Adsorption of Congo red Dye from Aqueous Solution onto Wheat Husk in a Fluidized Bed Reactor

Israa Sabah[a] and Abeer I. Alwared[b]

[a] Ministry of Water Resources
[b] Environmental Eng. Department, University of Baghdad

Abstract

The purpose of this paper is to examine absorbance for the removal of the Red Congo using wheat husk as a biological pesticide. Several experiments have been conducted with the aim of configuring breakthrough data in a fluidized bed reactor. The minimum fluidized velocities of the bed were found to be 0.031 mm/s for mish sizes of (250) µm diameter with study the mass transfer be calculated K_L values. The results showed a well-fitting with the experimental data. Different operating conditions were selected: bed height (2, 5 and 10) cm, flow rate (90, 100and 120) ml/sec and particle diameter (250, 600, 1000) µm. The breakthrough curves were plotted for Congo Red, Values showed that the lower the bed, the lower the number of adsorbents and the potential of the weak bed to condense the density of the solution, which also increases the flow rate and will increase the mass transfer rate.

1- Introduction

Dyes are one of the types of organic compounds that have the ability to provide a bright color that lasts for various materials [1]. More than 100,000 paints are available for commercial uses, which are specially formulated to be highly resistant to fading when exposed to sweat, light, water and oxidizing agents, and are thus highly stable and difficult to analyze.[2].

Synthetic dyes have many uses, especially in textiles, leather, paper, rubber, plastic, cosmetics, pharmaceuticals and food industries. Often "these complex aromatic molecular structures make them more stable and have low biodegradability [1; 3]. Azo dyes have many uses and are widely used by different industries. Some of the dyes used for industrial coloring paints are thrown into the environment. CR is toxic to many organisms and is a suspected carcinogen and mutagen.

The colored Wastewater in the water bodies is not only unpopular but negatively affects aesthetics as well as prevents light entering and reduces photosynthesis. There are many dyes that have toxic, carcinogenic, mutagenic and teratogenic effects on aquatic life and humans.[4].

Therefore, the process of removing dyes from wastewater is important to prevent environmental pollution on an ongoing basis.

There are different types of biological and physical/chemical treatment methods for the disposal of pigments found in liquid industrial wastes, such as coagulation, membrane separation, electrochemical oxidation, ion exchange, and adsorption.

Among these methods, adsorption is currently considered to be the best treatment potential in general and has proved to be an efficient and economical process to remove dyes using different mazes.[5].

Much attention has been focused on studying different types of low-cost materials such as sub-agricultural products, which are arbitrarily removed or burned, resulting in loss of resources and environmental damage.[6], such as coconut husk, wheat straw, corncobs, and barley husks. Fixed and fluidized beds have been used widely by chemical industry, pharmaceutical industry, food industry, wastewater treatment and recovery of different substance [7].

FBR Reactor, a type of reactor device used to operate different types of chemical reactions. In this type of reactor, it enters the liquid (gas or liquid) through a granular material (usually the catalyst in the form of small balls) and quickly enough to work on lifting the particles and treating them as if they were liquid.

This provides vulnerable families with adequate space. There is no contact between the particles and the intimate contact of the entire surface with the polluted current, making the process faster by increasing the adsorption surface area of the adsorbents by reducing the dead areas between the particles [8].

Basis of adsorption and Fluidized bed reactor can be considered common and important reactors in process engineering due to the good mass and heat transfer rate between liquid and particles, between particles and the side wall of columns[9].

