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RESEARCH ARTICLE

WATER QUALITY MODELING: A BRAZILIAN EXPERIENCE IN WATER RESOURCE MANAGEMENT FOR DECISION MAKING IN WASTEWATER TREATMENT PLANTS

[1,*]Letícia de Barros Macedo, [2]Guilherme Henrique Cavazzana, [3]Mariana Antonio de Souza Pereira, [4]Fernando Henrique Garayo Junior and [5]Fernando Jorge Corrêa Magalhães Filho

[1]Sanitary and Environmental Engineering – Dom Bosco Catholic University
[2]Environmental Engineer and Doctor of Environmental Sanitation and Water Resources – Federal University of Mato Grosso do Sul
[3]Sanitary and Environmental Engineering – Dom Bosco Catholic University
[4]Environmental Engineer - Pontifical Catholic University of Campinas, Master in Environmental Technologies – Federal University of Mato Grosso do Sul
[5]Sanitary and Environmental Engineer – Dom Bosco Catholic University, Doctor of Environmental Sanitation and Water Resources – Federal University of Mato Grosso do Sul. Professor of the Post-Graduate Program of Environmental Sciences and Agricultural Sustainability - Dom Bosco Catholic University

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ABSTRACT

In order to reduce water conflicts and to attend to multiple water uses, this study evaluated water quality in the Ribeirão das Botas Stream basin in Brazil's Central-West region, in regards to the evolution of legal and institutional aspects at the federal and state scope, mainly with the inclusion of the legal instrument to authorize water use rights. Through a self-purification study with effluent discharge simulated from a wastewater treatment plant, four points along the river were evaluated during the dry season, using the QUAL-UFMG model, for the parameters DO (dissolved oxygen), BOD (biochemical oxygen demand) and total coliforms. Three effluent discharge simulations were carried out. The first scenario encompassed a single criterion: maximum BOD concentration discharged according to legislation (120 mg.L^{-1}), where it resulted in DO below 7 mg.L^{-1} and BOD outside of the classification class 2, exceeding the value of 5 mgBOD.L^{-1}. The second scenario used the limit of the diluted concentrated value in the receiving water for the BOD (<5 mg.L^{-1}) and DO (> 5 mg.L^{-1}) parameters. The third scenario related the quantitative aspect linked to the authorization instrument to accommodate the uses of the river basin. The physical-chemical and biological analyzes with the presence of *E. coli* and total phosphorus parameters was in disagreement with the current standards, which shows that there is a negative impact due to anthropic activities in the region caused by inadequate urban effluent discharge and agricultural activities. It was observed that in scenarios 2 and 3, the evaluated parameters respected the river's support capacity, which presented DO above 7 mg.L^{-1} and BOD below 5 mg.L^{-1}. However, for the stream's support capacity to be met without changing its classification, the wastewater treatment plant that is to be implemented should have a maximum flow of 0.43 m^3.s^{-1} and a minimum efficiency of 96%, not 65% or 88% according to scenarios 1 and 2.This study permits assistance to the water resource management council for decision making in the face of multiple use conflicts with the use of mathematical modeling for self-purification studies according to the evolution in the legislation, taking into account not only qualitative aspects, but also quantitative and diverse water uses.

***Corresponding author:**

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INTRODUCTION

Water pollution has become a problem in many countries because of the growing demand from population growth, where basic infrastructure systems such as water distribution, domestic wastewater, rainwater drainage and solid waste management cannot sustain such developments, damaging natural water quality, due to inadequate disposal of generated liquid and solid waste. As a result of pollution and poor basic sanitation service distributions, it is estimated that 80% of the world's population faces water shortage risks (Bakker, 2012).

