DYE REMOVAL FROM WASTE WATER BY ADSORPTION ON ACTIVATED CARBON

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ABSTRACT

This Investigation was conducted to study the removal of dyes from waste water in the textile cotton industry. Three different industrial dyes were used, these are direct blue, sulphure black and vat yellow with the following maximum concentrations in solution of 6,10 and 16 ppm respectively. The method used is adsorption on activated carbon.
The results showed that adsorption onto activated carbon with surface area of 626 m^2/g was found to be very effective for the removal of the different dyes considered, where the percent removal was 96.7%, 98.7% and 98.4% for direct blue, sulphure black and vat yellow respectively.

الخلاصة

تخصص هذا البحث بدراسة إزالة اللون من المياه الصناعية الملوثة بالصبغة والخارجة من مصانع الانسجة القطنية. اما الاصباغ التي تمت دراستها فهي الازرق والاسود والاصفر وبتراكيــز ٦ و ١٠ و ١٦ جــزء بالمليون في المحلول المطروح من المصنع.

تم إستخدام طريقة الامتزاز بالكاربون المنشط ذو مساحة سطحية مقدارها ٦٢٦ م٢/غرام. واتضح ان العملية كفوءة جدا حيث كانت نسبة إزالة اللون هي ٩٦,٧% و ٩٨,٧% و ٩٨,٤% للون الازرق والاسود والاصفر على التوالي.

KEY WORDS

Adsorption, Colour removal, Dye removal by adsorption.

INTRODUCTION

The textile industry continually strives to minimize pollution, particularly when dyeing cotton and cotton blend fabrics where a large amounts of salts and colour dye pollutants are discharged into water.
There are several methods to remove colour, these include: sedimentation, using flocculants or polyelectrolytes, biological treatment, ultrafiltration, ion exchange, adsorption, chlorination or ozonation (Mckay and McAleavey, 1988).
Many dyes used in textile industry are particularly difficult to remove by conventional waste treatment methods, since they are stable to light and oxidizing agents and are resistant to aerobic digestion. The removal of dyes in economic fashion remains an important problem although recently a number of successful systems have been evolved using adsorption techniques. These, commonly, include: adsorption by activated carbon and ion exchange (O.I.T. project, 1999).

Activated carbon as an effective adsorbent primarily is due to its extensive porosity and very large available surface area for adsorption (Jason, 1999).

Adsorption is a surface phenomenon where is the dissolved substances in wastewater are attracted to and adhere to the surface of the adsorbent. Activated carbon, with its extensive internal microporous structure, is the most commonly used adsorbent either in powdered or granular form. Adsorption on activated carbon is probably the most economical and technically attractive method available for removing soluble organics such as phenols, chlorinated hydrocarbons, surfactants, colour and odour producing substances from wastewater. Adsorption systems based on granular activated carbon can either be of fixed-bed type (flow down) or expanded-bed type (flow up) (Bansal, 1988).

After the bed becomes saturated, it is necessary to regenerate it for reuse. In thermal regeneration the activated carbon is dewatered and then passed through a multiple-hearth furnace where the adsorbed organics are oxidized at temperatures of 815 to 925°C.

The regenerated carbon is then water-quenched and stored for return to the treatment system. Instead of thermal regeneration, where carbon losses ranging from 5 to 10% per cycle occur because of oxidation and physical attrition, solvent regeneration of adsorbents has received more attention recently. Solvents, such as methanol, acetone and benzene desorb the organic matter from the adsorbent and the solvent is then removed by steam (Perrich, 1981).

Poots, et al. (1976), investigated the adsorption of Telon Blue (acid Blue 25) on peat. Perspex columns were used having an inner diameter of 5 cm, 50 cm length, and up to four columns could be operated simultaneously. Dye feed rates were maintained constant. The peat used was of constant particle size for all runs (150-255 μm). The contact time necessary to reach saturation for Telon Blue was 2-h. adsorption parameters for Langmuir and Freundlich isotherms were determined and the effect of contact time, initial dye concentration and peat particle size were studied.

Grutsch, et al. (1981) studied the use of activated carbon in wastewater treatment process. The carbon is generally added to wastewater having a pH from about 4 to about 11, and is commonly added after the wastewater has undergone primary treatment. Preferred modes of operation comprise using low concentration of activated carbon having a high surface area and a zeta potential greater than about-10 millivolts. It is also preferred to use activated carbon in conjunction with an activated sludge process having an average sludge age greater than about ten days, especially where the wastewater undergoes a pretreatment prior to the activated sludge process to reduce chemical oxygen demand, oil and solids content. Low concentrations of activated carbon based on feed wastewater are generally used while maintaining substantially higher concentrations in the process.

