



P-ISSN: 2349-8528

E-ISSN: 2321-4902

www.chemijournal.com

IJCS 2022; 10(1): 106-113

© 2022 IJCS

Received: 13-11-2021

Accepted: 17-12-2021

Md. Abdur Rahaman

Department of Chemistry,
Mawlana Bhashani Science and
Technology University, Santosh,
Tangail, Bangladesh

Md. Tozammel Haque Sumon

Department of Chemistry,
Mawlana Bhashani Science and
Technology University, Santosh,
Tangail, Bangladesh

Sultana Razia

1. Department of Chemistry,
Mawlana Bhashani Science and
Technology University, Santosh,
Tangail-1902, Bangladesh and
2. Department of Chemistry,
Rajshahi University of
Engineering and Technology,
Kazla, Rajshahi, Bangladesh

Md. Abu Rashed

Department of Chemistry,
Mawlana Bhashani Science and
Technology University, Santosh,
Tangail, Bangladesh

Corresponding Author:

Md. Abdur Rahaman

Department of Chemistry,
Mawlana Bhashani Science and
Technology University, Santosh,
Tangail, Bangladesh

A comparative study of the adsorptive removal of toxic amaranth dye from aqueous solution using low cost bio-adsorbents

Md. Abdur Rahaman, Md. Tozammel Haque Sumon, Sultana Razia and Md. Abu Rashed

Abstract

Here, the potentiality of low cost, environment friendly and abundantly available bio-adsorbents prepared from rice husk (RHA) and saw dust (SDA) are reported for the removal of toxic anionic dye, Amaranth dye (AMD) from the artificial wastewater. The influence of the parameters that may affect the removal process including contact time, pH, adsorbent dosage and initial dye concentration was investigated in order to properly select the removal process optimization parameters. The adsorption kinetic and isotherm of removal of AMD was also carried out. Kinetic studies have shown that the absorption process can be explained smoothly by the pseudo-second sequence, where the absorption of AMD strongly follows Langmuir's isothermal models. The adsorption isotherm indicates the maximum adsorption capacities of AMD on RHA and SDA are 74.07 and 78.13 mg g⁻¹, respectively.

Keywords: Adsorption, azo dye, industrial wastes, kinetics, Langmuir isotherm

1. Introduction

Water is one of the essential constituents for the survival of the human race on earth, but a significant number of people are still deprived of access to safe water [1]. Safe and accessible water is important not only for public health, but also for domestic, food production or recreational purposes. With population growth, urbanization and industrialization, the use of water is increasing day by day, along with the problem of water scarcity and increasing pollution of natural water sources [2, 3]. One of the reasons for the contamination of water resources, especially surface water, is industrial wastes, which affects both the quality of the ecosystem and the health of all living things. Industrial wastes contain a variety of organic pollutants including dyes, detergents, oils, and other organic compounds and among them the most harmful component is organic dyes, which are originating from various industrial activities such as textiles, dyeing, tanners, paper, paints and pigments [3-6]. This water pollution has become a serious problem for some developing countries as they discarding industrial wastes into the nearby aquatic systems without any treatment [7]. However hopefully, a variety of research is going on about this field and scientists are trying to find out how to keep water safe by removing dyes from wastewater using low cost materials.

Among the organic dyes, azo dyes are regarded an acute threat to ecology and human health. Amaranth dye (AMD) is a well-known azo dye (Fig. 1) that is extensively used in coloring textiles, paper, phenol-formaldehyde resins, wood and leather industries [8, 9]. Besides, it is employed in food as food additives for jams, jellies, ketchup and cake decoration [8, 10]. But importantly, its use has been prohibited in many countries due to its toxicity, mutagenicity, and carcinogenicity [11, 12]. Additionally, it is now well recognized that a persist use of AMD can repercussion to tumors, allergy, respiratory problems and birth defects in the human being [10]. Thus, it is very significant to remove AMD from wastewater considering the negative health and environmental impact.

Furthermore, since Amaranth is highly soluble in water, so it is not so easy to remove it from wastewater using conventional physical and chemical treatment methods [10]. Though, many approaches have been proposed for its removal including chemical oxidation, biological degradation, and adsorption [13-15]. But, among them, due to some attractive features like high proficiency, low price and straightforward operation, adsorption is still considered as the

Thus, it is very significant to remove AMD from wastewater considering the negative health and environmental impact.

Furthermore, since Amaranth is highly soluble in water, so it is not so easy to remove it from wastewater using conventional physical and chemical treatment methods [10]. Though, many approaches have been proposed for its removal including chemical oxidation, biological degradation, and adsorption [13-15]. But, among them, due to some attractive features like high proficiency, low price and straightforward operation, adsorption is still considered as the superior method to remove Amaranth from wastewater [3, 6, 8]. Although adsorbents selection still remains a significant concern, different types of materials have been examined as adsorbents [2, 8-10, 16-21]. Besides, many low-cost adsorbents have been used directly or by transferring to stimulated carbon for the removal of dyes. In this case, considering the "green adsorbents" concept not only adsorption capacity but also simplicity, cost effective, reliability and eco-friendly nature are important [22]. Therefore, eco-friendly bio-adsorbent materials are highly in-demand for the removal of Amaranth from wastewater that would be beneficial commercially as well as environmentally.

