# INFLUENCE OF CYCLOHEXANONE ON OXYGEN TRANSFER

***J. Derco[1] and A. Kovács[2]***

[1]Department of Environmental Engineering, Faculty of Chemical and Food Technology, Slovak University of Technology, SK-812 37 Bratislava, Tel.: +421-2-59325231, Fax: +421-2-52493198, e-mail: derco@chtf.stuba.sk
[2]Department of Forensic Medicine, Faculty of Medicine, Comenius University, SK-881 08 Bratislava

***Abstract.*** *The influence of cyclohexanone on oxygen transfer rate from air to water was studied. Significant changes of bubble size and distribution in a bioreactor were observed, particularly at higher cyclohexanone concentration values. The rate of water saturation with oxygen was markedly higher in fresh water in comparison to activated sludge suspension. Considerable change in the rate of oxygen saturation of water in the absence of sludge was observed already at cyclohexanone concentration 100 mg.l$^{-1}$. On the other hand, insignificant differences in the rate of oxygen saturation were measured in activated sludge suspension. The relationships between oxygen transfer coefficient values and cyclohexanone concentration for fresh water and sludge suspension were evaluated. These relationships enable to specify the description of oxygen transfer and oxygen balance in modelling of synthetic or real wastewater with cyclohexanone content as predominant organic substrate.*

***Key words:*** *activated sludge, industrial wastewater treatment, influence on oxygen transfer, overall mass transfer coefficient, oxygen transfer, and respirometric measurements*

## Introduction

Oxygen transfer into water can be influenced by the presence of some organic substances, mainly surfactants as a consequence of interface of phases area variation and consequently due to changes of oxygen transport coefficient value. Similar phenomenon was observed during experimental and mathematical modelling of industrial wastewater treatment processes. Biological processes of simultaneous nitrification and denitrification processes performed in the industrial Carrousel activated sludge reactor were investigated in our previous work [1]. The research was aimed to study an availability of separate wastewater stream with predominant content of cyclohexanone as a carbon source for biological denitrification. Other goal was to develop and verify mathematical model for description dynamic behaviour of the above processes.

Significant changes in size and distribution of air bubbles were noticed in activated sludge reactor after addition of cyclohexanone during experiments focused on modelling of simultaneous nitrification and denitrification processes. The concentration of cyclohexanone in term of COD was about 800 mg.l$^{-1}$. The shift from coarse-bubbled aeration in activated sludge with fresh water to fine-bubble aeration in the presence of cyclohexanone was observed. The influence of this phenomenon on oxygen transfer had been assumed.

The main goal of this work was to evaluate the influence of different concentration values of cyclohexanone in fresh water on oxygen transport rate. Another aim of the work was to study the influence of cyclohexanone on oxygen transfer rate in the presence of an activated sludge.

## Theoretical

In the systems used in the field of wastewater treatment, the rate of gas transfer generally is proportional to the difference between the existing concentration and the equilibrium concentration of the gas in solution. This relationship for oxygen transfer rate can be expressed as follows [2]:

$$\frac{dC}{dt} = (K_L a)(C_S - C) - (r_V) \qquad (1)$$

where

| | | |
|---|---|---|
| $(K_L a)$ | denotes overall mass transfer coefficient for oxygen | [s$^{-1}$] |
| $C_S$ | - saturation concentration of oxygen in solution | [g.m$^{-3}$] |
| $C$ | - concentration of oxygen in solution | [g.m$^{-3}$] |
| $r_V$ | - rate of dissolved oxygen consumption by biochemical reactions | [g.m$^{-3}$.s$^{-1}$] |
| t | - time | [s] |

The term $r_V$ in brackets indicates that this term is active only when biochemical reactions take place.

For estimation of the parameter $(K_L a)$ value Equation 1 was integrated analytically. The term $r_V$ was not considered during this procedure. Following equation was obtained by integrating of Equation 1 between $c_0$ and $c_t$ and $t_0$ and t (initial conditions $c_0 = 0$ and $t_0 = 0$):

$$c_t = c_S.\left(1 - e^{(K_L a.t)}\right) \qquad (2)$$

The values of overall mass transfer coefficient for oxygen were determined by grid search method.

