (RR; RB-133) dye.

Adsorption is one of the most popular methods for eliminating color from wastewater (Amtul J. S., Yasha N. B. & Sitara N. 2018) due to its selectivity, efficiency, cheap operating costs, and absence of toxic byproducts (Abd Malek et al. 2020). A variety of adsorbents, such as alumina, broken bricks, peat, sand, charcoal, silica, apricot, etc., are used to remove colors from aqueous solutions (Nargish et al. 2013). Adsorption, filtration, and antibacterial activity are the three processes (Badawy A. A. et al.2019) by which chitosan purifies water; these processes are essential to guaranteeing the supply of clean water (Chelu M. 2023). These processes demonstrate Chitosan's ability to develop environmental protection (Demarchi C. A. et al.2015). and water purification technologies.

In recent years, the global community has witnessed a growing concern over environmental pollution, particularly in the realm of wastewater management (Nargish et al. 2013). As industries expand and populations burgeon, the demand for effective and sustainable wastewater treatment methods becomes increasingly imperative. Industrial dye wastewater from the production of textile printing and dyeing, food, paper, plastic and other products (Elham B. A. Alireza B. & Jahan B. G. 2019). has caused serious health and environmental pollution due to its obvious bright colors, high toxicity and difficult decomposition processes(Laka M.et al.2006). Most organic dyes are toxic, carcinogenic and mutagenic to human health and marine life due to the presence of aromatic rings in their structure, low biodegradability, high toxicity and high stability against photo degradation. In this regard, controlling this sort of liquid waste is challenging. (Shaimaa M. Ibrahim*, Hany M. Hassanin, and Marwa M. Abdelrazek ,2020)

A number of processes are used to purify wastewater containing dyes, but most of these processes require appropriate conditions and are expensive to operat (HuanhuanM. et al.2018). Adsorption has proven to be a very promising method for removing textile dyes(Chelu M. 2023). from wastewater. The adsorption process is an effective, cost-effective, simple, efficient and non-reactive separation technology with toxic substances (Ahmed R., Inas A.& Dina B. 2019). This kind of water is treated in several ways, including intricate mixes of physical, chemical, biological, and biological procedures (Elbadawy A. K..2016). It was found that physical treatment which includes membrane, filtration, and adsorption processes was the most effective.

In addition to the world population's rapid growth, industry, unplanned urbanization, agricultural methods, and chemical misuse have all contributed to environmental contamination (Gupta, 2009). Organic and inorganic wastes produced by Human activity is the cause of high amounts of polluted water (Fatima-Zahra B. et al. 2019), which puts human health and the health of other living creatures in jeopardy (Ceyhan &Baybas 2001). Between 40 L/kg and 65 L/kg of the product, wastewater is typically generated in huge volumes fast at each stage of the textile process, making the textile industry one of the main generators of industrial waste, along with other dyeing industries like paper, printing, leather, food, and plastic. (Mezohegyi ,van der Zee 2012). In aquatic environments, low dye concentrations can reduce photosynthetic activity since they are easily noticeable and can prevent light and oxygen from penetrating the system (Crini 2006). Dyes (Haytham Bouammali a.et al.2023), are substances that are not biodegradable and retain their stability in a range of conditions due to their complex aromatic components and synthetic origin (Buthelezi, Olaniran, & Pillay 2012). Furthermore, dyes have both direct and indirect harmful effects on people due to their associations with mutations, cancer, jaundice, tumors, skin irritation, allergies, heart difficulties, and other conditions (Alver & Metin 2012) and (Hariharasuthan, Rao, & Bhaskaran 2013).

Understanding the origin, composition, and creation process (Ponnusami V. et al.2008) of wastewater is essential to removing dyes from it and improving the quality of treated wastewater returned into the environment. Numerous treatment techniques have been used to remove contaminants from wastewater at trace levels. Chemical precipitation (Kurniawan Chan

Lo & Babel 2006), flocculation/coagulation (Chafi, Gourich, Essadki, Vial&Fabregat 2011), electrochemical reaction (García-Gabaldón, Pérez-Herranz, García Antón, &Guinon 2006), and electro-dialysis (Mohammadi, Razmi &Sadrzadeh 2004) are among the several methods available. However, there are a number of disadvantages to all of these approaches, such as high initial or ongoing expenditures, low efficiency, and the creation of excess sludge.