Recently, different waste products such as house hold wastes, agriculture products have been used for generating low cost adsorbents. They display some common but important advantages like granular structure, chemical stability. Again, since they can be collected locally at very low cost, they need not restored again. Herein, we demonstrate the removal of toxic Amaranth from the artificial wastewater using low cost bio-adsorbent that prepared from rice husk and saw dust. Thus, we have examined the adsorption activity of these adsorbents on AMD considering the different parameters like contact time, pH, adsorbent dose, dye concentration, etc.

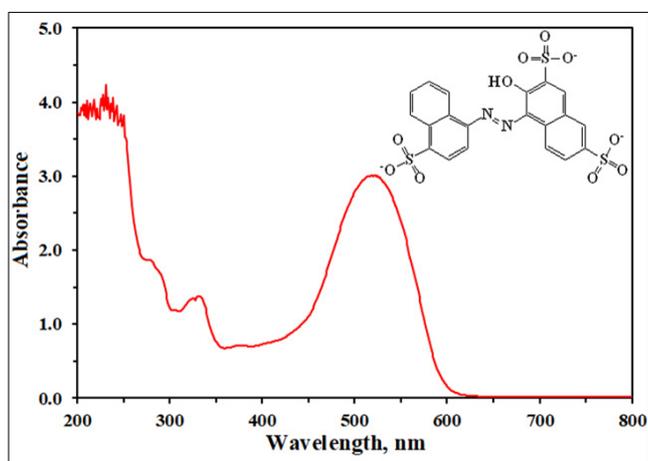


Fig 1: UV-Vis absorption profile of amaranth anion (maximum absorption peak at 521 nm).

2. Materials and Methods

2.1 AMD and its aqueous solution for bio-sorption experiments

AMD (tri-sodium 3-oxo-4- [(4-sulfonatophthalen-1-yl)hydrazinylidene] naphthalene-2, 7-disulfonate) ($C_{20}H_{11}N_2Na_3O_{10}S_3$) is its empirical formula and the formula mass is 604.47) was purchased from the commercial supplier. A stock solution of 0.01 M was prepared by dissolving 1.52 g AMD in 250 mL de-ionized distilled water, latterly from this the desired initial concentration of AMD was obtained by appropriate dilution. In addition, the aqueous solution of AMD displays a maximum absorption at wavelength = 520 nm.

2.2 Collection and Preparation of Bio-adsorbents

All the bio-adsorbents raw materials (Rice husk and saw dust) were collected from the local market at Tangail district in Bangladesh. And following the physical activation treatment method adsorbents were prepared from these materials separately [23]. In this process, the raw materials were rinsed at first with distilled water repeatedly to discharge the pollutant, and dried by sunlight. After that, the materials were then dried in an oven at 150 °C for 48 h and screening through the MIC sieves after grinding. The resultants were then stored separately in the desiccator and used for AMD removal without further physical or chemical treatment.

2.3 Adsorption studies

Adsorption equilibrium profiles of AMD on the selected bio-adsorbents were investigated in a liquid phase at RT following the batch experiments method. These batch adsorption experiments were conducted at desired adsorbent dose, contact time, pH value, and initial concentration of AMD. The concentration of Amaranth solution, before and after the adsorption experiments, was studied using a UV-Vis spectrophotometer (Shimadzu UV1800, Japan) at maximum wavelength 520 nm. Although before that, the desired initial concentration of Amaranth solution was made by proper dilution of stock solution and pH of the solution was regulated by using 0.1 M HCl or 0.1 M NaOH as needed. As a typical way, the desired solution of Amaranth was taken in a 500 mL reagent bottle (with screw cap) and after adding required amount of the adsorbent to the solution the mixture was shaken for a given period of time at 150 rpm using a magnetic stirrer. The mixture was then settle down for some time and filtered for removing the adsorbents and after that the filtrate was preserved for analysis. The adsorbed dye amount per unit mass of the adsorbent, q was calculated following the mass balance equations:

$$q_t = (C_0 - C_t) \times V/m \quad (1)$$

$$q_e = (C_0 - C_e) \times V/m \quad (2)$$

where q_t , q_e represents the adsorbed amount of AMD at any time and at equilibrium condition, respectively (mg dye adsorbed onto the mass unit of adsorbent, $mg\ g^{-1}$), C_0 , C_t and C_e (mgL^{-1}) are the concentration of AMD at initial, any time and equilibrium conditions, respectively, V is the volume of the dye solution, L and m is the mass of respective adsorbent, g. Besides, the removal efficiency was calculated with the formula:

$$\text{Removal efficiency, \%} = (C_0 - C_t)/C_0 \times 100 \quad (3)$$

3. Results and Discussion

3.1 Batch adsorption studies

Since AMD is considered as pollutant for water, so the removal process (adsorption) has been investigated considering the various factors such as contact time, t between the adsorbent and the adsorbate, the solution pH, the adsorbent dosage and the initial dye concentration, etc.

Effect of contact time

Since the time of contact between adsorbents and dyes gives an idea of the time required to reach the adsorption equilibrium, so it is a very significant parameter for designing various adsorbents at low cost. Also, its role in studying the different kinetic models of absorption is immense. However,

at first we have examined the adsorption activity of the two examined adsorbents on AMD considering a function of contact time with variable adsorbents doses (Table 1), and Fig. 2 displays the results.