## Experimental

The influence of cyclohexanone on oxygen transfer was investigated in lab-scale completely mixed activated sludge reactor. One set of experimental measurements was performed with fresh water and without the presence of activated sludge. The aim of other trials was to include and evaluate the presence of activated sludge on the phenomenon.

The decrease of pH and decantation of activated sludge were applied to minimize respiration activity of activated sludge. The activity of activated sludge microorganisms was suppressed by decreasing pH in the reactor to value 2. After this procedure sludge was several times decanted with fresh water in order to increase pH value back up.

A zero dissolved oxygen concentration in system before each measurement was reached by stripping process using nitrogen-gas.

The batch experiments were carried out at a temperature of 20 °C. The analyses of COD and MLSS concentrations were performed in accordance with standard methods [3]. Syland Dissolved Oxygen Meter was used to measure the dissolved oxygen concentrations. The measurements of specific respiration rates of activated sludge were performed by respirometric method [4] with the aim to evaluate the changes of activated sludge respiration activity.

## Results and Discussion

In Figure 1 there are shown some examples of the curves for oxygen saturation obtained by measurements performed in water without presence of sludge. Similarly in Figure 2 are plotted examples of the curves obtained by measurements performed in water with the presence of sludge. Cyclohexanone concentration values expressed as COD varied from 0 to 800 mg.l$^{-1}$ during the both measurements.

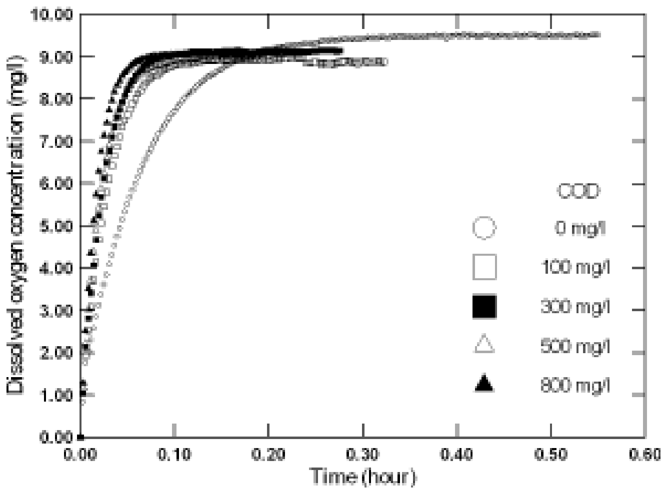


**Figure 1.** The influence of cyclohexanone on oxygen transport rate in water

From Figures 1 and 2 it is obvious that cyclohehanone significantly influences oxygen transfer into water. As it was mentioned, in both media, i.e. in fresh water and in water suspension of sludge there were observed considerable changes in the bubble size and distribution, particularly at higher cyclohexanone concentration values.

The rate of water saturation with oxygen is markedly higher in the absence of sludge, i.e. in fresh water. Figure 1 demonstrates significant change in rate of oxygen saturation in water without sludge presence already at cyclohexanone concentration 100 mg. l$^{-1}$. On the other hand, there are insignificant differences in the rate of oxygen saturation in the case of sludge suspension (Figure 2).

The values of oxygen transport coefficient for various cyclohexanone concentrations were obtained by applying Equation. 2. Influences of cyclohexanone concentration on these values are for both media (water and sludge suspension) shown in Figure 3.