Keirsse et al. (1986) studied adsorption on clay and activated carbon, using various types of wastewater as a raw material. The best carbons produced were evaluated for their adsorptive capacity for phenol, pentachlorophonate, p-toluensulphonate, and dedcylbenzene-sulphonate. Results obtained were compared with performance of Chemviron F400. In general the properties of the carbons obtained were comparable to those of commercial qualities. Some of the activated carbons tested will soon be evaluated using synthetic and real phenolic industrial wastewaters (1.5% of phenol).

Konduru et al. (1997) showed that high removal of acid dyes by fly ash and slag, while peat and bentonite exhibited high basic dye removal. For the acid and basic dyes, the removals were comparable with that of granular activated carbon, while for the dispersed dyes, the performance was much better than that of granular activated carbon.

Lambert et al. (1997) observed that removal of reaction dyes using synthetic clay was the most effective adsorbent over the pH range (5.5-8.5), although comparable dye removals were exhibited by activated carbon, activated bauxite was as effective as activated carbon. Fuller's earth was largely ineffective. With regard to the removal of pesticides activated carbon was highly effective, whereas the three inorganic adsorbents showed negligible removals.

EXPERIMENTATION

The industrial wastewater from cotton textile treatment unit has a maximum concentration of each dye in the solution as

Direct Blue	6 ppm
Sulphur Black	10 ppm
Vat Yellow	16 ppm

Then a model dye solution was prepared by dissolving a weighed amount of the powder dye (from cotton-textile factory) in distilled water.

Experimental procedure

The adsorption abilities of activated carbon under dynamic conditions for the three different dyes were investigated using glass columns with a diameter of 2.54 cm and a length of 100 cm, cocurrent flow and specific volumetric rates of 1 L/h. The columns contained 150 gm of activated carbon. The carbon granules ranged in size between 2 to 3 mm.

The known quantity of activated carbon is placed in the adsorption column and packed by gentle tapping through its length, the activated carbon bed was confined in the column by fine stainless steel screens, see **Fig. (1).**

The standard solutions of the maximum concentration of each dye were prepared, as well as the mixtures of the solution.

Then each dye solution was introduced at the top of the column by means of the dosing pump at the desired flow rate. Samples were taken every 10 minutes. The concentration of each dye in these samples was measured using UV-spectophotometer. Breakthrough curves were, then, determined by plotting effluent concentration against time.

Adsorption Isotherm Determination

Different concentrations of each dye-water solution were prepared. A measured volume of the binary mixture, whose composition was known, was added to a known weight of adsorbent (granular activated carbon of 2-3 mm size) in a flask. These standards were put in a constant temperature shaker. After equilibrium was reached, a sample of the non-adsorbed liquid was analyzed by means of UV-spectophotometer. The experiments were carried out at a temperature of 27°C.

The adsorption isotherm was obtained by plotting the weight of the dye adsorbed per unit weight of activated carbon against the equilibrium concentration of the dye in the solution.

DISCUSSIONS

Adsorption using activated carbon appears to offer the best prospects for overall treatment. In water and wastewater treatment systems, activated carbon is almost always used as a filter medium in an independent treatment operation.

Adsorption Isotherms

Figs. (2) to (4) show the adsorption isotherms for different dye solutions (Direct Blue, Sulphur Black and Vat Yellow), on granular activated carbon of size (2-3 mm) at a temperature of 27°C. The isotherm is somewhat convex upward, because a relatively high activated carbon loading were obtained at low concentration of dye in water. This isotherm is of favorable type. These figures

show the isotherm for the dye in water separately, as well as the isotherms for the dye in the mixture of dyes solution, found from mixing rule used for designing adsorption columns.
The equilibrium data are correlated well with Langmuir equation rather than Freundlich equation, for all used dye solutions but with different degrees. The monolayer capacity (a) and the Langmuir equation constant (b) were calculated from computer fitting program to experimental data, their values with the correlation coefficients were tabulated in **Table (1)** for each type of dye solution, and **Table (2)** for each dye in the solution mixture.
However, even with equal GAC concentration levels there were great differences in the adsorption isotherms for different dyes (Direct Blue, Sulphur Black and Vat Yellow). Since the process of adsorption with activated carbon largely depends on the characteristics of the dyes e.g. molecule structure, weight, polarity, pH and ionization, this result is not surprising.
The equilibrium isotherm for each dye in the solution mixture had a lower equilibrium isotherm in comparison with the solution of each dye separately.
Similarly, because the adsorption of one substance will tend to reduce the number of open sites, hence the "concentration" of adsorbent available as a driving force to produce adsorption effects on rates of adsorption of the other substance, mutually depressing effects on rates of adsorption may be predicted.
Data have been obtained for both rates of adsorption and adsorption capacities on carbon for mixed solutions, which indicate that each solute competes in some way with the adsorption of the other.