Some of these methods (Bishir Usmanaet al.2021), are inappropriate for use by small businesses (Kobya, Demirbas, Senturk & Ince 2005). while Adsorption is preferred over alternative methods because it is rapid, simple to apply, and opaque to toxic compounds. Additionally, the treatment unit produces innocuous byproducts, can be easily constructed and maintained, and requires little initial investment. (Abbasi &Alikarami 2012; Yadla, Sridevi & Chandana Lakshmi 2012).

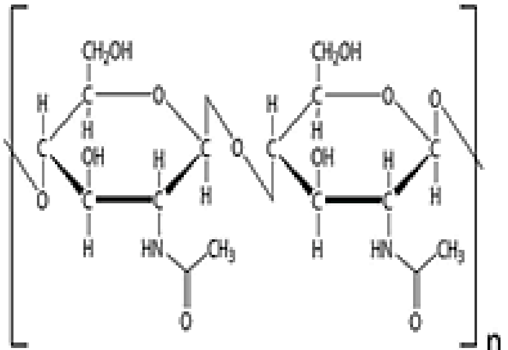


Fig.1

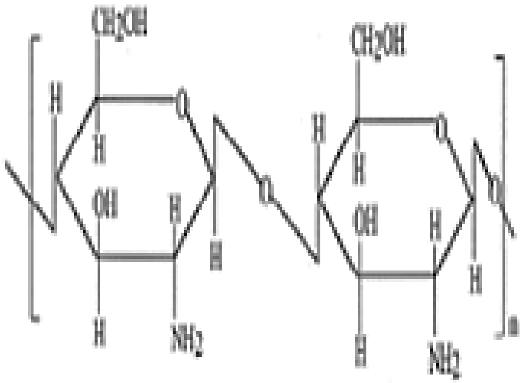


Fig. 2

On the other hand, The nature and type of the adsorbent affect adsorption efficiency. Both organic and inorganic materials could be used as adsorbents to remove dyes, Agricultural solid wastes (Wang, Zhou, Jiang & Sun 2008), clays (Öztürk &Malkoc 2014), peat (Fernandes, Almeida, Menezes, Debacher& Sierra 2007), zeolites (Alver & Metin 2012), silica gel (Gaikwad & Misal 2010), industrial by products, actuated carbon (Guibal, McCarrick, & Tobin 2003) and alumina (Iida, Kozuka, Tuziuti& Yasui 2004), zeolites (Alver & Metin 2012), and polysaccharides (Saha et al. 2011). The ideal adsorbent for dye removal, according to Crini and Badot (2008), has a large surface area, a high adsorption capacity, suitable pore size and volume, easy accessibility, cost-effectiveness, mechanical stability, compatibility, ease of regeneration, environmental friendliness, high selectivity to remove a wide range of dyes and low processing procedure requirements (Hariharasuthan, Rao, & Bhaskaran 2013).

So, Researchers have recently focused on developing materials based on natural polymers, including chitosan, to produce alternative adsorbents with improved adsorption capacity without sacrificing their low cost (Wan Ngah, Teong&Hanafiah 2011) and (Acosta N, Jimenez C., Borau V., Heras A. 1993).

Based on the aforementioned, the current work's goal is to investigate chitosan's capacity for the adsorption process, which necessitates the usage of many distinct catalysts. To address this issue, scientists and environmental engineers have developed innovative solutions. One such option is the usage of chitosan, a biopolymer derived from chitin, a naturally occurring polysaccharide that is extensively present in the shells of crustaceans, such as shrimp and crabs.In the present study, we investigate the use of chitosan in the removal of malachite green and Remazol red dyes from aqueous solutions, assessing its efficacy in pollutant removal. We hope to further sustainable wastewater management techniques and, in the process, create a cleaner, healthier environment for current and future generations by utilizing the special qualities of chitosan.