Corresponding Authors: Name: Israa Sabah, Email: sabah.israa@yahoo.com, Name: Abeer I. Alwared, Email: dr.Abeer.wared@coeng.uobadghdad.edu.iq

It is possible to expect that the bed with the activated carbon has shown an increase in the efficiency of removing some pollutants in the wastewater compared to the fixed bed under the same working conditions[10]. The aim of this work was to study the influenced of some parameters that have an effect on the behavior of liquid fluidized bed for the removal of CR dye from wastewater using wheat husk, other studies were performed in fluidized bed reacter [11; 12] and in adsorption [13]

2- Experimental Work

2.1. Adsorbent Material

Wheat husk (WH) is an organic sorbent that has been collected from one of the wheat fields in Wasit province. The removal of foreign objects was done by hand and was then washed several times with tap water and then with distilled water to make sure dirt is removed. The material was washes and then tapped to reach the desired size of the grain. After that, it was dried for 2 hours in an oven preserved at 125 ° C, then allowed to cool to laboratory temperature and then kept in closed glass containers until being used, Fig. **1**.

Fig. 1. Wheat husk (WH) before and after grinding

Table 1. Physical Properties of Wheat husk

Item Name	Granular wheat husk
Base	W.H.
Bulk Density	334.56 kg/m3
Particle Density	(1502.6) kg/m3
Surface Area	0.8329 m2/g
Internal Porosity	0.777

2.2. Adsorbate Material

Congo red (CR) is one of the most commonly used materials for the dying of cotton, wood, silk and is considered a chemical compounds heterogeneous cycle ($C_{32}H_{22}N_6O_6S_2Na_2$; molecular weight 696.68) as molecular formula and a molecular weight. A stock solution of 1000 mg/l of CR dye was prepared for calibration purposes.

From the stock, different concentrations of CR were prepared by diluting with water. pH, and concentration mg/l were kept constant 6.7 and 25 m\l, respectively. The various chemicals used in this study are considered analytical.

The process of preparation of the artificial wastewater used in this experiment contains the required amount of dye by dissolving the calculated amount of the CR dye in the distilled water.

The concentration of the dye was subsequently determined using Spectrophotometer (ADVANCED MICROPROCESSOR UV-VIS SPECTROPHOTOMETER SINGLE BEAM LI-295) at the predetermined maximum absorbance wavelength (λmax=497nm) of the CR dye for different concentrations of CR subsequently.

2.3. Fluidized Bed Experiments

The experimental setup consists of a fluidized film; fluidized bed reactor having an effective volume of 0.0024m³. The specification of the experimental set up is given in Table **2** and schematic diagram is shown in Fig. **2**.

Table 2. Physical features and process parameters

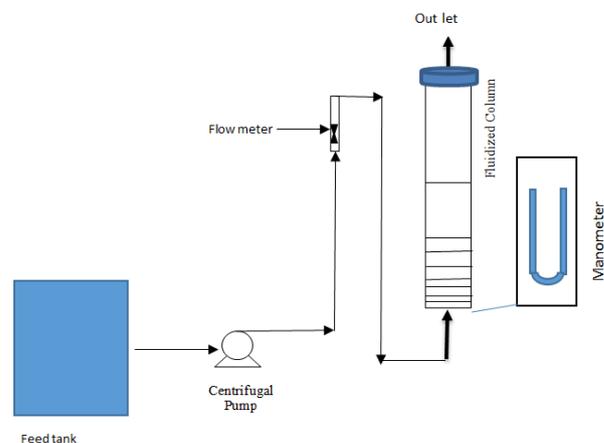| S.No.	Specifications	Details
1	Effective Volume of Reactor	0.0024 m³
2	Diameter of Reactor	0.05m
3	Height of Reactor	1.2m
4	Height of fluidized bed before fluidization	3 Nos.
5	Flow Distributer	3 Nos.
6	Particle size of wheat husk	3 Nos.

Fig. 2. Experimental model of fluidized bed reactor

3- Results and Discussion

3.1. Estimation of the Minimum Fluidization Velocity

The work to determine the minimum dilution rate (Umf) is piloted by calculating the low pressure across the layer of wheat straw particles. One particle size was used in these study (250) micrometers.

The column was partially filled with particles from the known mass and then mixed strongly with water to arrange the particles and break any internal structure, then left the bed to settle down.

