Dissolved oxygen measurements on Uberabinha River for determining the oxygenation constant.

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Eight stations were chosen, in the twenty-one kilometers of the Uberabinha River, for DO measurements. As a result, two different modeling approaches were adopted to calculate the oxygenation constant (k_1). In this paper, the modeling results of the segment of the river in Brazil are presented. Experimental data provides a very useful tool to calculate the oxygenation constant (k_1). DO measurements can help the analyses of all weekly and positions variations of dissolved oxygen, replacing the unique value of one measurement in two models. The results of deoxygenation and reaeration constants versus time have shown a representative overview of the surface water quality status.

Keywords: dissolved oxygen; aeration constant; deoxygenation constant; river.

1. Introduction

In several countries around the world, monitoring data are collected and provided to the public through the internet. Measurements include quantity and quality data for groundwater and surface water bodies, from water table and discharge to specific conductance, temperature and dissolved oxygen [Littlejohn et al., 2002, Simonet, 2002]. Recently, Salama et al., 2012 described a hydro-optical model (HydroSat) for deriving water quality variables from satellite images. HydroSat corrects images for atmospheric interferences and simultaneously retrieves water quality variables and some applications for the Nile River demonstrated that reliable estimates of water quality were obtained. It is unclear about the transformation behavior of water quality parameters. The network in Uberabinha River was developed without any assistance of the local prefecture, and it was an important concern of the university group that certain small industries put on the river, in the form of waste disposal.

The objectives of this study are to measure DO and temperature of the river water and examine the spatial variations and monthly or seasonal fluctuations of the deoxygenation and reoxygenation constants in a narrow river in Brazil. The work basically deals with the dissolve oxygen measurements at eight locations on a river in Brazil for estimation of rate constants (k_1 and k_2) using standard procedures i.e. using Streeter and Phelps equation and O'Connor and Dobbins equation (O'Connor, 1967).

Understanding the seasonal and position changes of the deoxygenation and reoxygenation parameters gives insight into the process mechanism involved and helps devising short and long term operational strategies.

2. Methodology

For the measurements of dissolved oxygen and temperature, the Oxymeter (model DO 5519) with appropriate oxygen probe was used. It is portable two-wire equipment. Water column DO (mg O_2 L^{-1} or % saturation), temperature (T, ^{0}C), declivity (m/km), depth (m) and river speed were continuously monitored in surface and bottom waters at eight stations at Uberabinha river (Fig. 1):

S1 at the BR 050, S2 Arame Bridge, S3 Bom Jardim, S4 Caça-Pesca, S5 Cidade Jardim, S6 Silvio Rugani, S7 São Pedro, S8 at the BR 365.

The same oxymeter probe was used at each station; the sonde collected data from the surface to the bottom at 0.5 m intervals in depth and at 2 m intervals transversally. Data were collected at approximately 4 days intervals from April to October, 2012. No variations were observed in the values when sampling in depth, then transversal results will be shown only. Sondes were inspected, checked for drift, recalibrated and the data were downloaded bi-weekly. For the period studies, the river speed was in the range of 0.18-0.34 $m.s^{-1}$ and deeper position was less than 1.69 m.

3. Results and Discussion

3.1. Determining k_1 using the Streeter & Phelps equation (1925).

Between the stations A7 (Fig. 8) and A8 (Fig. 9), it was possible to obtain k_1 using the classical Streeter & Phelps model. Stations are separated by 3.0 km, approximately. Station A7 is regarded the polluted source. This one has presented average DO in the range of 3.0 – 4.1mg/L, and the temperature varied in the range from 23.5 to 26.8°C. Then, it was possible to calculate the initial deficit (D_a) in this location after the mixing of the streams. For the Station A8 (BR 365 bridge) it was obtained average values for oxygen deficit (D_t) at four transversal positions (A1-A4), ultimate BOD (L_a), reoxygenation constant (k_2) and the time t (time travel, d^{-1}). The ultimate BOD was estimated using incubation method at 20°C for a period of 20 days, following the procedures described in NBR 12614. For the period the result was found to be around BOD_{20}=17.5 ± 0.3 mg/L. Table 1 illustrates the average values for each month. The frequency of sampling was four times per month and twice a week.

The integrated form of the classical Streeter-Phelps deficit equation (2) is:

$$D_t = \frac{k_1}{k_2 - k_1} L_a \left(e^{-k_1 t} - e^{-k_2 t} \right) + D_a e^{-k_2 t} \tag{2}$$

where:
D_t= oxygen deficit at any time t, (mg/L);
L_a= ultimate oxygen demand (BOD) (mg/L);
D_a= oxygen deficit below the pollutant discharge location, (mg/L);
k_1= deoxygenation constant (d^{-1});
k_2= reoxygenation constant (d^{-1});
t= time travel (d^{-1}).

The deficit in dissolved oxygen (DO) is the difference between saturation (maximum dissolved oxygen the water can hold) and the actual DO.