2. The Theoretical Framework

The majority of the exoskeleton of crustaceans is composed of chitosan (Feng, T. et al. 2011), which is acknowledged as the most prevalent and reasonably priced biopolymer in nature. Poly-(1, 4)-2-amino-2-deoxy-b-D-glucose, or chitosan, is a high molecular weight polysaccharide with a wide range of uses in pharmacology, medicine, and agriculture. It is nontoxic (Zivanovic et al. 2007), heterogeneous, linear, cationic, biocompatible, and biodegradable (Jiménez-Gómez C.P. et al. 2020). Its 6.9% nitrogen concentration, which acts as a chelating agent in relation to other polysaccharides, enables the biomedical, pharmaceutical, and wound healing industries to use it for a range of applications (Blackburn, R. S. 2004).

Chitosan (Aranaz I. et al. 2021) has a unique structure because of the presence of active amino (-NH2) and hydroxyl (-OH) groups, which are reactive adsorption sites for a range of organic and inorganic water pollutants (Saud et al. 2019).Chitin's deacetylation produces a free -NH2 group that helps chitosan be modified to produce different Schiff bases by reacting with different aldehydes and ketones (Manimohan et al. 2019).Chitosan reportedly possesses antioxidant qualities because of its capacity to bind metal ions and scavenge free radicals, which prevents hydrogen (Salama, H. E., Saad, G. R. &Sabaa M. W. 2015), from being supplied. Appropriate oxidation is essential for the production of energy organisms, which drives biological processes (Jiang H.et al .2013).
Nevertheless, a number of serious illnesses, including cancer, ischemic injury, rheumatoid arthritis, myocardial infarction, Alzheimer's and Parkinson's disease, and atherosclerosis, are brought on by excessive oxidative stress, which is the outcome of an imbalance between the antioxidant defense system and the unchecked generation of free radicals (Adhikari H. S.& Yadav P. N. 2018).

Free radical scavengers, or antioxidants, have the ability to improve and prevent disease in both people and animals. Still, there is a possibility that some artificial antioxidants (Tanhaei B. et al. 2016) cause liver damage and perhaps cancer. Because there is a much lower chance of harmful byproduct formation when using biocompatible and nontoxic natural antioxidants than when using some synthetic antioxidants, replacing harmful antioxidants as preventive and therapeutic agents is of great interest to the important application in the pharmaceutical, cosmetic, and food fields (Pu et al. 2019). Since cancer (Adhikari H. S.; Yadav P. N. 2018) is one of the leading causes of mortality worldwide, extensive study has been concentrated on developing more effective anticancer medication development tactics for a number of decades. In spite of this, there are still few clinical intervention choices for many kinds of human cancers (Santosh K. et al 2014).

Chitosan and its derivatives have garnered significant attention recently from the pharmaceutics industry (Truong,Thi Cam,Trang,Kobayashi andTakaomi2020) because to its non-immunogenicity, biodegradability, biocompatibility, and lack of toxicity. In contrast (Wang et al. 2009) reported that the anticancer activities of chitosan oligomers depend on their molecular size and charge properties in addition to their chemical structure.

Chitoligosaccharides (COS) derived from chitosan or chitin were demonstrated to exhibit anticancer activity at the beginning of the 1970s. Eventually, it was recognized that these chemicals' apparent anticancer effects are also significantly influenced by their molecular weight. The cationic property that amino groups exert is the main reason this activity was first postulated. Moreover, it is thought that the immune-stimulating property of COS is probably responsible for these activities because N-acetyl-chitohexose, which is not cationic, also possesses anticancer properties.

It is imperative to employ therapeutic chitosan-based compounds that exhibit little toxicity towards non-cancerous cells. Chitosan has been categorized by the US Food and Drug Administration (FDA) as a nontoxic and biocompatible polymer for use in wound dressings, with generally recognized as safe (GRAS) designation (Adhikari & Yadav. 2018). Furthermore, food packaging can make use of chitosan's film-forming capabilities, which helps to increase shelf life and decrease food waste.

