A COMPARATIVE STUDY OF THE BOD RATE CONSTANT OF INDUSTRIAL WASTEWATER AND SEWAGE

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Abstract

The BOD is the amount of oxygen in mg/L required to stabilize polluted water completely by means of an aerobic process. The reactions occur in the BOD bottle as well as in streams are very complicated, it could be first order, or half order, or second order, or a mixture of these reactions. In this work the reaction would be considered as a first order reaction. A comparison of the BOD rate constant k of an industrial waste and a sewage sample was made. In this case The BOD rate constant k of the industrial waste was higher than that of the sewage sample. An analytical solution as well as a FORTRAN program were used to solve for the value of the BOD rate constant and the ultimate first stage BOD value .The period of the first stage could be known too.

Keywords: BOD, Rate constant, Industrial wastes, Sewage.

1. Introduction

The determination of the BOD rate constant is important for understanding the nature of the wastewater. In case of discharging this wastewater into streams, the rate constant would help in predicting the impacts of discharging the wastewater: on the life in the stream, on the dissolved oxygen values in the stream, and on the BOD values in the stream.

Tsivoglou [2] in his study of the factors affecting self-purification of polluted streams, he discussed the kinetics of de-oxygenation. The author considered both multicomponent BOD reactions (that is, simultaneous but independent first-order reactions) and sequential first-order BOD reactions resulting from the chain degradation of complex organic compounds, and indicates the use of such BOD reaction kinetics to obtain information on the oxygen-depleting characteristics of industrial wastewaters, and the value of this information in the design of treatment plants.

Hartmann [3] and others show from a literature review and from specially-devised experiments that the complex course of the BOD process cannot be described by one mathematical formula. They concluded that for low loads, the second-order reactions most representative, as the load increases the Michaelis-Menten law becomes, the controlling factor.

Jenelle and Gaudy [4] studied the kinetics and mechanisms of BOD, in open systems, simulated stream device, an open stirred reactor, in quiescent and stirred closed systems Biological solids concentration, bacterial and protozoan numbers, substrate analysis, and COD as well as biochemical oxygen utilization were employed to asses the performance of these systems. The results showed an increase of the oxygen uptake rates with the concentration of carbon source. A hyperbolic function similar to the Monod relation linked oxygen uptake and substrate concentration.

Landine [5] conducted long-term (1.5 - 3 months) BOD tests on samples comprised of different proportions of municipal sewage and river water at temperatures from 20^{o}C to 0.5^{o}C and an attempt was made to fit the data to first or second-order equations. They found that a second-order equation produced a better fit.

From literature the BOD rate constant k_1 (to the base 10) for domestic sewage is found to be about 0.1 d $^{-1}$ at 20^{o}C.In case of industrial wastes k would be different for each waste, it may be much higher than k of the sewage. The higher the k value is, the faster would be the depletion of the DO in streams (in case of disposing of the industrial wastes into streams without proper treatment).

This research work was conducted for the determination of the BOD rate constant for sewage and for one of the industrial wastes as an example. The industrial waste considered in this work was one of the effluents from RAKTA. The analysis of the waste as well as the value of k were taken from (Abdelrasoul 1996), and will be shown here as well for comparison with the municipal wastes values from the Eastern Sewage Treatment Plant in Alexandria.

2. The BOD reaction

The BOD is the amount of oxygen in mg/L required to stabilize water completely by means of an aerobic process. This process takes about 30-60 days to complete both the carbonaceous matter and the nitrogenous matter. The carbonaceous matter is attacked first by the bacteria where this process is called the first stage of the BOD. The first stage BOD is the only stage will be discussed here.