Li (2010), in studies about water quality, points out that with industrialization and rapid urbanization, the quality of water bodies has degraded. According to the National Sanitation Information System, 42% of Brazilian families do not have a wastewater service, and in addition, from the collected wastewater only 41% receives treatment before being discharged into water bodies (SNIS, 2017). During wastewater treatment plant (WWTP) designs, Von Sperling (2005) states that it is necessary to carry out specific studies on the natural mechanisms in the water. These mechanisms consist of dilution capacity, biological oxidation of organic matter, reaeration and sedimentation, which are capable of restoring the quality of water bodies, close to the pre-discharge quality. This process is called self-purification and determines the capacity of a water body to receive discharge from a given treated effluent. In addition, there should be no sudden changes in the water quality of an aquatic environment, nor should it prevent the water resource from having multiple uses, mathematical models are commonly used.

For Mendes and Cirilo (2001) and Teodoro *et al*. (2013), mathematical models are efficient tools to represent the natural behavior of water resources, to assist in the management and qualitative monitoring, as well as to evaluate the impacts of pollutant loads in discharged water. It also allows for the simulation of different scenarios of water resource use, obtaining useful information for a reflection on adequate planning and efficient decision making in a river basin (Cunha *et al*. 2013). Being possible to choose appropriate effluent treatment technologies for each reality, such as UASB reactors, with BOD removals varying between 60-75% and 90%, stabilization ponds in the order of 85 and 90% BOD removal, activated sludge with BOD removals close to 98% in addition to nitrification capacity (Von Sperling, 2014), or even more sustainable and ecological technologies, with high BOD removal (over 90%), nutrient recovery, and lower implementation, operation and maintenance costs such as constructed wetlands (Masi, 2009; Vymazal, 2011; Langergraber, 2013).

Several studies involving water quality modeling in rivers have used the QUAL2E model, and more recently QUAL2K (Gastaldini*et al*., 2002; Zhang *et al*., 2012a). Von Sperling (2007), developed a QUAL-UFMG platform, based on QUAL2E simplifications, thus adapting its equations. Since then, several authors have started to use the QUAL-UFMG model (Costa *et al*., 2010, Teodoro *et al*., 2013, Oliveira *et al*., 2017). Through these models, carrying out studies on different water quality scenarios, Gastaldini *et al*., (2002) on the Rio Ibicuí-RS, Costa *et al*., (2010) on the Ribeirão do Ouro-SP and Zhang *et al*. (2012a) on the Honggi-China River, have shown that the factor that has the greatest influence on water pollution deteriorating its quality is the discharge of inadequate effluents. Without adequate treatment and without complying with the maximum limit allowed results in contaminating soil, water bodies, animals and biota, compromising self-purification of rivers and degrading the environment. Globally, water quality reduction is a major contributor to fresh water scarcity, and this requires more integrated water management; linked to availability and quantity (Ayandiran, 2018), as there are problems arising from conflicts due to multiple uses of this resource as evidenced in several basins, such as the Paraopeba River, Brazil (Silva *et al*., 2010). This required an adequate water resources management program. Thus, there was a great advance with the creation of the Federal Law 9.433/97, which instituted the National Policy of Water Resources, in which one of its instruments is toauthorize water use rights and states have autonomy in water management. In Brazil, in the State of Mato Grosso do Sul, anauthorization manual for water resource use rights was created as a management tool, established by the State Policy for Water Resources, State Law N° 2,406, January 29, 2002 and regulated by State Decree N° 13990, July 2, 2014.This tool is used to ensure qualitative and quantitative control of water resource use. In this context, the present work had the objective of evaluating Ribeirão das Botas Stream's support capacity located in the State of Mato Grosso do Sul, Brazil, in self-purifying discharged treated domestic wastewater in three efficiency scenarios. The scenarios are based on the legislative evolution in relation to discharge concentrations, using (i) the maximum allowed concentration by legislation, (ii) the dilution capacity of the discharged effluent, including quantitative aspects and (iii) the concern of quality and quantity, also regarded authorization and multiple use, with concern for conflict management between users. This study permits assistance to the water management council for decision-making in the face of multiple use conflicts, as well as to guide water distribution and wastewater collection and treatment services regarding the feasibility of implementing a WWTP.