After which, the flow rate gradually increased from 0 to 120 ml / sec using the flowmeter. As each flow rate increase, pressure reduction was recorded using a pressure gauge. Fig. **3** shows the pressure drops across the bed against the superficial fluid velocity in scale. The graph is used to read the minimum fluidization velocity (U_{mf}). The U_{mf} can be read from the sharp change in the pressure drop over the fluidized bed region. The low pilot fluid velocity is roughly equal to theoretical velocity. Therefore, the lower flow using the continuous experiments is equal to 80 ml / min. Different flow figures greater than the minimum flow rate were used for the purpose of increasing contact and its impact on the efficiency of CR removal. Theoretically, minimum fluidized velocity value calculated using Equation (1) and it was equal to 0.031 m/s (minimum flow rate = 88 ml/sec).

$$U_{mf} = \mu / d_p . \rho_l Re \qquad (1)[14]$$

Where: U_{mf} is the minimum fluidized velocity. dp is the particle diameter, ρ_l is the density of liquid and μ is the liquid viscosity(water $=1\times10^{-3}$).

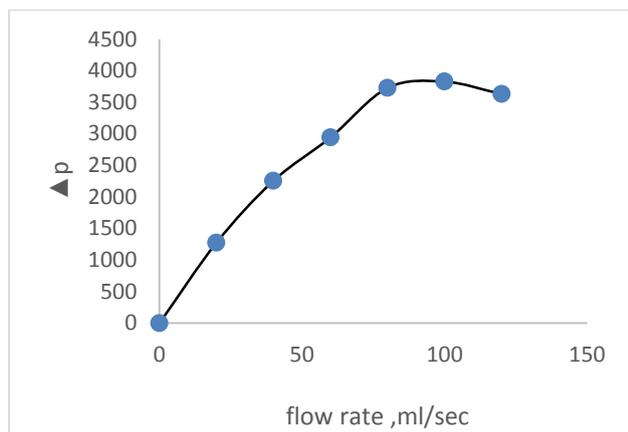Fig. 3. Pressure drop vs. superficial fluidized flow rat in wheat husk bed of 250 μm particles diameter

3.2. Estimation of Mass Transfer in Fluidized Bed Reactor.

Fluidized bed reactor offers high available surface area, since there is no contact between particles. This development depends on the balanced data of the different velocity continuous flow fluidized-bed system. The correlations used in this study were listed in eq. (2). These correlations were developed in a fixed and fluidized bed system. The calculated K_L values using these correlations were listed in Table (3). The high flow rate leads to a cycle of reynolds, which results in a higher Sherwood number. The number of Sherwood is directly proportional to the coefficient of the material carrier, so the high number of Sherwood works to increase the coefficient of the material carrier and the overall mass transfer rate [14].

It is expected that the change in flow rate will affect the film diffusion but not the intra-particle diffusion. The higher the flow rate the smaller the film resistance to mass transfer and larger K_L values.

$$S_h = 0.35\ Re^{0.6}Sc^{1/3} \qquad (2)\ [15]$$

$$D_m = 2.74*10^{-9}(Mw)^{-1/3} \qquad (3)[16]$$

In which the Schmidt number ($Sc = \nu/Dm$) is calculated using the liquid kinematic viscosity, ν (m^2/s), and the liquid phase diffusivity, D_m (m^2/s). Several methods may be used to calculate the liquid phase diffusivity, one of the most widely used [17].

Table 3. Calculated K_L values of CR at different flow rate

WH	Flow rate (ml/sec)	Sh, ($K_L.d/D_m$)	K_L*10^5 (m/s)
	80	214.9	27.2
CR	100	245.8	31.1
	120	274.2	34.6

3.3. Breakthrough Curves

The breakthrough curves for CR dye solution were obtained by plotting C/Co versus time at different operating conditions.

The concentration of the primary dye varies, as well as the height of the bed, the flow rate of CR absorption on the studied bed and the removal efficiency in the fluid system.

a. Effect of Adsorbent Bed Height

Fig. **4** shows the breakthrough curves obtained for CR adsorption on the wheat husk for three different bed heights of (2, 5 and 10) cm, at a constant flow rate of 100 ml/sec.