Chitosan is a versatile biopolymer generated from chitin that is becoming more and more well-known due to its biocompatibility, biodegradability, and non-toxicity, making it a prime option for multiple uses in medicine, agriculture, and industry (XingY. et al 2007). Due to its distinct chemical structure, chitosan, the second most abundant natural polysaccharide, can interact with a variety of biological components and provide a platform for novel approaches in wound healing and medication administration, among other applications (Aider M. 2010). Tissue Engineering: According to (Riva et al 2011), chitosan acts as a scaffold in tissue engineering, encouraging cell proliferation and regeneration. Further, because of its advantageous effects on weight loss and lowering the absorption of fat, chitosan is a prominent element in numerous nutritional supplements and pharmaceuticals, (Xiya Yang et al. 2022) such as Diet-One, Fitochitosan, and Delfat.

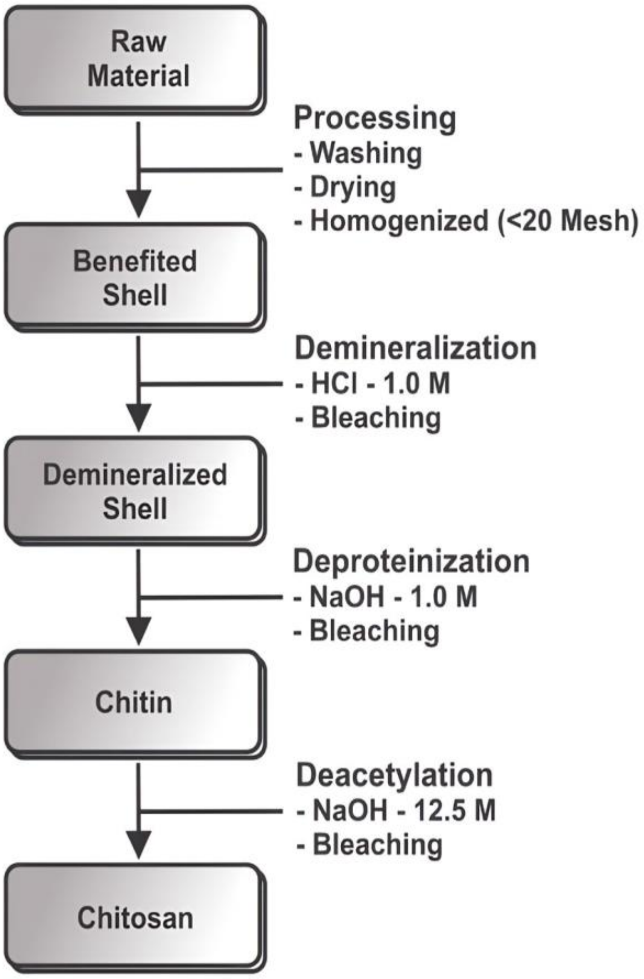
Chitosan is a versatile ingredient in skin care products that can be found in many different formulations, including: Chitosan is utilized in moisturizing creams because of its capacity to establish a protective layer on the skin and its hydrating characteristics. Face masks: To improve skin texture and moisture, some face masks include chitosan (Aflakseir A. 2021).

Chitosan is included to anti-aging treatments (Xiaoxiao J. et al. 2009) because of its ability to increase the formation of collagen and minimize the appearance of wrinkles. Acne Treatment Products: Because of its antimicrobial qualities, it is used to treat acne and possibly lessen inflammation. Skin peeling preparations: To improve the elimination of dead skin cells and soften the skin, chitosan can be added as an ingredient (Ba R.E.S. 2020) such as various medications for hair healing (AranazI.et al.2021).

Numerous biological characteristics of chitosan, including its antibacterial activity, which is essential in medical applications, are based on its cationic nature. Moreover, controlled drug release systems are made possible by chitosan's capacity to form films and gels, which presents a viable way to increase therapeutic efficacy (Aider M. 2010).

Chitosan has been considered as a promising applicable biomaterial in the area of biomedical engineering, food packaging, cosmetics, and agriculture, in view of its good biodegradability, biocompatibility, nontoxicity, and film forming properties (Tan et al. 2019).