Adsorption Breakthrough Curve

Figs. (5) and (6) show the experimental breakthrough curves for adsorption of dye from its pure solution and from dye solution mixture. It can be noted that the breakthrough curve is different from one dye solution to another.
Though activated carbon is effective in adsorption of many types of chemicals, it is especially known for its power in adsorption of organic compounds. As it is discussed previously, carbon's particular affinity for organics is due to its non-polar nature. In fact, the effectiveness of activated carbon in adsorbing an organic compound is inversely related to the compound's solubility in water, which is in itself a function of the compound's polarity. It is also apparent that larger molecules tend to be adsorbed more strongly on activated carbon than smaller ones. Interestingly, the location of the group on the molecule does not affect the adsorption, but the number of groups seems to have a large effect. The lower adsorption of larger molecules has also been attributed simply to molecular size, because larger molecules present a larger surface for the intermolecular attractions known as Van der Waal's forces.
Fig. (7) illustrates the difference between the breakthrough curves (C_A/C_0 vs. t) for adsorption of Direct Blue dye from its pure solution and from a mixture of dyes in a column of activated carbon, where C_A is the concentration of dye at any time t and C_0 is its initial concentration. It is readily apparent that the presence of other solutes in the mixture adversely affects the adsorption of the first, leading to a much more rapid breakthrough of this material.

CONCLUSIONS

1- Adsorption of Direct Blue through activated carbon represents the adsorption of the whole dye mixture solution on activated carbon.
2- Adsorption through granular activated carbon with surface area 626 m^2/gm is an effective method for dye removal of different types of dyes as shown in the following Table:

Type of dye	Initial concentration, ppm	Concentration of treated solution, ppm	% Dye removal
Direct Blue	6	0.20	96.7
Sulphur Black	10	0.13	98.7
Vat Yellow	16	0.25	98.4

3- The adsorption isotherm data for all three dyes follow Langmuir equation.
4- The removal of each dye independently in its own solution is better than when it is in a mixture solution of the three dyes together.

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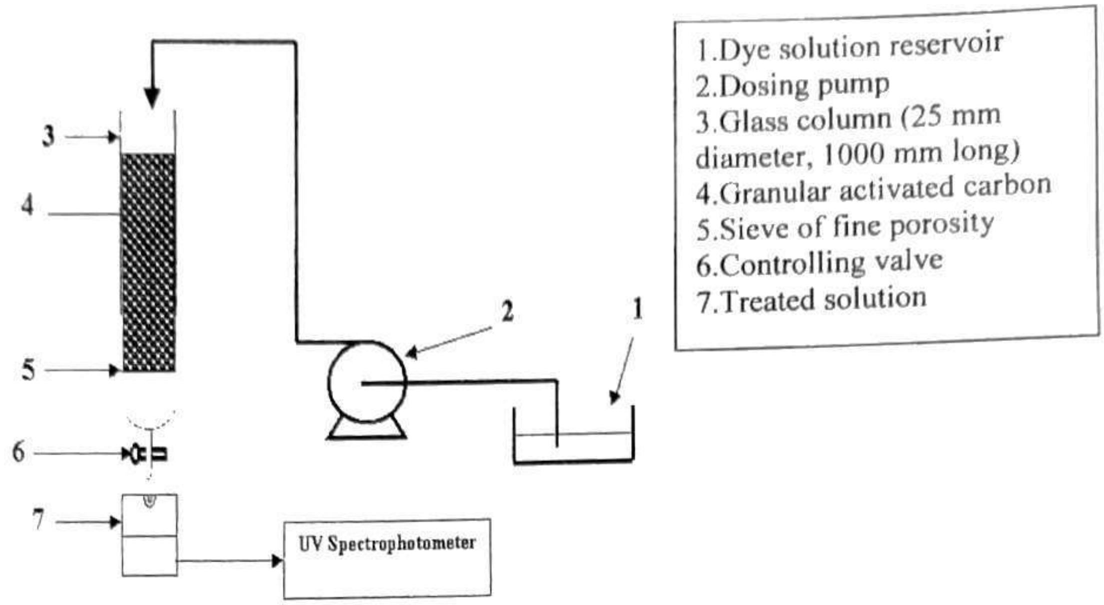

