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# Influence of Everzol Black B dye concentration on its adsorption on the powdered activated carbon

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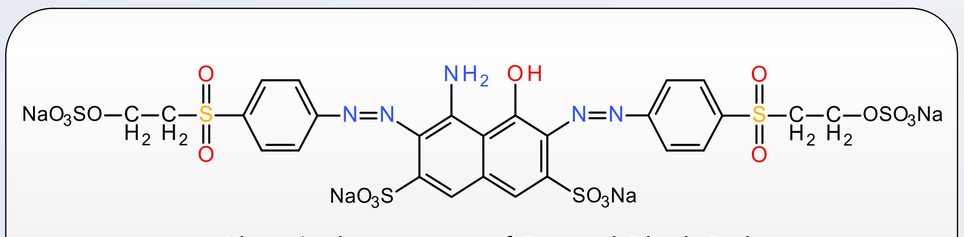
The aim of this work was to investigate the adsorption efficiency of commercially available powdered activated carbon for the removal of the Everzol Black B dye in a concentration range from $c_0$ = 300 mg dm$^{-3}$ to $c_0$ = 500 mg dm$^{-3}$.

Isothermal batch adsorption studies was carried out at 45 (±1) °C with 0.1 g of activated carbon in the periods from 30 minutes to 16 hours when equilibrium was reached. Additional aims were to determine the adsorption rate and mechanism, and to calculate standard Gibbs free energy of adsorption to determine if adsorption process is spontaneous.




*Chemical structure of Everzol Black B dye*

## Results and Discussion

$q_t$ (mg g$^{-1}$) – amount of dye adsorbed at any time $t$
$q_e$ (mg g$^{-1}$) – amount of dye adsorbed at equilibrium, *i. e.* after 16 hours (adsorption capacity)
$c_0$ (mg dm$^{-3}$) – initial dye concentration
$c_t$ (mg dm$^{-3}$) – dye concentration in liquid phase after appropriate time of adsorption
$c_a$ (mg dm$^{-3}$) – concentration of adsorbed dye ($c_a = c_0 - c_t$)
$V$ (dm$^3$) – volume of liquid phase
$m$ (g) – mass of adsorbent
$E_d$ (%) – efficiency of decolouration (percentage of adsorbed dye)