In almost all cases, removal of AMD at a certain concentration of adsorbent increases rapidly in the first 1 h but decreases gradually over time. Actually, after 1 h the removal capacity increases gradually until it shut down to equilibrium state in around 2.5 h. In the case of RHA, comparatively higher removal capacity after 1 h was observed compared to SDA, but this is not increase much with the passage of contact time although there was a concentration of adsorbents varies from 7 gL^{-1} to 11 gL^{-1} . It may due to the higher interaction between dye and adsorption site of RHA which increases the removal capacity firstly.¹⁸ Later, even if more time is given, the dye molecule is not adsorbed very much to reduce the absorption site. However, our experimental results showed that the tendency to remove dye decreases after reaching 2.5 h of equilibrium, which is thought to be due to the removal of dye from adsorbent surfaces. From this above discussion, it is clear that adsorbent made from rice husk is highly acceptable for dye removal

application from wastewater compare to adsorbent made from saw dust.

Table 1: Effect of contact time on the AMD adsorption by rice husk and saw dust mediated adsorbents.

t / min	removal of Amaranth, %					
	1.0 g Ad	3.0 g Ad	5.0 g Ad	7.0 g Ad	9.0 g Ad	11.0 g Ad
Rice husk mediated adsorbent (RHA)						
20	11.19	18.09	24.40	27.31	34.80	38.61
40	18.93	27.38	38.43	40.63	44.41	44.51
60	25.41	35.40	43.59	46.82	48.29	50.43
80	31.60	42.39	52.48	53.26	54.10	56.64
100	33.60	46.53	54.33	56.68	58.35	59.26
120	36.51	48.55	55.03	57.28	59.35	60.05
Saw dust mediated adsorbent (SDA)						
20	9.53	16.18	24.60	31.15	34.53	38.88
40	15.93	24.44	33.09	39.88	41.82	42.63
60	21.11	31.73	38.44	43.66	45.58	46.91
80	25.37	36.63	41.89	45.57	47.01	48.98
100	26.52	39.01	43.18	47.57	48.51	50.07
120	27.50	40.55	44.70	48.27	48.68	50.61

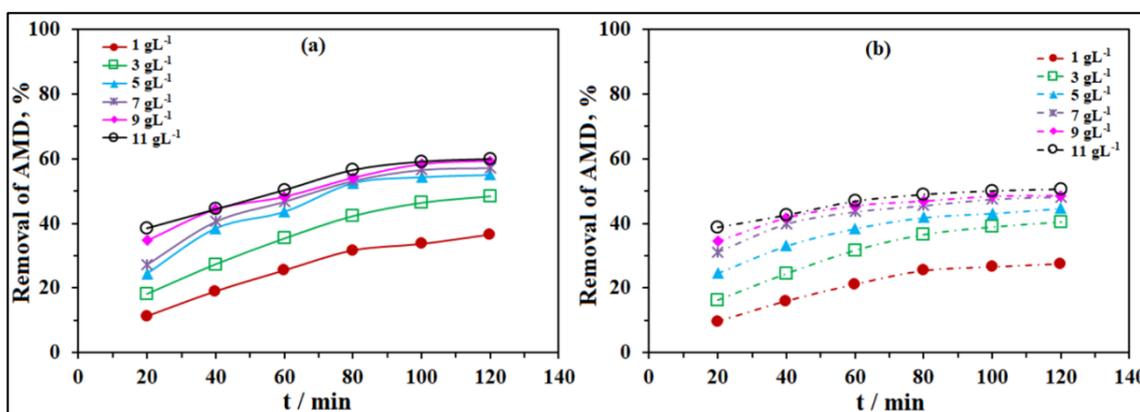


Fig 2: Plot of contact time effect on the Amaranth adsorption using (a) RHA and (b) SDA

Effect of pH of the adsorption solution

The pH acts as the most important parameter among the parameters that affect adsorption efficiency, because it can regulate surface charge of the adsorbent, can separate functional groups of the adsorbent on the active sites, and suited of ionizing the adsorbing molecules in the solution.²⁴ In this scenario, for both the adsorbents the dependence of pH on adsorption performance was examined in the pH range of 1.5 to 10.8 at a fixed dose of adsorbents (3 gL^{-1}). Fig. 3 displays

the variation of the pH on adsorption efficiency, that strongly influences the removal of the AMD. At the adsorbent dose mentioned above, RHA can remove AMD about 76.65% at pH 1.53 and about 50.48% at pH 10.06. That is, RHA can remove the maximum amount of AMD in the acidic solution. As like as RHA, almost the similar trend of results is observed in case of SDA. Though later on, as the pH increases, both the maximum percentage of Removal efficiency, % and adsorbed dye amount per unit mass of the adsorbent, q_e decline.

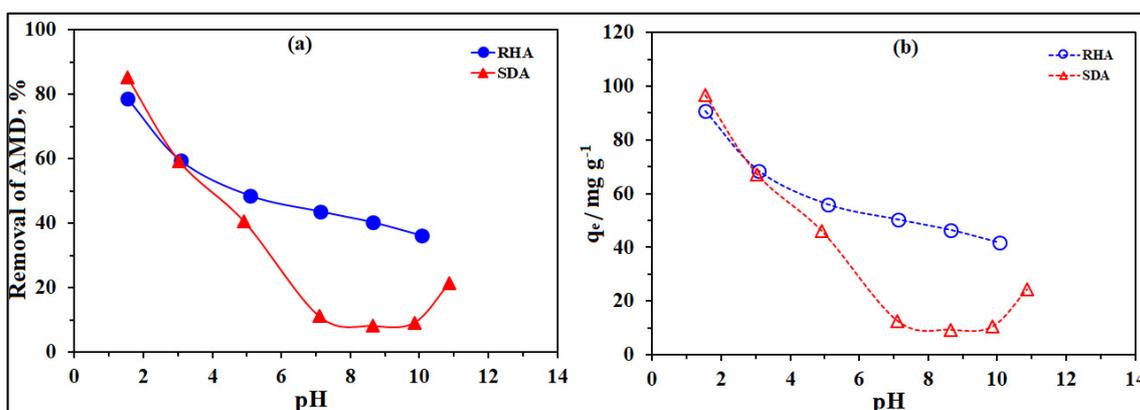


Fig 3: Plot of pH effect on the adsorption of AMD using RHA and SDA adsorbents (a) % removal of AMD, % and (b) q_e (mg g^{-1})