MATERIALS AND METHODS

Description of the study area

The Ribeirão das Botas Watershed is located in the municipalities of Campo Grande and Jaraguari, in the State of Mato Grosso do Sul, Brazil. It has a total area of 581.72 km² and is part of the Planning and Management Unit of Rio Pardo - UPG Pardo, which, in turn, belongs to the Paraná River Hydrographic Basin (Figure 1). The Ribeirão das Botas Stream is close to a superficial spring used for water distribution (by Águas Guariroba, the local water concessioanary) in the municipality of Campo Grande, which supplies 34% of the population. The blue area in Figure 1 is Guariroba's Environmental Protection Area (APA Guariroba). Due to its proximity to the Miguel Letteriello Business Center (northwest of the municipality), there are industrial effluents and sanitary wastewater treated by individual systems installed and held responsible by each of the industries.

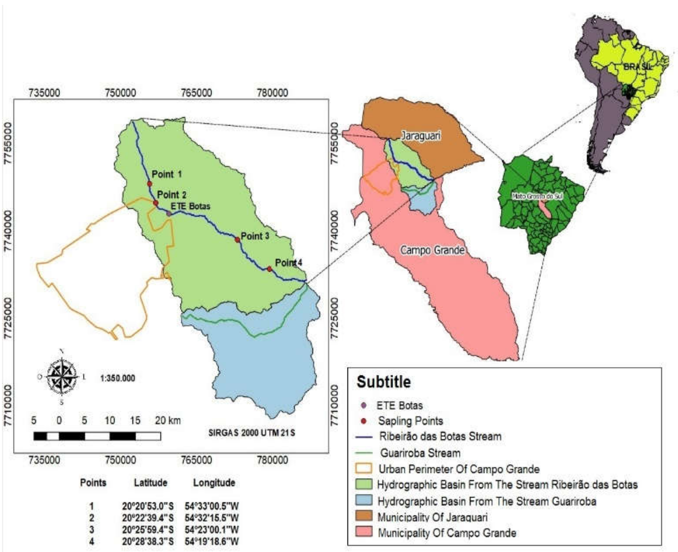

Figure 1. Ribeirão das Botas Stream Location Map.

Escherichia coli (E. coli) was observed at some of the points monitored by SEMADUR (2009) along the Ribeirão das Botas Stream, which is indicative of clandestine domestic wastewater discharge in rainwater galleries due to the proximity to the Nova Lima neighborhood, also located to the northwest of the municipality. Currently, this neighborhood has no sewage system.

Water Quality Monitoring, Sampling and Analysis: The monitoring points were located in places to represent the characteristics of the river basin and to be homogeneously distributed throughout the study area (Figure 1): Point 1, upstream of the municipality, without urban interference; Point 2, with interference from possible clandestine discharges; Points 3 and 4, downstream of the Botas WWTP. The latter two were used for the calibration of the model and, consequently, for the self-purification capacity forthe design studyof a WWTP in the region. The collection, storage and preservation procedures for the physical-chemical and microbiological parameters analyzed were: temperature (T), pH, color, transparency, turbidity (Tu), dissolved oxygen (DO), biochemical oxygen demand (BOD) total dissolved solids (TDS), sedimen table solids (SS), total coliforms (TC) and fecal coliforms (*E.coli*), according to recommendations by the Standard Methods for the Examination of Water and Wastewater (APHA, 2012). Flow measurements were performed at the same points and dates of the qualitative samplings. The flow measurement procedures were carried out using Newton Windlass equipment (Hidromec, Brazil), following the Equal-Width-Increment (EWI) methodology. This methodology was proposed by ANA (2012) and applied by Maldonado *et al.* (2015) and Garbossa *et al.* (2015) in different regions of Brazil.