3. The BOD equation

The reactions occur in the BOD bottle as well as in the streams are very complicated it could be a first order, or half order, or second order reaction. It could be a mixture of these reactions. However, the reaction will be considered here as a first order reaction, so the equation is:

$$y = L\,(1- e^{-kt}) \qquad (1)$$

Where:

y = the BOD consumed (mg/L)
L = the ultimate first stage BOD (mg/L)
k = the rate constant (t^{-1}) to the base e
t = time in days

According to Taylor's expansion for the e^x, Equation (1) could be rewritten as follows:

$$y = L (1 - e^{-kt)} = L\,kt\,(1 - kt/2 + (kt)^2 /3! - (kt)^3/4! + ... \qquad (2)$$

with an approximation of Equation (2) and by using the binomial theorem.

Equation (2) could be rewritten as:

$$y = L\,kt(1 - kt/2 + (kt)^2/6 - (kt)^3/21.6 + ... \qquad (3)$$

which again could be rewritten as :

$$y = L\,kt/(1+kt/6)^{3} .... \qquad (4)$$

Equation (4) could be rewritten as a straight line equation

$$(t/y)^{1/3} = 1/(Lk)^{1/3} + (k^{2/3}/6\,L^{1/3})\,t .... \qquad (5)$$

Where: $1/(L\,k)^{1/3}$ = intercept of the line

$(k^{2/3} /6\,L^{1/3})$ = slope of the line

4. Solution for k and L

A FORTRAN program was written to solve for the slope and intercept of the line and hence for k and L.

5. Samples

The sample of RAKTA wastewater was taken from pulp mill number 1, see [1].

The sample of the Eastern Sewage treatment Plant was taken from the influent of the plant in February 1999.

6. Experimental Work

For each sample, the following procedure was done. Two dilutions of the sample were made for the BOD test:

- 21 BOD bottles for each dilution were put in the incubator at 20°C.
- The D.O for three bottles from each dilution was measured each day for the determination of the BOD. The BOD of the blank was also done.

7. BOD and DO determination

The BOD determination was according to the Standard Methods [7]. The whinkler Azide modification was used for the determination of the DO.

8. Analysis of results

Table 1 shows the analysis of the wastewater for RAKTA as well as the analysis for the sewage sample.

Table 2 shows the average BOD values for each day for the six days period for RAKTA sample as well as for the sewage sample.

These BOD values were considered as the data for the computer program that solves for k and L. the regression lines for Equation (5) for the two samples are shown in Fig. 1 and Fig. 2 .

9. RAKTA wastewater results

The equation of the line for Equation (5) is:

$$(t/y)^{1/3} = 0.009051 (t) + 0.168627$$

k = 0.322 d-1
L = 647.6 mg/L

10. The sewage sample results

The equation of the line for Equation (5) is:

$$(t/y)^{1/3} = 0.009616 (t) + 0.259461$$

k = 0.2224 d^{-1}
L = 257. 5 mg/L

11. Conclusions

1. The rate constant k of the BOD reaction of one of RAKTA's wastewater as well as the sewage from the Eastern Sewage Treatment Plant were determined for a 20^oC temperature.

2. A procedure was established for more work on the subject. For example, a recommended future study is to determine the effect of temperature on the reaction rate constant.
3. The BOD reaction rate constant as well as the ultimate first stage BOD could be determined for different wastewaters.

Nomenclature

BOD = Biochemical oxygen demand (mg/L)
y = the BOD consumed (mg/L)
L = the ultimate first stage BOD (mg/L)
k =the rat constant (t^{-1}) to the base e
k_1 =the rate constant (t^{-1}) to the base 10
t = time in days
S.S. = Suspended solids (mg/ L)
COD = Chemical oxygen demand (mg/L)

Table 1. Analysis of Rakta and the Sewage Sample

Sample	Parameter			
	pH	S.S. mg/L	BOD_5 mg/L	COD mg/L
RAKTA	8.1	825	487.2	1200
Sewage Sample	7.4	243	174.5	400

Table 2. Average BOD values for each days for the two samples in mg/L

Sample	Days					
	1	2	4	5	6	7
RAKTA	147.9	399.3	467.9	487.6	538.6	567.2
SewageSample	50.0	95.0	153.0	174.5	186.0	200.0