Table 1 – k_1 results obtained through calculations using Eq. (2)

Month/year	k_1 (d^{-1})				$\overline{DO}$ mg/L	T(°C)
	A_1	A_2	A_3	A_4		
apr/12	0.23	0.23	0.23	0.23	4.4	23.7
may/12	0.34	0.43	0.41	0.37	4.7	21.8
jun/12	0.29	0.37	0.36	0.31	5.1	20.9
jul/12	0.46	0.47	0.46	0.42	5.0	20.6
aug/12	0.15	0.14	0.15	0.15	4.6	21.3
sep/12	0.08	0.10	0.10	0.07	4.1	23.1
oct/12	0.07	0.12	0.11	0.09	4.2	24.5

The k_1 values varied from 0.07 to 0.47 d^{-1} the differences could be attributed for the draughts and rainy periods. The higher results for k_1 were found in the months of April to July, when the weather presented heavy rains. This result was also observed by some researchers [Mcbridge et al., 2005), which have shown that there is a close relation with k_1 and seasonal periods. In addition, it can be noted that the DO level in this sector presented a maximum result in June and the values decreased from August.

3.2 Global mass balance to calculate the deoxygenation constant (k_1).
It is appropriate to write a mass balance diagram of DO in this small stretch of river which has 20.85 km of length. This comprehensive mass balance accounts for all the inputs (BR 050 Bridge (e_1), Bom Jardim station (e_2) and São Pedro small stream (e_3)) and outputs (BR 365(s_1)). It is considered that are three streams entering and only one leaving the reach or control volume. Also, in this mass balance equation, the mass of DO entering from the atmosphere will be represented by $k_2 D$ and the mass removed by all consuming will be written as $k_1 L_o$. The simplified mass balance equation (3) is then:

$$\dot{Q}_{H_2O}^{e_1} \cdot DO_{O_2}^{e_1} + \dot{Q}_{H_2O}^{e_2} \cdot DO_{O_2}^{e_2} + \dot{Q}_{H_2O}^{e_3} \cdot DO_{O_2}^{e_3} - \dot{Q}_{H_2O}^{s_1} \cdot DO_{O_2}^{s_1} = k_1(VC)L_a - k_2(VC)D \qquad (3)$$

where: $\dot{Q}$ is the mass flow rate of water (kg/day) and e_1; e_2; e_3; s_1 are the stream of water in and out. The measurements of DO were made four times per month (A1-A4) and the mean value, for three or four positions, in each sector (e_1-e_3, s_1), was used to calculate k_1 which is presented in Table 2. The control volume (VC) was monthly calculated using de mean values for depth and width of the stretch considered. The mass flow rates of streams entering and leaving were monthly estimated measuring speed and area available in each station.
Having all values in hand, for each measurement made in each month the analytical solution of equation (3) gives the results in Table 2.

Table 2 – Estimated values of k_1 using global mass balance modeling.

k_1(d^{-1})

Month	A1	A2	A3	A4	DO (mg/L)	VC (L)	T (°C)
Apr/12	0.30 ± 0.02	0.21 ± 0.02	0.23 ± 0.02	0.27 ± 0.03	4.4	597773.21	23.7
May/12	0.26 ± 0.02	0.19 ± 0.02	0.20 ± 0.02	0.24 ± 0.02	4.7	582729.47	21.8
Jun/12	0.25 ± 0.01	0.18 ± 0.01	0.19 ± 0.01	0.23 ± 0.01	5.1	572481.70	20.9
Jul/12	0.24 ± 0.02	0.18 ± 0.04	0.19 ± 0.04	0.22 ± 0.02	5.0	561578.07	20.6
Aug/12	0.28 ± 0.03	0.20 ± 0.02	0.21 ± 0.02	0.25 ± 0.03	4.6	544484.78	21.3
Sep/12	0.32 ± 0.01	0.24 ± 0.01	0.25 ± 0.01	0.30 ± 0.01	4.1	515791.01	23.1
Oct/12	0.34 ± 0.03	0.26 ± 0.03	0.27 ± 0.03	0.32 ± 0.03	4.2	523989.23	24.5

Generally, as can be seen, in Table 2 the k_1 values varied in the range of 0.18-0.32 d^{-1} in the period studied. According to literature (Gray, 2004) the river can be considered as not polluted slow stream. Low values for standard deviations lead us to conclude that deoxygenation coefficient can not change with the transversal position more than 10%. Besides, regarding the same month, it can sometimes increase or decrease in around 40%, then the classification of the river has a seasonal relation. There is a minimum point in July when the day is colder than the other. Then, this river is characterized by significant seasonal variation of k_1 constant; otherwise for k_2 values had been observing that spatial and seasonal variations have really affected them.

4. Conclusions

Using both models, observing results in these Tables 2-3 were revealing to be very similar and can be considered as representative of the river water quality, as far as oxygenation is concerned, and it also outlines a part of the natural processes that take place along the river bed.

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