BOD exertion kinetic constants for small paper mill wastewaters

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ABSTRACT

The first stage BOD exertion kinetic constants for agro-residues based small pulp and paper mill (ARSPPM) effluents have been determined and subsequently, the most suitable statistical method for the evaluation of these constants have been foundout. Various statistical methods have been reviewed and used for estimation of BOD reaction rate constant (K) and ultimate BOD (L). The average value of K and L for pulping section effluents (stream A) is 0.1673 d^{-1} and 2123 mgl^{-1} respectively, whereas, for paper making section effluents (stream B) these values are 0.1182 d^{-1} and 189 mgl^{-1} respectively. Based on kinetic constants, the total time (t_u) required to decompose the organic matter to tolerance limit by natural process (without treatment) has been estimated to be 10 and 5 days respectively for stream A and B.

Te check the statistical confidence between the observed and estimated values, standard deviation, regression coefficient and coefficient of correlation calculated, indicate that, the method of moments with and without lag phase consideration gives the best approximations.

INTRODUCTION

The 5-day BOD is a widely used parameter to assess wastes in water and sewage. BODvalue determined by a solitary analysis has no statistical confidence in its reliability, Moreover, it reveals nothing about the magnitude of the ultimate BOD nor can it make any estimate of the velocity of reaction K By knowing value of constant K, the value of BOD for any time t, including the theoretical ultimate BOD of the first stage equation can readily be determined.

Apparently, no literature is available on BOD kinetic studies particularly on ARSPPM effluents. Therefore, attempt has been made to evaluate K and L values for BOD removal for effluents from a small paper mill, essentially using agricultural residues.

MATERIALS AND METHODS

BOD DATA GENERATION

A typical small paper mill producing 10 to 14 tons per day unbleached kraft paper using agro-residues (50%) like paddy straws, bagasse, hessian (35%) and waste paper (15%) was selected for effluents collection. The effluent generation is about 150 m^3 per ton of paper with total pollution load in terms of total solids, total suspended solids, biochemical oxygen demand and chemical oxygen demand of the order of 750, 320, 145 and 440 kgt^{-1} of paper, respectively. Approximately 90% of the total pollution load is due to stream A only (Goyal, 1989).

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Stream A is constituted by poucher washer, beaters and hydrapulper (used mainly for internal secondary fibres recycling and the waste from the hydrapulper is discharged periodically), whereas, stream B includes paper machine drain (white water), thickener and fresh water tanks overflows and rejects from centricleaners. Composite samples were collected from both the outlet effluent streams and were analysed as per standard methods (APHA, 1985) to determine the daily BOD value and hence to evaluate K and L using various statistical methods available.

METHODS USED FOR ESTIMATION OF BOD KINETICS

The first order equation for first stage BOD has been widely adopted and several methods have already been developed for solving the equation based on experimentally determined BOD data The rate of bio-chemical oxygen demand of organic matter has been observed to be proportional to the remaining concentration of unoxidised substrate. This can be represented by the following equation:

$$\frac{dy}{dt} \; \alpha \; (L-Y) \quad \text{or} \quad \frac{dY}{dt} = k\,(L-Y)$$

Various methods used for the estimation of BOD rate constant and ultimate BOD are listed here with reference.

- Log difference method (Fair, 1936)
- Reed Theirault method (Theirault, 1927)
- Thomas slope method (Thomas, 1937)
- Two point method (Rhame, 1956)
- Finite difference method (Fujimoto, 1964)
- Thomas graphical method (Thomas, 1950)
- Wiegand method (Wiegand, 1954)
- Sletten method (Sletten, 1966)

Method of moments, without lag period (Moore et al., 1950)

Method of moments, considering lag phase (Moore et al., 1950)

RESULTS

Experimentally observed daily BOD values for both the streams are presented in **Table-1**.

Table 1 Observed BOD values

Time, days	BOD values, mg l^{-1} Stream A	Stream B
1	720	45
2	1160	80
3	1440	105
4	1640	125
5	1800	140

Table 2 BOD rate constant K, ultimate BOD L, decomposition time t_u and standard deviation σ

Method	Stream A K	L	t_u	σ	Stream B K	L	t_u	σ
Log difference	0.1649	2128	9.9	26	0.1198	187	4.8	0.4
Reed theirault	0.1854	2015	8.7	15	0.1262	177	4.4	1.4
Thomas slope	0.1916	2010	8.4	17	0.1245	185	4.6	0.3
Two point	0.1916	1979	8.3	17	0.1249	183	4.5	0.5
Finite difference	0.1463	2196	11.2	33	0.9180	215	6.9	2.1
Thomas graphical	0.1769	2035	9.1	14	0.1164	192	5.0	0.8
Sletten	0.1229	2600	14.0	99	0.1115	194	5.3	0.8
Method of moments	0.1880	2012	8.5	16	0.1210	186	4.7	0.3
Wiegand	0.1527	2140	10.7	25	0.1215	188	4.7	0.5
Considering lag phase								
Thomas slope	0.1643 $t_o = -0.1032$	2100	9.8	9	0.1210 $t_o = -0.016$	187	4.8	0.4
Method of moments	0.1560 $t_o = -0.162$	2130	10.6	8	0.1210 $t_o = -0.0064$	186	4.8	0.3

The BOD values indicate that approximately 54% and 43% of the ultimate BOD is exerted in first two days for stream A and B, respectively and as the time passes the process of organic matter consumption slows down. To decompose all the organic matter, it takes about 20 days time.

The average value of K, L and t_u have been calculated by taking the arithmatic mean of the values determined by the methods mentioned above and based on the determined values of K and L, the daily BOD values have been computed and compared with the observed experimental values. Standard deviation between the experimentally observed and theoretically calculated values have been computed and presented in **Table 2.**

CONCLUSIONS

For stream A, the value of K ranges between 0.1229 to 0.1916 d^{-1} with an average of 0.1673 d^{-1}, whereas, for stream B, it ranges between 0.0918 to 0.1262 d^{-1} with an average of 0.1182 d^{-1}.

For stream A, the value of L ranges between 2010 to 2600 mgl^{-1} with an averge of 2123 mgl^{-1}, whereas, for stream B, it ranges between 177 to 215 mgl^{-1} with an average of 189 mgl^{-1}.

The total time required to decompose the organic matter present in the effluent streams to the corresponding values of 50 mgl^{-1} BOD (as tolerance limit specified for effluent discharge) by natural process of oxygen transfer from the atmosphere (without any treatment) is estimated to be about 10 days and 5 days, for stream A and B, respectively.

Based on standard deviation, regression coefficient and coefficient of correlation, it is observed that the method of moments with and without lag Phase consideration produces best approximation. Besides these, Thomas slope method with and without lag phase consideration and Reed Theirault method produce good enough approximations for stream A, whereas, for stream B, all the methods show more or less comparable approximations.

It is interesting to note that, the estimated BOD values are in close approximation to the experimentally observed values. It indicates that the assumption of first order equation for BOC exertion kinetics, is true for ARSPPM effluents.

The knowledge of the values of BOD exertion kinetic constants will help the engineers in design and operation of wastewater treatment systems and in the estimation of the effluent quality requirements for ultimate disposal into receiving streams.

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NOTATIONS

The following symbols are used in this paper :

BOD = biochemical oxygen demand

C.R. = cross reference

K = reaction rate constant (base 10), d^{-1}

L = ultimate BOD, mgl^{-1}

t = time intervals, day

t_u = total time required to decompose the organic matter corresponding to the BOD value of 50 mgl^{-1}, day

Y = BOD corresponding to t days, mgl^{-1}

σ = standard deviation