Scenarios Simulated: Figure 2 shows the one-line diagram for the simulated scenarios. Scenario 1 (S1) was based on maximum domestic characteristic values of treated effluent discharge, as recommended by CONAMA Resolution 430/2011, which, for the parameter BOD, is 120 mg.L^{-1}, for a water course receiving low concentrations of raw sewage. Scenario 2 (S2) took into account CONAMA Resolution 357/2005 and 430/2011, which states that the discharge concentration will depend on a receiving body's self-purification capacity study. This confirms that the minimum concentrations of dissolved oxygen (DO) and biochemical oxygen demand (BOD) will not be disobeyed by the reference flow conditions (Q_{95}), with the exception of the mixing zone. Scenario 3 (S3), in addition to taking into account the qualitative conditions, according to the S1 discharge concentration restrictions, and quantitative questions related to the S2 receiving body's reference flow, the condition proposed by the State Decree N°13.990/2014 was included, which regulated authorizations for the right to use water resources, in the State of Mato Grosso do Sul, which ruled that the maximum use of diluted flow (Qdil) for that purpose is 30% of the flow Q95, according to Equation 1 (MATO GROSSO DO SUL, 2015).

It was identified, through the permanence curve, that the reference flow for the Ribeirão das Botas Stream is 1.43m³.s^{-1}, resulting, therefore, with an authorized Qdilof 0.43m³.s^{-1}. In addition to the maximum authorized flow criterion, State Decree N° 13.990/2014 outlined that, while the framework is not approved, fresh water will be considered as Class 2, with a permissible BOD of up to 5 mg.L^{-1} (C_{perm}) (MATO GROSSO DO SUL, 2015).

$$Q_{dil} = Q_{ef} \cdot \frac{(C_{ef} - C_{perm})}{(C_{perm} - C_{nat})} \qquad (1)$$

Where:

Q_{dil} is the diluted flow rate (30% of Q95);
Q_{ef} is the treated effluent discharge flow rate;
C_{ef} is the effluent concentration;
C_{perm} is the maximum permissible concentration in the stream post-mixing (for Class 2, equal to 5 mgDBO.L^{-1});
C_{nat} is the natural concentration measured in the field (equal to 2 mgDBO.L^{-1}).

The proposed scenarios for the Ribeirão das Botas Stream capacity simulation for receiving treated effluent from a WWTP, differed in the BOD release concentration, based on the drought period, as this was the least favorable period (lowestflow rate). The model'sinput data are shown in Table 1. As for the discharge point, this was also indicated by the concessionaire as being the probable location of the WWTP installation; being positioned between points 2 and 3, near the confluence of the Coqueiro Stream; this is justified because it is where the two streams meet, increasing the dilution capacity, as well as being far from the urban area, avoiding environmental damage to any odors generated.

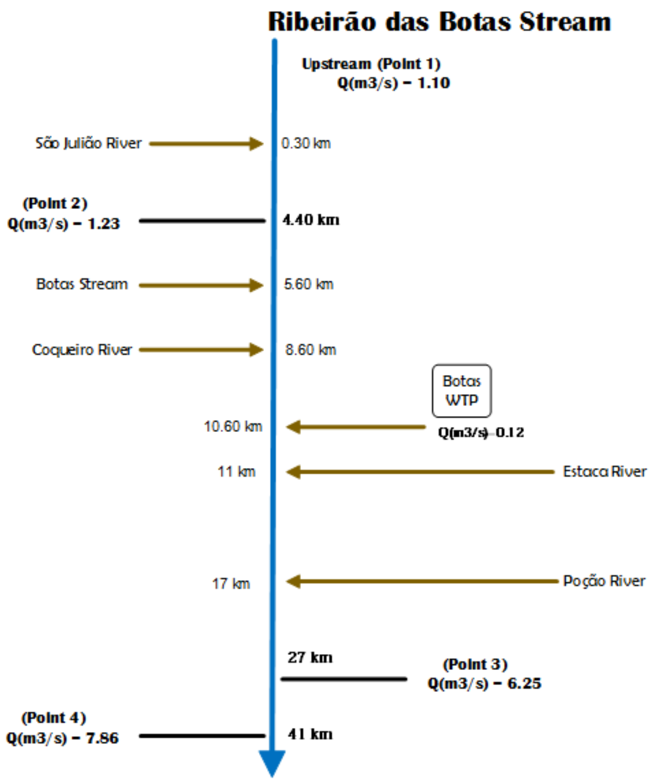

Figure 2. Single-line diagram of the Ribeirão das Botas Stream

Input data: The coefficient adjustments were based on the qualitative and quantitative analytical results of the aforementioned parameters. A modeling of the Ribeirão das Botas Stream behavior was carried out in the current condition, that is, for the current scenario, without diluting the effluent with a WWTP. Next, the proposed scenarios were simulated.