This figure shows that increasing of bed height will increase the adsorption capacity; in addition to that, the increase in bed height gives the time to connect these molecules to condense on the absorbing surfaces, suggesting that at the height of the low bed, the density of the effluent increases more rapidly than the height of the upper bed.

Also, in a low bed, the bed is saturated at less time.

The height of the low bed corresponds to a small amount of adsorbents and a weak capacity for the bed to condense the density of the solution.

When the flow rate remains constant, increasing the height of the bed will increase the time of solubility in the bed, improving the solvent removal efficiency.

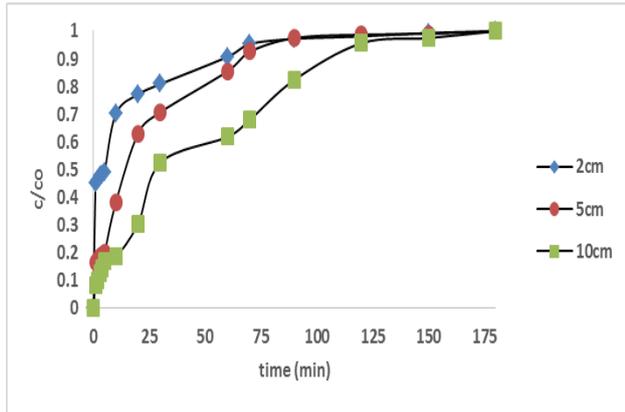These results are consistent with those obtained before (17; 18).

Fig. 4. The Experimental Breakthrough Data for Adsorption of C.R. onto wheat husk at different bed depths, Q=100 ml/sec, Co=25.0 mg/l, pH=6.7, D=250µm

b. Effect of the Solution Flow Rate

In this part of the work, flow rate and CR adsorption using wheat husk were studied using different sprays (80, 100 and 120) ml / sec, with a fixed height bed of 0.05 m, as shown in the penetration curves in Fig. **5**.

The higher the flow rate, the higher the penetration curves. The downtime is less time remaining in the column than the few. Because of the increased flow rate, the suction solution leaves the column before reaching full equilibrium because the contact time is short. The higher the flow rate, the smaller the thickness of the surface layer which is considered to be resistant to mass transport. Increasing the flow rate will increase the mass transfer rate. Increasing the flow rate leads to a connection (mixing) which makes penetration and passage of adsorbed particles through the molecules that occupy the site (s) on the adsorbent easier. This is because there is sufficient contact time that affects the amount of capacitance. The few flow rates that will have enough contact time to occupy the space within the particles, this result is consistent with that obtained previously (17; 18).
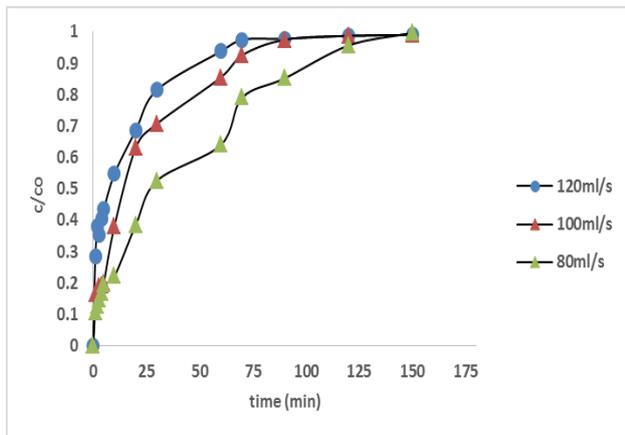

Fig. 5. The Experimental Breakthrough Data for Adsorption of CR onto wheat husk at different flow rates, L=5 cm, Co=25 mg/l, pH=6.7, D=250µm

c. Effect of Particle Size

Different particle size of WH (250, 600, 1000) µm were used for the removal of Congo red from aqueous solution at constant flow rate (100) ml/sec in WH, and dyes concentration (25) mg/l , bed height (5)cm as shown in Fig. **6**.

The results indicate that the shape shows well the penetration curves, and increases with the size of the lower particles.