Chitosan also exhibits antioxidant activity and, could be used as a replacement for synthetic antioxidants such as butylated hydroxyl toluene (BHT), butylated hydroxyl anisole (BHA), and tert-butyl hydroquinone (TBHQ). One important mechanism of antioxidation involves scavenging of hydrogen radicals. DPPH (2,2-diphenyl-1-picrylhydrazyl) has a hydrogen-free radical with a characteristic absorption at 517 nm, allowing its detection as the purple color of the DPPH solution fades rapidly when it reacts with proton radical scavengers (Jimenezet al.2020) The DPPH radical scavenging activity of WSC, COS, and ascorbic acid is shown in figure 4. At 1 mgmL¹, all chitosan products exhibited the highest scavenging ability. The scavenging ability proved to be dose dependent (Avelelas et al. 2019).



3. Experimental

3.1. Chemicals

Source of Chitin (Shells from shrimp) / Hydrochloric acid / Sodium hydroxide / Glacial acetic acid / Distilled water / Filter paper / PH meter

We bought Malachite green and Remazol red (RB-133) from Sinopharm Chemical Reagent Company Limited. Every reagent was analytical grade and used exactly as supplied. Every preparation utilized distilled water.

3.2. Extraction of chitosan

1. To extract chitin, shrimp shells were isolated and gathered from several locally accessible sources. The chitin was then cleaned, dried in the sun for four days, and then demineralized and deproteinized.

2. A diluted HCl solution was used to carry out demineralization. Therefore, several methods of treatment were applied to the chitin resources that were acquired. To demineralize the shrimp shell, 1.0 M HCl was used. After that, the solid was thoroughly cleaned of any remaining acid by washing it in distilled water. The materials that had been demineralized were then dried (Sagheer et al. 2009).

3. At room temperature, 0.5 N NaOH was used to deproteinize chitin for eighteen hours. Following multiple sample treatments, the sample's complete deproteinization was ultimately demonstrated by the solution's lack of color, even after being left undisturbed for a whole night. Following the chitin's extraction from the liquid medium, the sample was neutralized by repeatedly washing it in distilled water. Following that, dried chitin that has been purified (Liu et al.2012).

4. Chitin's deacetylation becomes chitosan In order to conduct preliminary studies, chitin was refluxed in a strong NaOH solution under standard atmospheric conditions. Low Deacetylation content was produced after more than 20 hours of experimentation, and the reaction was accompanied by a sharp degradation of the final chitosan. The refluxing was carried out in an alkaline solution to prevent prolonged heating durations. Even after several hours of heating (five to six hours), the resultant chitosan showed only a partial solubility in acetic acid, suggesting a low degree of deacetylation (Abdou et al. 2008). According to Kurita (2006), the deacetylated solid is filtered, collected, and

then cleaned with distillate water before being dried to produce chitosan.

3.3. Preparation of dye solution

Remazol red (RB-133) and malachite green (10-2M) were dissolved in 25 millilitres of distilled water to create a stock solution. Dilution was used to create the concentration—10 ppm—that was required for the experiment.

3.4. Adsorption experiments

The adsorption of Remazol red (RB-133) and malachite green dye from aqueous solution onto chitosan was investigated in batch tests. In every experiment, 10 ppm dye solution was mixed with a fixed amount of adsorbent (100 mg), agitated at 150 rpm, and the temperature was kept constant until equilibrium was reached. A sample of dye solution was separated at different intervals, centrifuged for 15 minutes at 7000 rpm, and the absorbance measured at 520 and 612 nm for Remazol red (RB-133) and Malachite green, respectively, using a UV–vis spectrophotometer (Jasco V-550, Japan) at λ ranging from 400 to 800 nm to determine the concentration of the non-adsorbed dye. Then, the % amount of the dye on the adsorbent and the adsorption capacity can be estimated, and their equations as the following :

q_e(mg/g) is the amount of adsorption at equilibrium time t, and is calculated by

$q_e = (C_0 - C_e) \times V/W$ ……………………….(1)

Where C_0 and C_e (mg/L) are the concentrations of dye at t=0 min and at equilibrium time, respectively; V is the volume of dye solution (L); W is the mass of dry adsorbent used. Study of kinetics were obtained and measured at different time from 0 to 60 min.