The QUAL-UFMG model was used and the input data are shown in Table 1, where the values of Von Sperling (2007) are recommended. In order to avoid adjusted coefficient errors, simulations were performed for the decomposition (Kd), deoxygenation (K1) and reaeration (K2 –shallow and rapid water body with waterfalls) coefficients, with maximum and minimum values.

Table 1. Model's input data

	Scenario 1	Scenario 2	Scenario 3
	Recommended Value	Min value	Max value
k_1	0.30-0.40	0.40	0.30
k_2	>1.61*	24.36*	20.27*
k_d	0.5-1.0	1.20	1
k_s	0.125		
DO_r		8.08	
		2	
BOD_r		1.43	
		0.12	

*unit of values in d^{-1}

The adjustments of the calibrated values were obtained from the statistical indicator coefficient of determination (CD), which represents the ratio between the sum of the errors or residuals, squared, by the total variance of the observed data (Equation 2), which seeks to minimize to the maximum extent, from numerous interactions carried out by the Microsoft Excel® Solver plug-in.

$$CD = 1 - \frac{\sum(Y_{obs} - Y_{est})^2}{\sum(Y_{obs} - Y_{med})^2} \quad (2)$$

Where:

Y_{obs} is the analytical value of sampled DO or BOD;

Y_{med} is the mean DO or BODobserved values;

Y_{est} is the estimated value of DO or BOD.

Deoxygenation rate coefficient (k1)

This coefficient varies according to the temperature, organic matter characteristics and the presence of inhibitory substances. The value adopted in this study is within the range expected for rivers that receive primary effluents and concentrated raw sewage. Values close to this were also adopted in the work of Lima *et al*. (2018) in the AçudeAcarape do Meio River Basin located in the State of Ceará, where raw sewage is also released. Another study by Costa and Teixeira (2010), in Rio Ribeirão do Ouro-SP, also adopted values close to this due to their simulation being discharged effluent.

Decomposition coefficient (kd)

Von Sperlin (2007) suggests the following ranges presented in Table 1 for kd values, based on the finding that shallower rivers are more influenced by the biomass present in sediments, which also contributes to the decomposition of BOD. This value was used because Ribeirão das Botas Stream was considered shallow and because this value was less varied than the simulated and observed values. Values very close to this were also used in the work of Calmon *et al*. (2015), in Rio Pardo-ES, due to the river having low depth and medium flow.

Reaeration coefficient (k2)

The reaeration coefficient (k2) was adjusted using the solver tool. The values are above the average values tabulated in literature (VON SPERLING, 2014), based on a qualitative description of the river. However, the Qual2E model manual (EPA, 1987) records several k_2 data points effectively measured in water courses with very high values, which can reach between 10 and 100 d^{-1}. The hydraulic characteristics of the Ribeirão das Botas Stream such as its shallow depth and high speed with the presence of many rocks, rapids and curves, justifies the k_2 values (20-24). In Ide and Ribeiro's (2009) study, 20.55 was used in the Taquarizinho-MS basin, due to the fact that the river presents several waterfalls, and the amount of DO in its waters is quite high, coming close to saturation. The study by Corrêa and Araújo (2015), in Córrego Limoeiro-SP, obtained 19.88, due to the hydraulic characteristics of the river.

RESULTS AND DISCUSSION

The water quality analysis results (Table 2) show that fecal coliform parameters (*E. coli*) and total phosphorus are the only parameters in disagreement with the established standards, for both the local ECSC resolution nº 036/2012and the federal CONAMA resolution nº 357/2005. According to SEMADUR (2009), all the streams in the municipality are Class 2, except for the Imbirussu Stream. From the results obtained it is possible to verify that the Ribeirão das Botas Stream has urban wastewater contributions and the presence of agricultural activities. As with Oliveira (2017), in Rio Poti, Brazil, non-conformance of the *E.coli* parameter in relation to the CONAMA resolution nº 357/2005 (Class 2) was also observed. Capoane *et al*. (2014) also verified the presence of total phosphorus in surface waters and justified that the studied watershed presented areas with agricultural and livestock production.