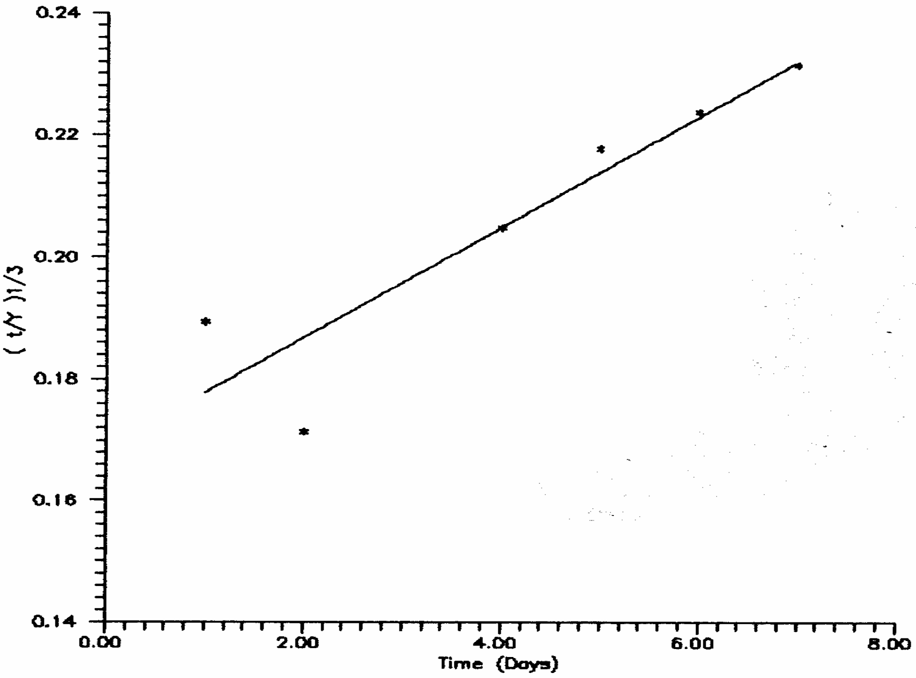

Fig. 1. Regression line for Eq. (5) for RAKTA sample

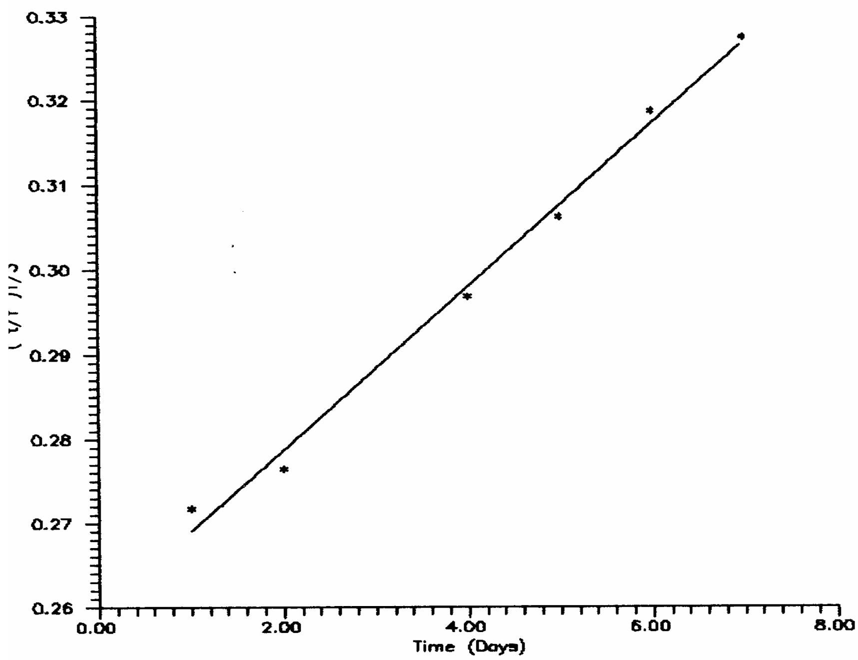

Fig. 2. Regression line for Eq. (5) for the sewage sample

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