Basically, any adsorption arises due to interaction between adsorbent and adsorbate (dye). We can interpret the above results in this way: At high pH the number of active neutral sites on the adsorbing surface decreases, as well as the negative sites increases due to deprotonation [15, 25]. As a result, the amount of electrostatic repulsion of both the dye and the adsorbent surface increases and the adsorbing dye dissociates and its basic molecules transferred into anionic mode. Since the negative sites of the adsorbent surface are not suitable for adsorbing the anion of dye molecules due to robust electrostatic repulsion, the adsorption capacity decreases rapidly. This results indicates that adsorption

characteristics of the adsorbents are highly dependent on pH and robustly connected with the change of the adsorbents surface charge [10, 15, 24].

Effect of adsorbent dose

To avoid unnecessary use of adsorbent materials and get maximum removal efficiency, various amounts of adsorbent doses were tested on adsorption efficiency maintaining certain dye concentrations. Fig. 4 displays the adsorption of dyes against the adsorbents (RHA and SDA) dose. In both the cases, both the removal efficiency and amount of adsorbed dye (q_e) increases with the adsorbent doses.

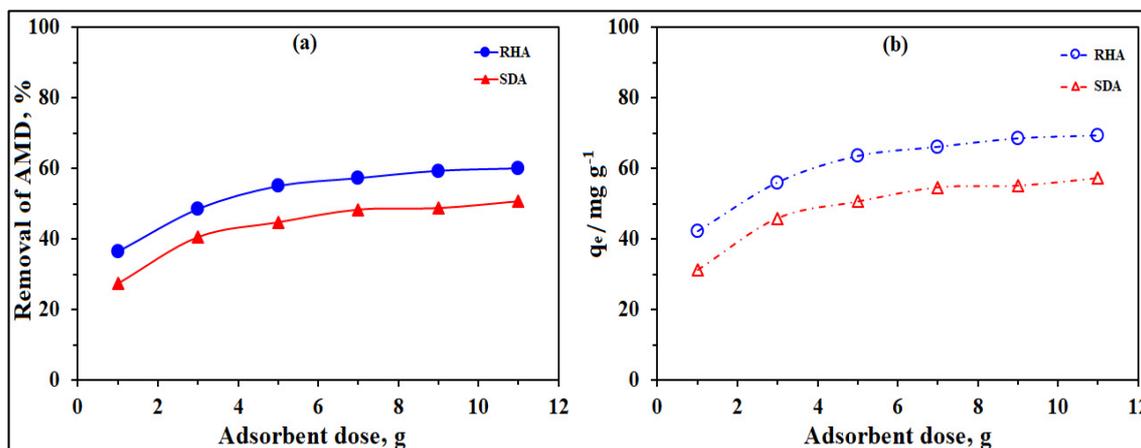


Fig 4: Plot of adsorbent dose effect on the adsorption of AMD using various adsorbents (a)% of removal (b) q_e (mg g⁻¹)

It is clearly evident that if the adsorbent dose is increased, the number of active adsorption sites increases compared to a certain number of AMD molecules, which shows an imperative role in increasing the amount of AMD adsorption [10]. Again, since the number of AMD molecules does not increase compared to the adsorbent in the solution, adding a certain amount of adsorbent to the solution results in no more dye molecules remaining in the solution, as almost all dye molecules are adsorbed [2]. It then ensures the formation of a dynamic balance between the number of adsorbed and desorbed dye molecules. This has been observed in both the cases that no significant adsorption is detected after adding 9 gL⁻¹ of adsorbents to the solution.

Effect of initial concentration of AMD

It has already been established from the various results reported earlier that the initial concentration of adsorbate species significantly influences the adsorption phenomenon. For this purposes, we scrutinized the adsorption efficiency of examined adsorbents using variable initial concentration of AMD in a fixed adsorbent dose considering the other conditions remained unchanged (the amount of adsorbent = 3 gL⁻¹, pH \cong 5.0, adsorption time = 2 h) (Fig. 5). According to the results represented in Fig. 5, it reveals that as the introductory concentration of AMD increases, the removal amount of AMD by the examined adsorbents decreases.