The adsorption process was carried out at (293K or 20 °C) and pH = 7. The adsorption amount at time t, qt (mg/g), is calculated by the following equation:

$q_t = (C_0 - C_t)V/W$ ……………………………(2)

The removal percentage of dye (R%) was calculated by eq. (3):

$\% R = \frac{Co-Ct}{Co} x100$ ……………………………..(3)

4.Results and Discussion

4.1. Results of IR

Characterization of the prepared Chitosan. The FT-IR spectra of Chitosan was illustrated in Fig.3. The spectra of Chitosan Showed the Characteristic absorption.

Peak of OH and NH_2 at 3,361 and 3,291 Cm^{-1}. The peaks at 2,921 and 2,877 Cm^{-1} are attributed to C-H Stretching vibration. The characteristic absorption Peaks of NH, $-CH_3$ and the second hydroxyl absorption peak (OH) happen at 1,645 – 1,423 – 1,325 respectively.

This suggests the formation of inter- and intra-molecular hydrogen bonds in the presence of free amino groups Chitosan.

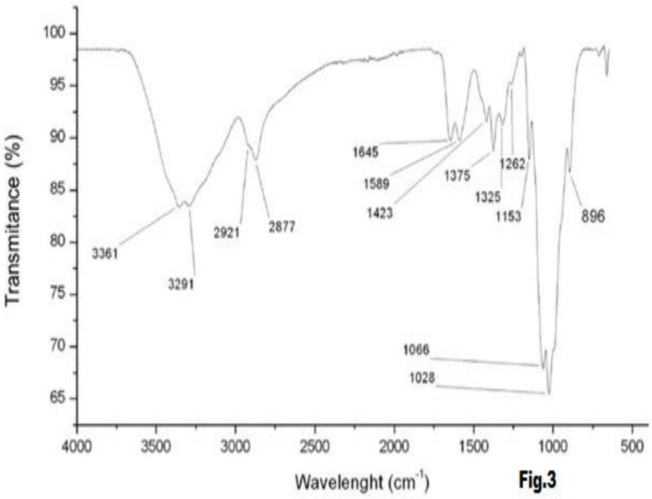


Fig.3

4.2. Adsorption of Dyes studies

Fig.4 (a,b) shows that equilibrium was started in a short time (%R completed in 40 minutes) with a dose of chitosan = 0.1 g. So far, dye removal was rapid (%R ~ 100%) and remained constant with increasing time. The initial increase in % of removal may be due to a large number of free sites; over time, the number of active sites decreased, causing the adsorption rate to decrease.