$$q = \frac{V * (c_0 - c_t)}{m}$$

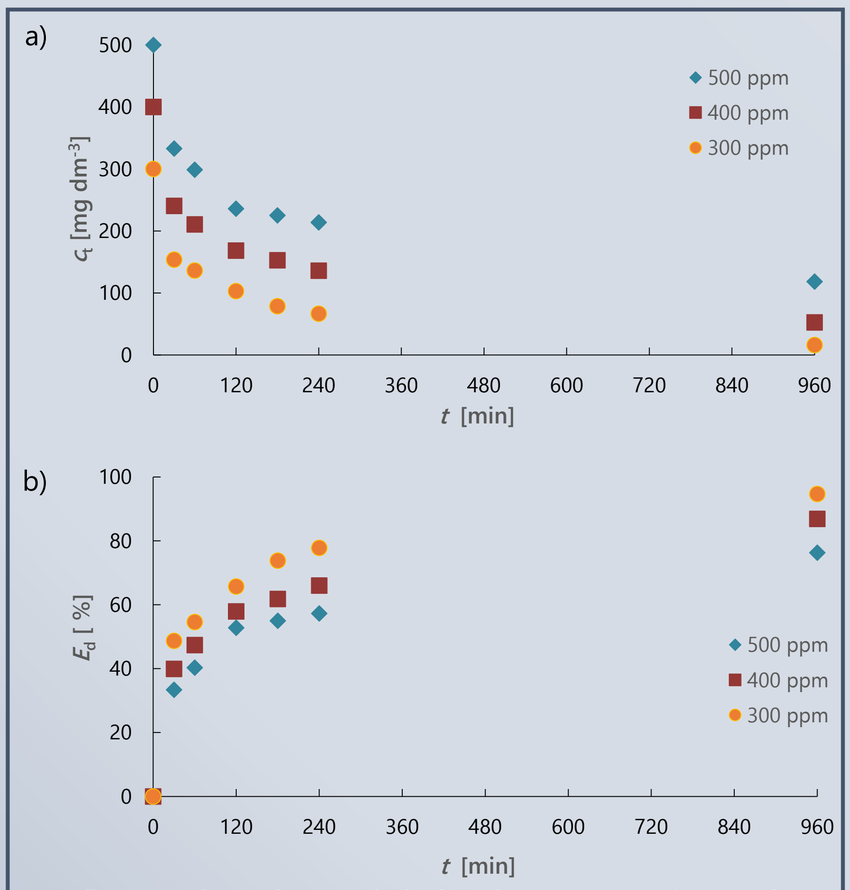
$$E_d = \frac{c_a}{c_0} * 100$$

**Pseudo-first-order kinetic model [1]** $\ln(q_e - q_t) = \ln q_e - k_1 t$

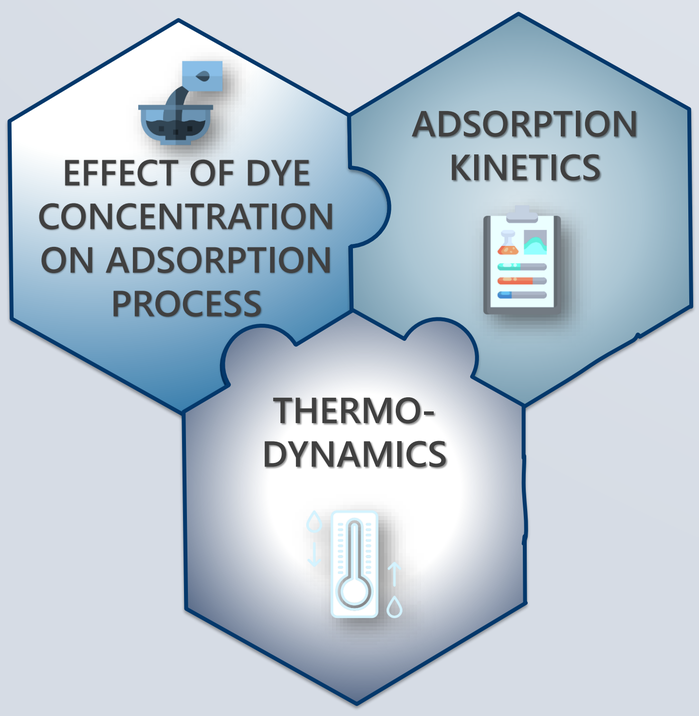
**Pseudo-second-order kinetic model [2]** $\frac{t}{q_t} = \frac{1}{k_2 * q_e^2} + \frac{1}{q_e}$

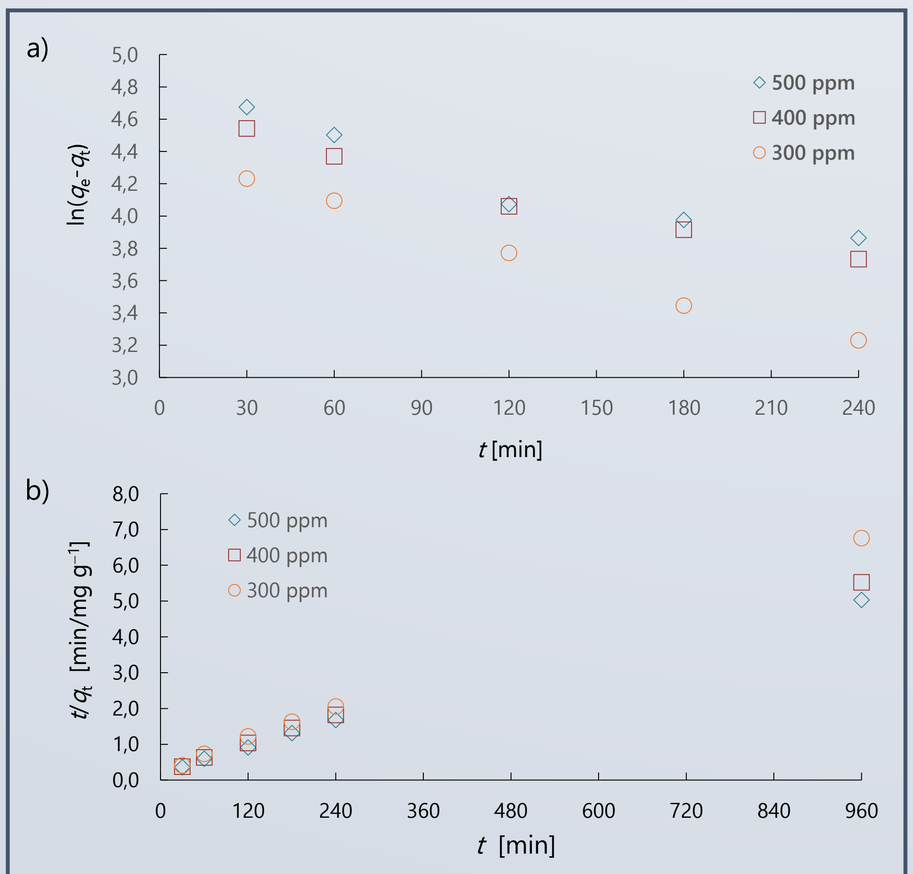
$k_1$ (min$^{-1}$) – rate constant of pseudo-first-order