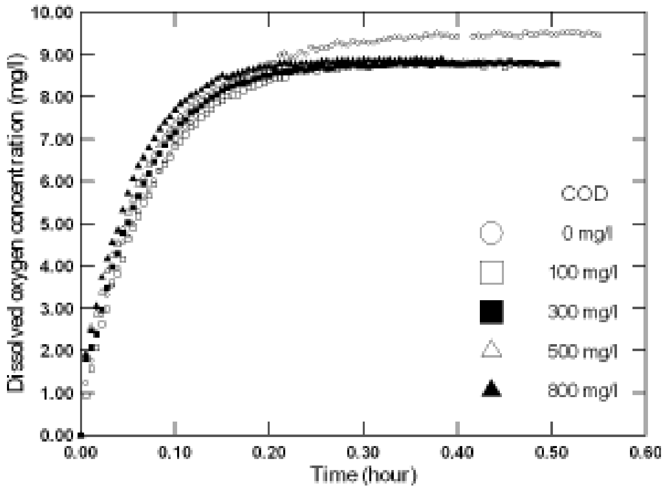


**Figure 2.** The influence of cyclohexanone on oxygen transport rate in water in the presence of sludge

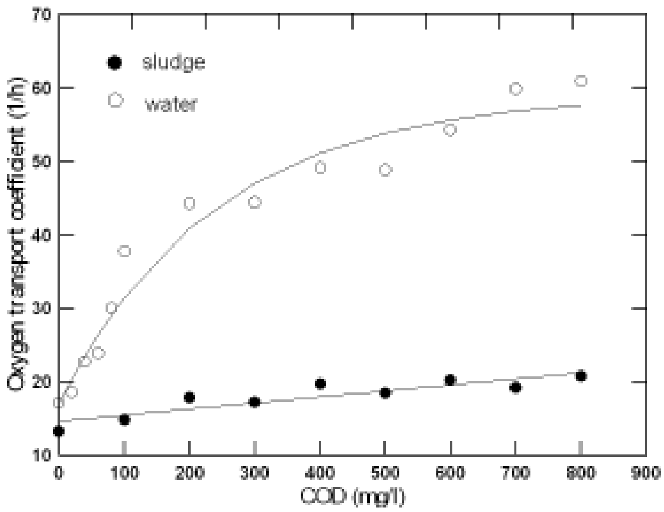


**Figure 3.** The influence of cyclohexanone on oxygen transport coefficient

Favourable influence of cyclohexanone on oxygen transfer rate in water without sludge presence is obvious from Figure 3. On the other hand, only a little increase of oxygen transport coefficient in the presence of sludge is evident. In addition, the value of oxygen transport coefficient in the presence of sludge in the system without cyclohexanone (COD = 0 mg.l$^{-1}$) is lower than the value measured in fresh water, i.e. in water without cyclohexanone and sludge presence.

The dependence of oxygen transfer coefficient values on the concentration of cyclohexanone values (given as COD) in fresh water can be expressed as follows:

$$K_L a = 59,1133 - 41,9406.e^{(-4,1688.10^{-3}.COD)} \qquad (3)$$

The relation between oxygen transfer coefficient values and cyclohexanone concentration in the presence of sludge can be described by the following equation:

$$K_L a = 14,6456 + 8,2305.10^{-3}.COD \quad (4)$$

## Conclusion

The aim of the work was to study the influence of cyclohexanone as organic component of an industrial wastewater on oxygen transfer, bubble size and distribution. The investigations were performed in the media of fresh water and suspension of activated sludge.

Coarse-bubble aeration was characteristic for the presence of cyclohexanone at concentration levels less than 300 $mg.l^{-1}$ COD in the both environments. The gradual change to fine-bubble aeration was observed at higher cyclohexanone concentration values.

Significant influence of cyclohexanone on oxygen transfer into fresh water follows from the work. The rate of water saturation with oxygen is considerably higher in the absence of activated sludge. Substantial change in rate of oxygen saturation in water without sludge occurs already at COD concentration 100 $mg.l^{-1}$. On the other hand, there are small differences in the rate of oxygen saturation of activated sludge suspension.

The parameter values of mathematical relations between oxygen transfer coefficient and cyclohexanone concentration values (given as COD) were estimated. These equations are valuable for modification of mathematical models for biological treatment of synthetic or real wastewater containing predominantly cyclohexanone as organic component of substrate. This enables to specify the description of oxygen transfer and oxygen balance in the above mentioned media.

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