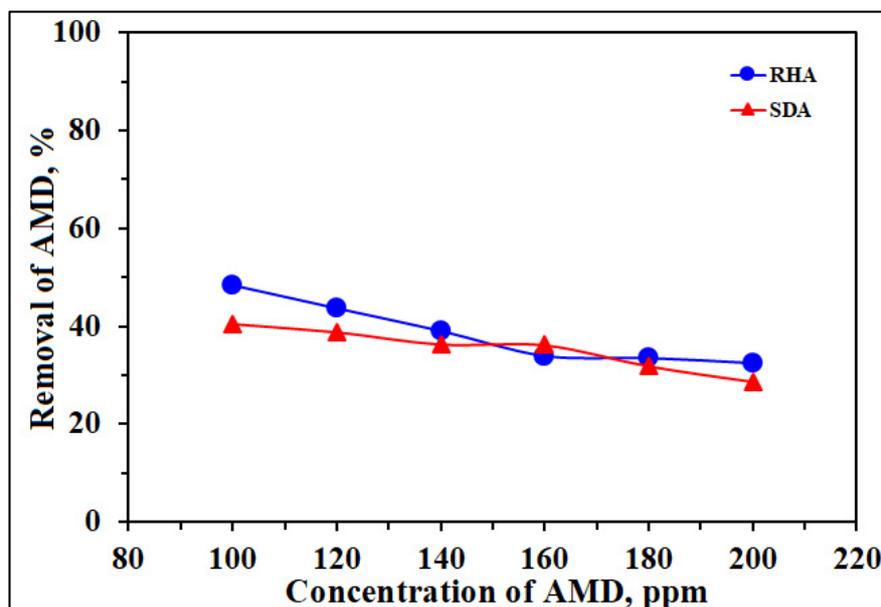


Fig 5: Effect of initial conc. of AMD on the adsorption efficiency using RHA and SDA

Generally, at a lower initial concentration of AMD, the number of effective adsorption places on the adsorbents is greater than the amount of competent AMD molecules. And for this reason, most of the AMD molecules are binded with the adsorbent surface and show higher adsorption efficiency. Again, since at higher initial concentration, the number of active adsorption sites available on adsorbents surface is less than the number of available AMD molecules, the AMD molecules have to contest with one another to interact with the certain adsorption places on the surface of adsorbents. In this case, AMD molecules that could not be attached to the adsorber's adsorption site are then persist free in solution.

3.2 Kinetic Studies of Adsorption

The adsorption kinetics analysis plays a vital role for the determination of adsorption mechanism and potential rate controlling steps. Pseudo first-order, pseudo second-order and intra-particle diffusion are the common kinetic models using for this purposes [26]. These models can be expressed as the following formula:

Table 2: Kinetic parameters for pseudo 1st-order, pseudo 2nd-order and intra-particle diffusion model and experimental values of q_e for the adsorption of AMD onto RHA and SDA

Adsorbent dose of RHA, gL ⁻¹	Pseudo 1 st -order kinetics			Pseudo 2 nd -order kinetics			Intra-particle diffusion kinetics		Equilibrium experimental value of q_e (mgg ⁻¹)
	$k_1 \times 10^2$ (min ⁻¹)	q_e (mgg ⁻¹)	r^2	$k_2 \times 10^4$ (gmg ⁻¹ min ⁻¹)	q_e (mgg ⁻¹)	r^2	k_{id} (mgg ⁻¹ min ^{-0.5})	r^2	
1	2.81	57.78	0.9815	1.25	78.74	0.9867	4.6186	0.9873	42.13
3	3.34	85.96	0.9502	1.66	88.50	0.9924	5.6594	0.9882	56.02
5	4.72	124.17	0.9421	2.94	86.21	0.9909	5.5681	0.9450	63.49
7	4.63	121.79	0.9138	3.40	86.21	0.9974	5.4219	0.9571	66.09
9	3.73	79.10	0.8921	5.28	81.30	0.9952	4.4578	0.9826	68.48
11	4.05	80.65	0.9186	6.23	80.65	0.9946	4.1141	0.9775	69.29
Adsorbent dose of SDA, gL ⁻¹									
1	3.75	52.55	0.9756	2.72	51.28	0.9805	3.2619	0.9639	31.13
3	3.45	66.24	0.9773	2.73	67.57	0.9949	4.4038	0.9741	45.91
5	3.29	46.80	0.9961	6.83	60.98	0.9995	3.4993	0.9528	50.60
7	3.78	45.11	0.9657	11.1	61.35	0.9999	2.9032	0.9263	54.64
9	5.11	59.48	0.9189	15.6	60.24	0.9998	2.4354	0.9076	55.11
11	3.87	36.28	0.9732	17.1	61.73	0.9992	2.1513	0.9598	57.29

The results mentioned above display two important observations: in the case of pseudo second-order kinetic model the correlation coefficient (r^2) for all the examined adsorbents are higher compared to that of the pseudo first-order kinetic model, and the calculated adsorbed amount of AMD is very close to the experimental adsorbed amount. These observations confirm that the absorption of AMD on the surface of RHA and SDA adsorbents pursuets a pseudo-second-order kinetic model, which appears to have been regulated by the chemisorption process and agreed with other studies [16, 24].

On the other hand, intra-particle diffusion model gives idea about the rate regulation steps of the adsorption process, which actually scrutinize the relative impact of surface and intra-particle diffusion to the kinetics process. The linearity of the plot of q_t vs t indicates the involves of intra-particle diffusion which can controls the adsorption rate (Fig. 6) [18, 24]. However, the experimental results confirms that intra-particle diffusion influences the rate of dye removal, but it is not just the rate regulation step, some other steps may be engaged with the adsorption process. Again, since AMD appears to be negatively charged in aqueous solutions, it can be concluded that electrostatic attraction between the negatively charged AMD and the positively charged adsorbents surface is responsible for the surface diffusion process. Although, external expansion of the dye molecules from the liquid phase to the solid surface, the adsorption on the solid surface and the

$$\text{Pseudo first-order model: } \log(q_e - q_t) = \log q_e - k_1 t / 2.303 \quad (4)$$