Fig. (1) Adsorption with activated carbon system

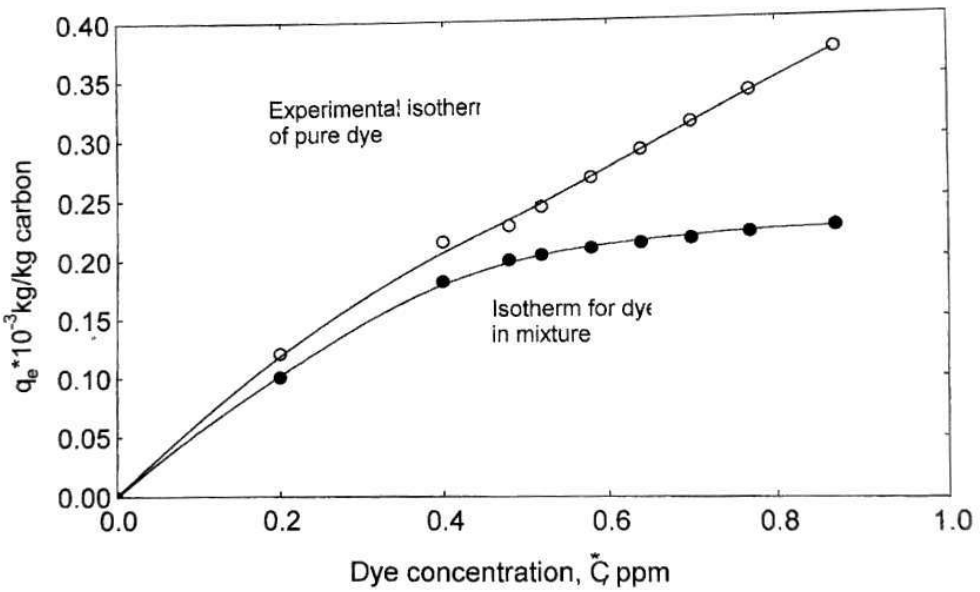

Fig.(2) Adsorption isotherms for Direct Blue dye on activated carbon at 27°C

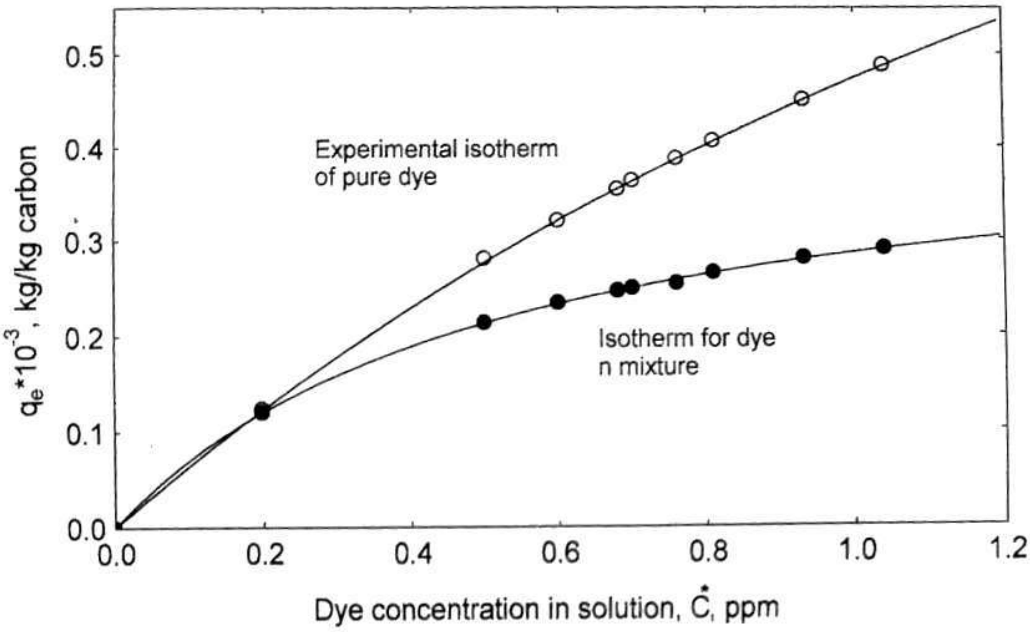

Fig.(3) Adsorption isotherms for Sulphur Black dye on activated carbon at 27°C