$k_2$ (g mg$^{-1}$ min$^{-1}$) – rate constant of pseudo-second-order




*Influence of initial Everzol Black B dye concentration on dye concentration in the liquid phase $c_t$ (a) and efficiency of decolouration $E_d$ (b) after appropriate time of adsorption*




*Pseudo-first-order (a) and pseudo-second-order (b) kinetic models for the adsorption of the Everzol Black B dye in a concentration range from $c_0$ = 300 mg dm$^{-3}$ to $c_0$ = 500 mg dm$^{-3}$*

$$\Delta G^\circ = -RT\ln(K_c)$$

$$K_c = \frac{c_a}{c_e}$$

$\Delta G°$ (kJ mol$^{-1}$) – standard Gibbs free energy value of the adsorption process
$R$ (J mol$^{-1}$ K$^{-1}$) – universal gas constant
$K_c$ – equilibrium constant
$T$ (K) – temperature

*Standard Gibbs free energy values of Everzol Black B dye adsorption on activated carbon [3]*

| $c_0$ / mg dm$^{-3}$ | $c_e$ / mg dm$^{-3}$ | $c_a$ / mg dm$^{-3}$ | $K_c$ | $\Delta G°$ / kJ mol$^{-1}$ |
|---|---|---|---|---|
| 500 | 118.3 | 381.7 | 3.22654 | **– 3.1** |
| 400 | 52.4 | 347.6 | 6.63359 | **– 5.1** |
| 300 | 16.0 | 284.0 | 17.75000 | **– 7.6** |

*Kinetic parameters for the adsorption of Everzol Black B dye on activated carbon*

| | | Pseudo-first-order model | | | Pseudo-second-order model | | |
|---|---|---|---|---|---|---|---|
| $c_0$ / mg dm$^{-3}$ | $q_{e,exp.}$ / mg g$^{-1}$ | $q_{e,calc.}$ / mg g$^{-1}$ | $R^2$ | $k_1$ / min$^{-1}$ | $q_{e,calc.}$ / mg g$^{-1}$ | $R^2$ | $k_2$ / g mg$^{-1}$ min$^{-1}$ |
| 500 | **190.9** | 111.0 | 90.90 | 0.0039 | **204.1** | **99.66** | $7.069 \cdot 10^{-5}$ |
| 400 | **173.8** | 99.7 | 97.20 | 0.0038 | **185.2** | **99.64** | $7.856 \cdot 10^{-5}$ |
| 300 | **142.0** | 79.3 | 99.48 | 0.0049 | **149.3** | **99.86** | $1.259 \cdot 10^{-4}$ |

## Conclusions

- Calculated $\Delta G°$ values indicate that adsorption of Everzol Black B dye on activated carbon is a spontaneous process.
- The lowest concentration of Everzol Black B dye on powdered activated carbon leads to a higher adsorption efficiency. This was also confirmed by thermodynamic calculations, in which the highest negative value of Gibbs free energy was achieved for a dye concentration of $c_0$ = 300 mg dm$^{-3}$.
- Adsorption of Everzol Black B dye on activated carbon is kinetically controlled assuming a pseudo-second-order process. The pseudo-second-order model consider chemical sorption or chemisorption as the rate-limiting adsorption process.

## References

[1] S. Lagergren: Zur Theorie der sogenannten adsorption geloster stoffe. *Kungliga Sevenska Vetenskapsakademiens, Handlingar* **24** (1898) 1–39.

[2] Y. S. Ho & G. McKay: Pseudo-second order model for sorption processes, *Process Biochemistry* **34** (1999) 451–465.

[3] N. A. Travlou, G. Z. Kyzas, N. K. Lazaridis, E. A. Deliyanni, Graphite oxide/chitosan composite for reactive dye removal, *Chemical Engineering Journal* **217** (2013) 256–265.