$$\text{Pseudo first-order model: } t/q_t = 1/k_2 q_e^2 + t/q_e \quad (5)$$

$$\text{Intra-particle diffusion model: } q_t = k_{id} t^{0.5} + C \quad (6)$$

where, q_t and q_e are, respectively, the adsorbed amount of AMD (mg g⁻¹) at time t and at the equilibrium, k_1 is the pseudo-first-order adsorption rate constant (min⁻¹), k_2 is the pseudo-second-order adsorption rate constant (g mg⁻¹ min⁻¹), k_{id} is the intra-particle diffusion rate constant (mg g⁻¹ min^{-0.5}) and C describes the boundary layer thickness. By plotting $\log(q_e - q_t)$ vs. t , the adsorption rate constant, k_1 and adsorbed amount, q_e for the pseudo-first-order can be determined from the slope and intercept, respectively. Likewise, for the pseudo-second-order model, the values of k_2 and q_e can be determined by plotting t/q_t vs. t , also, the value of k_{id} can be calculated from the slope of q_t vs. $t^{0.5}$ plot. The parameters of the kinetic models for the adsorption of AMD by RHA and SDA adsorbents displayed in the Table 2.

intra-particle expansion of the dye molecules inside the pores are the parameters that could greatly affect the adsorption of organic dye on the adsorbing surface [21].

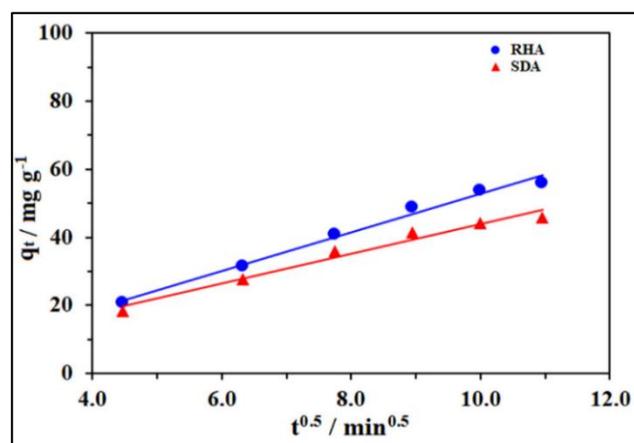


Fig 6: Intra-particle diffusion model for AMD adsorption using RHA and SDA as a fixed dose of adsorbents (3 gL⁻¹) at pH: 5 with the initial concentration of AMD: 100ppm.

3.3 Adsorption Isotherm

It is important to identify the relationship between the dye concentration in solution and the amount of dye adsorbed on the adsorbent in equilibrium state, as it can provide a clear idea of the various significant parameters affected in the

adsorbate-adsorbent interaction and cooperate to select an appropriate sorption system. However, the adsorption isotherms of AMD adsorption onto the selected three adsorbents were analyzed using two classic isotherm models such as the Freundlich and Langmuir adsorption isotherm models [27, 28]. The well-known form of these two adsorption isotherms are given as follows:

$$\text{Freundlich: } \log q_e = \log K_F + 1/n (\log C_e) \quad (7)$$

$$\text{Langmuir: } C_e/q_e = C_e/q_{\max} + 1/K_L q_{\max} \quad (8)$$

where, $1/n$ is the adsorption intensity and K_F is the Freundlich constant. And, these values are determined from the slope and intercept of the straight linear graph of the $\log q_e$ vs $\log C_e$, respectively. On the other hand, q_{\max} is the maximum amount of dye adsorbed corresponding to monolayer coverage, K_L is

the Langmuir adsorption constant related to the rate of adsorption. The value of q_{\max} and K_L are determined from the linear plot of C_e/q_e vs C_e , which gives a straight line of slope $1/q_{\max}$ and intercept $1/K_L q_{\max}$. The plots of the isotherms of the adsorption of AMD onto the separate adsorbents are displayed in Fig. 7 and the values of the corresponding parameters calculated from all isotherms are exposed in Table 3. Moreover, the favorability of the adsorption process was tested using the dimensionless constant known as equilibrium parameter, R_L , which signifies the essential characteristics of Langmuir isotherm. The R_L values specifies the type of the isotherm to be either favorable ($0 < R_L < 1$), unfavorable ($R_L > 1$), linear ($R_L = 1$) or irreversible ($R_L = 0$). Mathematically it is defined as-