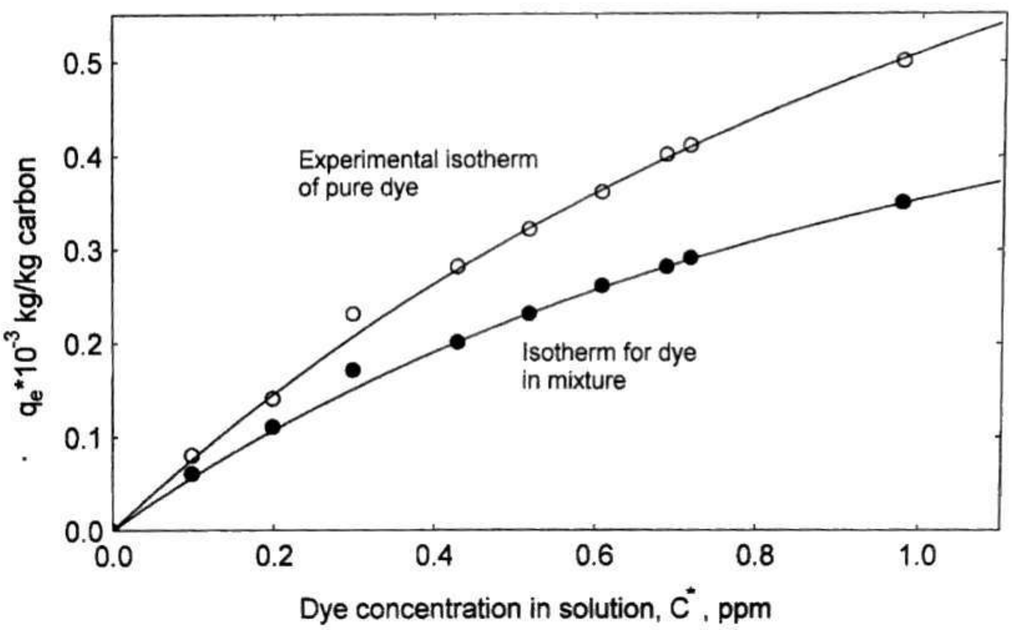

Fig.(4) Adsorption isotherms for Vat Yellow dye on activated carbon at 27°C

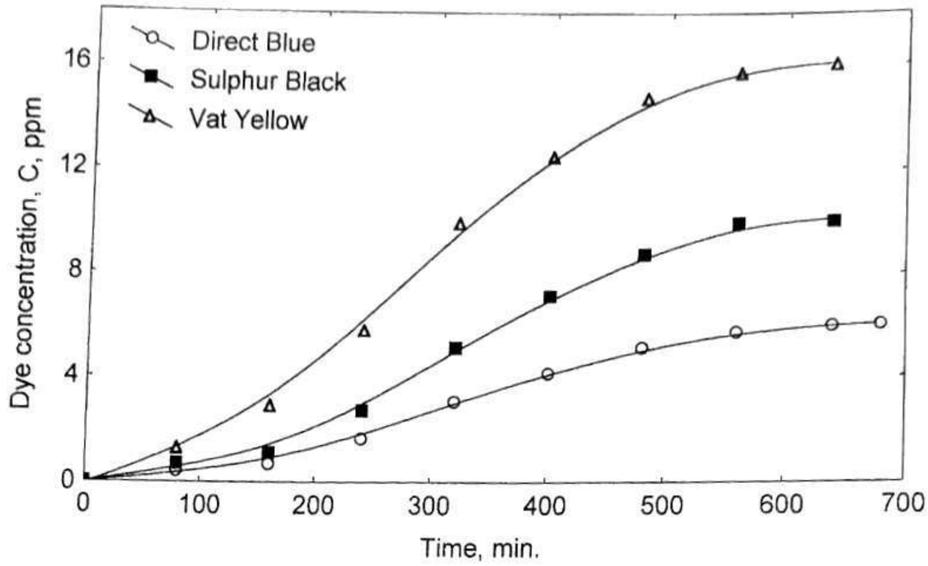

Fig.(5) The experimental breakthrough curves for adsorption of dye from its pure solution