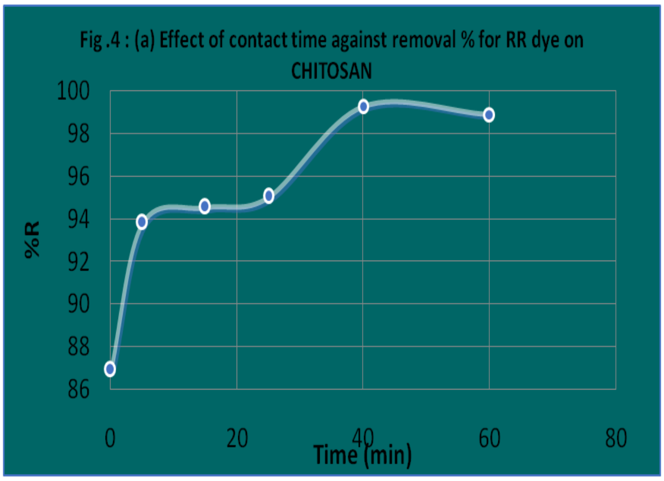


Fig.4 : (a) Effect of contact time against removal % for RR dye on CHITOSAN

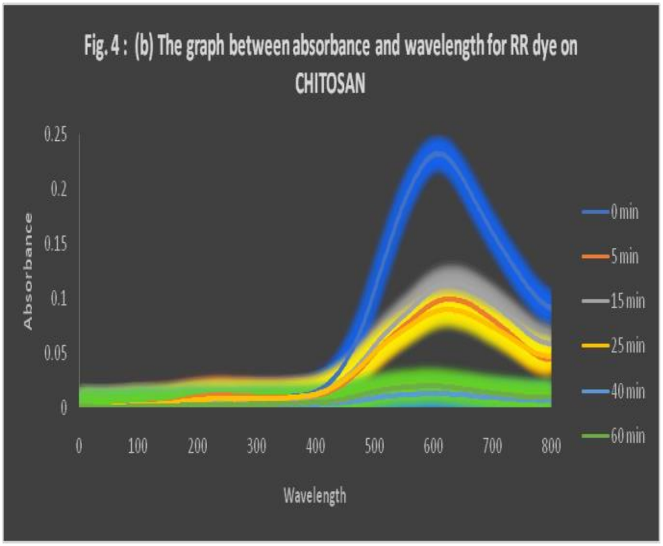


Fig. 4 : (b) The graph between absorbance and wavelength for RR dye on CHITOSAN

Conversely, as in Fig. 5 the chitosan less absorbed the Malachite green. This result refers to the high efficiency of the prepared modified polymer toward RR dye removal comparing with Malachite green.

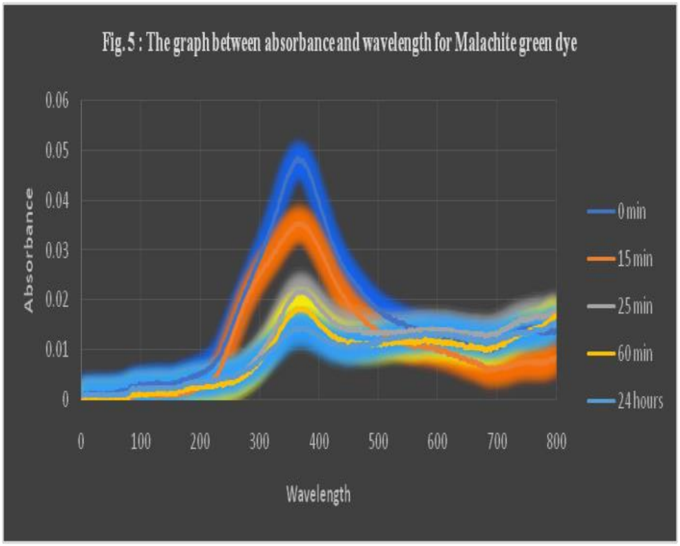
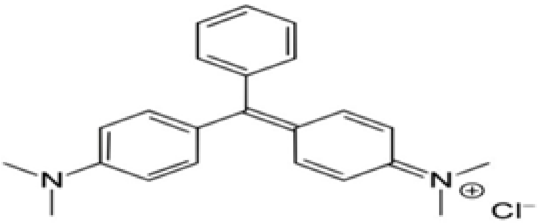
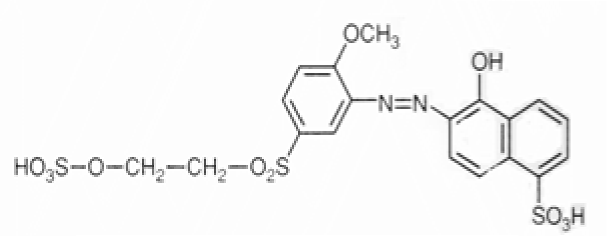


Fig.5 : The graph between absorbance and wavelength for Malachite green dye

So, this result may be due to the basic nature of chitosan with the existence amino group as obtained in IR results. For more details, from Structure 1 of the Remazol red dye, the presence of anions group radicals which are sulfonate $(-SO_3^-)$ and (or) carboxylate $(-COO^-)$, there is an attraction force between the dye and the chitosan compound. But, in the Structure 2 of Malachite green dye, the presence of cationic group (dimethyl amino ethyl $(N(CH_3)_2CH_2CH_2)$) attached to the aromatic core of the molecule was responsible for the cationic nature of the dye and led to a repulsion force between the dye and the chitosan compound.



Malachite green dye (Structure 2)



Remazol red dye (Structure 1)

4.3. Adsorption kinetics and mechanism of dye adsorption

It is known that kinetic study is applied to understand the mechanism of the adsorption reaction, so, in our study we used PFO, and PSO models and their equations respectively, as follows :

$$log(q_e - q_t) = log q_e - k_1 t/2.303 \text{ ....}(4)$$

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \text{.......................}(\mathbf{5})$$

We can find that the (q_e^{exp}) of the applied chitosan are closer to the (q_e^{theo})of pseudo-second order than pseudo-first-order kinetic model. In addition, the highest correlation coefficient (R^2) values were obtained for pseudo-second-order kinetic model (R^2=0.9996). From Fig.6. Therefore, pseudo-second-order kinetic model is the best in describing the adsorption kinetics of Remazol red on chitosan.