$$\text{Equilibrium parameter, } R_L = 1/(1+K_L C_0) \quad (9)$$

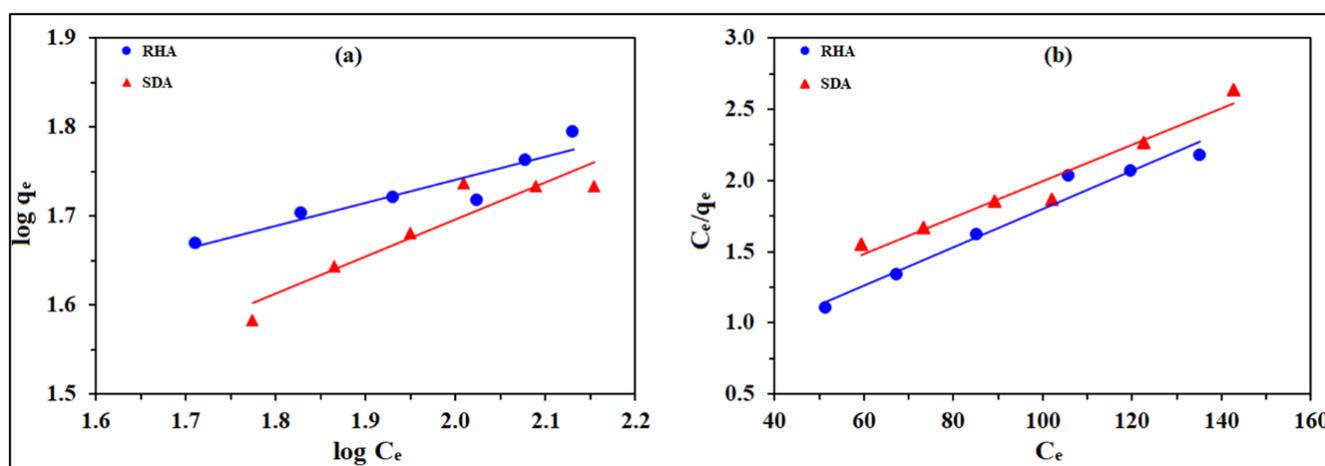


Fig 7: (a) Freundlich and (b) Langmuir adsorption isotherm of AMD onto RHA and SDA

From the above experimental results, it is clear that the higher linearity of the Langmuir isotherm plot indicates more suitability compare to the Freundlich model for explaining the adsorption of AMD, revealing the preferential monolayer structure. This further confirmed from the equilibrium parameter ($0 < R_L < 1$), which exposed favorable adsorption

occur using Langmuir adsorption model. In the case of adsorbent RHA and SDA, the maximum adsorption capacity was estimated to be 74.07 and 78.13 mg g^{-1} , respectively from the Langmuir model. Furthermore, the value of $1/n$ less than one (0.26 for RHA and 0.41 for SDA) indicates normal Langmuir isotherm [29].

Table 3: Freundlich and Langmuir adsorption isotherm constants for the adsorption of AMD onto RHA and SDA.

Adsorbent	Freundlich adsorption isotherm			Langmuir adsorption isotherm			
	Freundlich constant, K_F	$1/n$	r^2	Langmuir adsorption constant, K_L	$q_{\max}/(\text{mg g}^{-1})$	Equilibrium parameter, R_L	r^2
RHA	16.67	0.26	0.8642	2.97×10^{-2}	74.07	0.25 (for 100 ppm)	0.9621
						0.22 (for 120 ppm)	
						0.19 (for 140 ppm)	
						0.17 (for 160 ppm)	
						0.16 (for 180 ppm)	
SDA	7.36	0.41	0.8684	1.78×10^{-2}	78.13	0.14 (for 200 ppm)	0.9523
						0.36 (for 100 ppm)	
						0.32 (for 120 ppm)	
						0.29 (for 140 ppm)	
						0.26 (for 160 ppm)	
	0.24 (for 180 ppm)						
	0.22 (for 200 ppm)						

4. Conclusion

This research work mainly describes our keen efforts on the removal of toxic Amaranth dye from the artificial wastewater using low cost adsorbents considering the different parameters like contact time, dye concentration, pH. The batch adsorption study displayed that RHA can remove the maximum amount of AMD in the acidic solution at pH 1.53.

The kinetic study of AMD adsorption was found to follow the pseudo-second-order model, and controlled by the chemisorption process, which is supported from the adsorption isotherms studies, where Langmuir adsorption model confirms favorable adsorption occur during adsorption process.

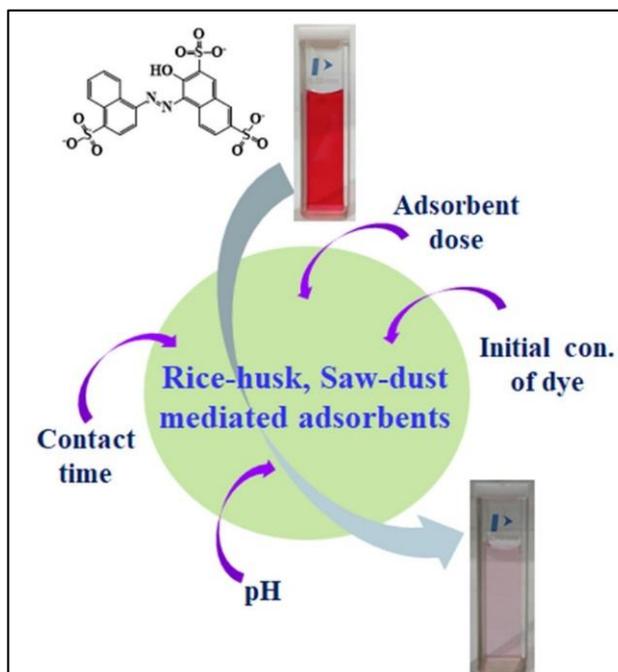


Fig 8: Adsorption of Amaranth dye using bio-adsorbents mediated from rice husk and saw dust

Acknowledgements

The authors are thankful to the department of Chemistry, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh for financial and logistic support for running the project.