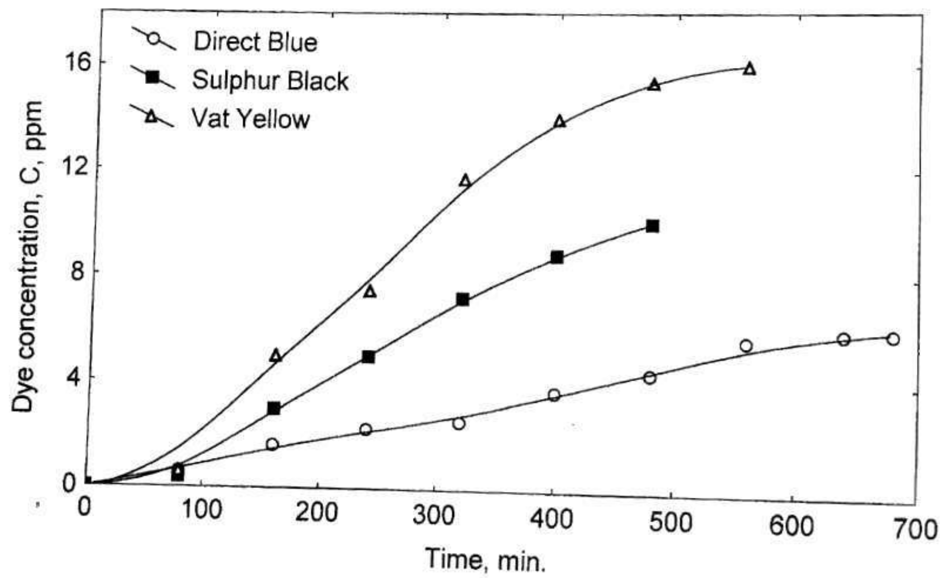

Fig.(6) The experimental breakthrough curves for adsorption of dye from dyes solution mixture

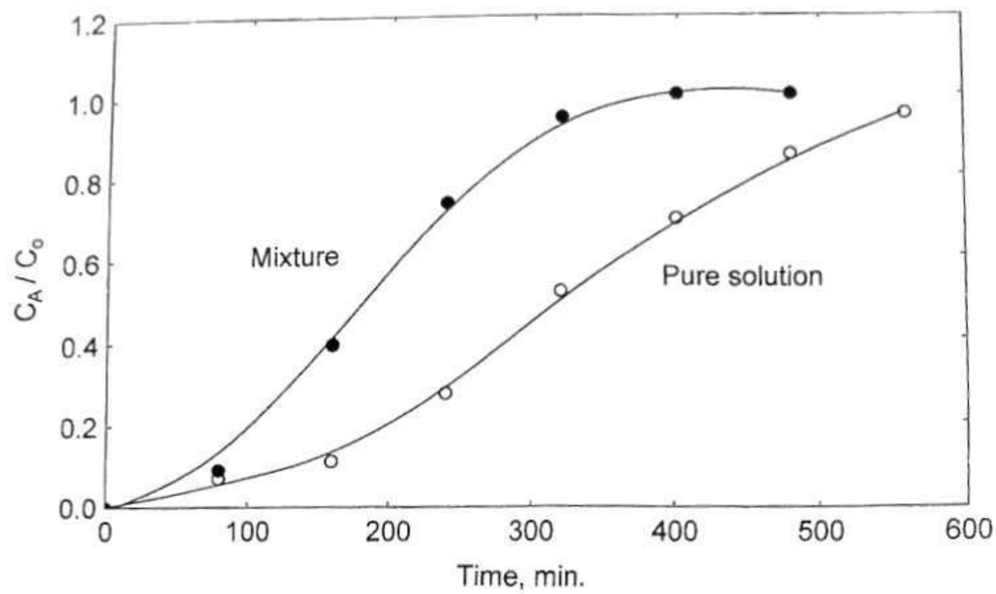

Fig.(7) Comparison between breakthrough curves for adsorption of Direct Blue dye from its pure solution and from dyes solution mixture.

Table (1) Langmuir equation constants for individual dyes

Type of dye	Symbol	a (kg/kg)	b(m^3/kg)	Correlation coefficient
Direct Blue	A	1.797	0.301	0.993
Sulphur black	B	1.647	0.404	0.998
Vat yellow	C	1.367	0.595	0.990

Table (2) Langmuir equation constant for mixed dyes

Type of dye	Symbol	a (kg/kg)	$b(m^3/kg)$	Correlation coefficient
Direct Blue	A	0.248	5.423	0.900
Sulphur black	B	0.437	1.899	0.990
Vat yellow	C	0.835	0.735	0.998