This indicates that the particles of exact size have outer transfer surface areas that are more effective than large-size particles with the same mass as WH.

Film diffusion is the basic rate mechanism for smaller particles that quickly reach saturation[19].
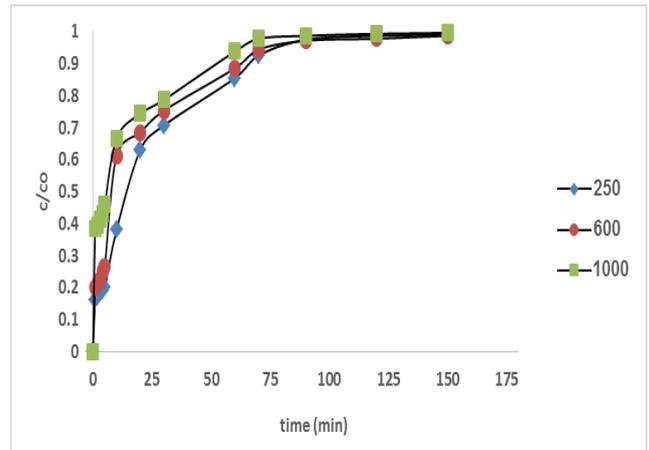

Fig. 6. The Experimental Breakthrough Data for Adsorption of CR onto wheat husk at different particles size, L=5 cm, Co=25 mg/l, pH=6.7

4- Conclusion

The purpose of the study was to remove CR from wastewater using wheat husk as an adsorbent in a fluidized bed reactor.

The curves showed a breakthrough for CR that breaks the time better compared to others.

This can be attributed to the largest electronegativity value compared with others. In fluidized bed system, the minimum fluidized velocities of bed were found to be 0.031 m/s, an increase in the bed height of wheat husk will increase the breakthrough time.

A decrease in the particle size will increase surface area of adsorption.

An increase in the discharge reduces the penetration time led to the reduction in the contact between absorbent with absorbent material. Also, that the flow rate decreases, the dye has enough time to fill out the areas within the particles.

Furthermore, increasing the particle size leads to a reduction at the time of the cutting point due to the surface area of the large particles being weaker than the small particles.

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امتزاز صبغة الكونغو الحمراء من المحاليل المائية باستخدام قشور الحنطة في مفاعل الحشوة المتميعة

اسراء صباح[1] و عبير الورد[2]

1وزارة الموارد المائية
2قسم هندسة الهندسة البيئية–جامعة بغداد

الخلاصة

يهدف هذا البحث الى دراسة امكانية ازالة الصبغة الكونكو الحمراء من المحاليل المائية باستخدام قشور الحنطة كمادة ممتزة في مفاعل الحشوة المتميعة حيث اجريت العديد من التجارب بثبات المتغيرات 6.7 الدالة الحامضية ، 25 ملغم /لتر تركيز اولي للصبغة وبدرجة حرارة الغرفة لغرض الحصول على مخططات الامتزاز الحيوي لكل عنصر و لقد تم الحصول على الحد الادنى لسرعة التميع تساوي 0.7474ملم / ثانية باستخدام دقائق قطرها (250) ميكرومتر من قشور الحنطة كما أظهرت النتائج ملائمة بشكل جيد مع البيانات التجريبية. تختلف ظروف التشغيل المختلفة: ارتفاع السرير (2 ، 5 ، 10) سم ، معدل التدفق (90 ، 100 و 120) مل / دقيقة وقطر الجسيمات (250 ، 600 ، 1000) ميكرومتر. تم رسم المخططات للكونغو الأحمر ، و تظهر النتائج أن انخفاض حشوة السرير المميع يتوافق مع كمية أقل من الممتزات وسعة ضعيفة للحشوة المتميعة من المحلول كما أن زيادة معدل التدفق سيزيد من معدل نقل الكتلة.

الكلمات الدالة: صبغة الكونكو الحمراء، قشور الحنطة، مفاعل الحشوة المتيعية