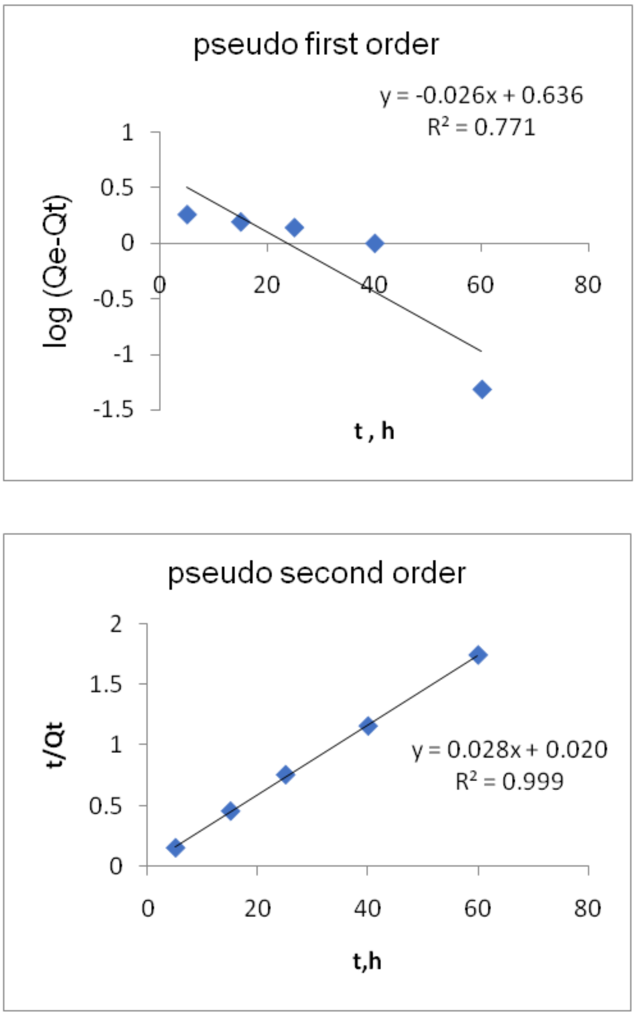


Fig. 6: Linear pseudo-first-order, and second-order kinetic models for RR dye adsorption onto the synthesized adsorbent

Order	Parameters			
	K	$q_{e(theoretical)}$ (mg/g)	R^2	$q_{e(experimental)}$ (mg/g)
Pseudo First order	K_1 (min^{-1}) $1.1374 x 10^{-3}$	37.17	0.7717	34.5
Pseudo Second order	K_2 ($g.mg^{-1} min^{-1}$) 0.04	35	0.9996	34.5

Table 1: Kinetic model parameters for adsorption of RR dye onto chitosan

5. Conclusion

The synthesis of chitosan from shrimp shells using different chemicals and distilled water is the main topic of the study. Shrimp shells were demineralized, deproteinized, neutralized, and then deproteinized again to extract the chitin. The typical absorption peaks in the FT-IR spectra were located at 3,361 and 3,291 Cm-1, while the C-H stretching vibration was responsible for the peaks at 2,921 and 2,877 Cm-1. Since chitosan comprises basic functional groups and attracts anionic dye (Remazol red) through its acid sites, removal in the Remazol red dye solution is greater than in the malachite green dye solution. Studies on the adsorption of dyes revealed that while the number of active sites declined over time, resulting in a decrease in the adsorption rate, the initial increase in the percentage of removal might have been caused by a large number of free sites. Pseudo-first and second-order kinetic models and associated equations were used to study the adsorption kinetics and mechanism of dye adsorption. The pseudo-second-order kinetic model was found to have the highest correlation coefficient (R2=0.9996), making it the most suitable model to explain the adsorption kinetics of Remazol red on chitosan.

6. Acknowledgement

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