5. References

- Dias EM, Petit C. Towards the use of metal-organic frameworks for water reuse: a review of the recent advances in the field of organic pollutants removal and degradation and the next steps in the field. *J Mater. Chem. A*. 2015;3(45):22484-22506.
- Bulgariu L, Escudero LB, Bello OS, Iqbal M, Nisar J, Adegoke KA, *et al.* The utilization of leaf-based adsorbents for dyes removal: A review. *J Mol. Liq.* 2019;276:728-747.
- Dutta S, Gupta B, Srivastava SK, Gupta AK. Recent advances on the removal of dyes from wastewater using various adsorbents: A critical review. *Mater. Adv.* 2021;2:4497-4531.
- Chen B, Yuan M, Liu H. Removal of polycyclic aromatic hydrocarbons from aqueous solution using plant residue materials as a biosorbent. *J Hazard. Mater.* 2011;188(1-3):436-442.
- Xi Z, Chen B. Removal of polycyclic aromatic hydrocarbons from aqueous solution by raw and modified plant residue materials as biosorbents. *J Environ. Sci.* 2014;26(4):737-748.
- Ali I, Asim M, Khan TA. Low cost adsorbents for the removal of organic pollutants from wastewater. *J. Environ. Manage.* 2012;113:170-183.
- Bhowmick AC, Rahaman MA, Islam M, Akther N, Hossain MS, Patwary MM. Comparative adsorption study on rice husk and rice husk ash by using amaranthus gangeticus pigments as dye. *Eur. Sci. J.* 2015;11(21):254-265.
- Lin KYA, Wu CH. Efficient Adsorptive Removal of Toxic Amaranth Dye from Water using a Zeolitic Imidazolate Framework: Lin and Wu. *Water Environ. Res.* 2018;90(11):1947-1955.
- Guerrero-Coronilla I, Morales-Barrera L, Cristiani-Urbina E. Kinetic, isotherm and thermodynamic studies of amaranth dye biosorption from aqueous solution onto water hyacinth leaves. *J. Environ. Manage.* 2015;152:99-108.
- Gupta VK, Jain R, Mittal A, Saleh TA, Nayak A, Agarwal S, *et al.* Photo-catalytic degradation of toxic dye amaranth on TiO₂/UV in aqueous suspensions. *Mater. Sci. Eng. C*. 2012;32(1):12-17.
- Sudrajat H, Babel S. Rapid photocatalytic degradation of the recalcitrant dye amaranth by highly active N-WO₃. *Environ. Chem. Lett.* 2016;14(2):243-249.
- Liang S, Tang J, Yao S, Zhu W. Removal characteristics of two anionic dyes by a polyethylenimine/poly (N,N-dimethylaminoethyl methacrylate) gel. *RSC Adv.* 2019;9(40):22907-22920.
- Lin KYA, Lin JT, Jochems AP. Oxidation of amaranth dye by persulfate and peroxymonosulfate activated by ferrocene. *J. Chem. Technol. Biot.* 2017;92(1):163-172.
- Ghodake G, Jadhav U, Tamboli D, Kagalkar A, Govindwar S. Decolorization of Textile Dyes and Degradation of Mono-Azo Dye Amaranth by *Acinetobacter calcoaceticus* NCIM 2890. *Indian J. Microbiol.* 2011;51(4):501-508.
- Ahmad R, Kumar R. Adsorption of Amaranth Dye onto Alumina Reinforced Polystyrene. *CLEAN – Soil, Air, Water.* 2011;39(1):74-82.
- Lawal IA, Moodley B. Synthesis, characterisation and application of imidazolium based ionic liquid modified montmorillonite sorbents for the removal of amaranth dye. *RSC Adv.* 2015;5(76):61913-61924.
- Mashkour S. Removal of Amaranth Dye from aqueous Solution using Pomegranate Peel. *Int. J. Basic Appl. Sci.* 2013;13(4):57-64.
- Liao H, Wang Z. Adsorption removal of amaranth by nanoparticles-composed Cu₂O microspheres. *J. Alloy. Compd.* 2018;769(0):1088-1095.
- Abdellaoui K, Pavlovic I, Bouhent M, Benhamou A, Barriga C. A comparative study of the amaranth azo dye adsorption/desorption from aqueous solutions by layered double hydroxides. *Appl. Clay Sci.* 2017;143:142-150.

20. Zargar B, Parham H, Hatamie A. Fast removal and recovery of amaranth by modified iron oxide magnetic nanoparticles. *Chemosphere*. 2009;76(4):554-557.
21. Salem A-NM, Ahmed M, El-Shahat M. Selective adsorption of amaranth dye on Fe₃O₄/MgO nanoparticles. *J. Mol. Liq.* 2016;219(0):780-788.
22. Kyzas GZ, Kostoglou M. Green adsorbents for wastewaters: a critical review. *Materials*. 2014;7(1):333-364.
23. Xu G, Yang X, Spinosa L. Development of sludge-based adsorbents: preparation, characterization, utilization and its feasibility assessment. *J. Environ. Manage.* 2015;151(0):221-232.
24. Azaman SH, Afandi A, Hameed B, Din AM. Removal of malachite green from aqueous phase using coconut shell activated carbon: Adsorption, desorption, and reusability studies. *J. Appl. Sci. Eng.* 2018;21(3):317-330.
25. Munir M, Nazar MF, Zafar MN. Removal of amaranth dye over surfactant modified dull pink clay from aqueous medium. *Int. J. Environ. An. Chem.* 2021;101(15):2848-2865.
26. Weber Jr WJ, Morris JC. Kinetics of adsorption on carbon from solution. *Journal of the sanitary engineering division*. 1963;89(2):31-59.
27. Freundlich H. Over the adsorption in solution. *J. Phys. Chem.* 1906;57:385-471.
28. Langmuir I. The adsorption of gases on plane surfaces of glass, mica and platinum. *J. Am. Chem. Soc.* 1918;40(9):1361-1403.
29. Tan I, Hameed B, Ahmad A. Equilibrium and kinetic studies on basic dye adsorption by oil palm fibre activated carbon. *Chem. Eng. J.* 2007;127(1-3):111-119.