Table 1. Water analysis results

Parameters	Units	Collection points			
		1	2	3	4
Chlorides	$mgCI.L^{-1}$	1.6	3.2	1.6	1.6
TC	$NMP.100mL^{-1}$	7,500	101,400	34,100	9,800
Cor	Pt.Co-¹	13	16	19	19
BOD	$mg.L^{-1}$	1.2	1.6	3	1.1
COD	mg.L-¹	2.7	3.2	6.5	2.5
E. Coli	$NMP.100mL^{-1}$	2,000*	3,100*	1,000	2,000*
TP	$mgPO_4^{-3}$.L-¹	0.05*	0.04*	0.08*	0.08*
TN	mgN.L-¹	0.2	0.2	0.2	0.2
DO	mg.L-¹	8.08	8.15	8	8.11
pH	-	6.38	6.22	6.09	6.67
TDS	mg.L-¹	11	34	34	23
SS	mL.L-¹	<0.1	<0.1	<0.1	<0.1
T	°C	24	26	22	22
Transparency	-	20	10	20	15
Tu	NTU	24	14	19	19
Flow rate	$m^3.s^{-1}$	1.1	1.23	6.25	7.86
Distance	km	4	8	15	14
Elevation	m	592	579	499	472

*non-standard values established by the CONAMA Resolution 357/2005 (6 <pH ≤ 9; OD ≥ 5; Tu ≤ 100; NT≤ 11; P≤ 0.025; BOD ≤ 5; TS ≤ 500; E.coli ≤ 1000; SDT ≤500 mg.L-1) and ECECA 036/2012 (chloride ≤250 mgCI.L-1; P≤0.05; SDT ≤500 mg.L-1)

According to SEMADUR's (2009) water quality evaluation of the streams located in the municipality of Campo Grande, some of the streams located in the municipality also have a parameter in disagreement with the current legislation, such as the Segredo Stream located in the northern portion of the urban area of the municipality that has an *E. coli* parameter above the class limits for the river. Like the Bandeira Stream, wastewater discharge with direct influence in one of the collected points was identified, being able to justify the different values of *E. coli* in the first quarter (5,000 NMP.100 mL^{-1}) and in the other quarters (1,000 NMP.100 mL^{-1}) when there were no further discharges. Evaluating the behavior of the DO and BOD parameters in the established scenarios (Figure 3), the BOD in S1 was above 5 mgBOD.L^{-1}, not meeting the recommended amount by legislation, remaining 22 km outside Class 2, while S2 and S3 met the recommendation because their remaining value was below 5 mgBOD.L^{-1}. On this account, the BOD concentration released in the first scenario was the maximum recommended by legislation, and the other scenarios respected the support capacity of the river. In all established scenarios, DO parameter values remained within the permitted legislation limit for Class 2 rivers, the lowest values found were from S1 being below 7 mgO2.L-¹, thus demonstrating the importance of adequate treatment. In order for the support capacity of the stream to be met at the discharge point and its class not changed, the maximum established flow should be in accordance with the authorized amount(0.43 $m^3.s^{-1}$) and the wastewater treatment system needs a minimum efficiency of 96% for BOD removal. Most of the studies only analyze the quality or quantity of water in a given watercourse. However, in this study, the criteria and parameters from the State Decree N° 13.990/2014 were articulated, which regulated the authorization for the right to use water resources in Mato Grosso do Sul, considering water quality with the QUAL-UFMG model. Note that the DO remains above the established amount by legislation according to the receiving body's class (5 mg.L^{-1}) in the three established scenarios (Figure 3d, Figure 3e, Figure 3f).

conditions and the adoption of the minimum k1, k2 and kd coefficients, the appropriate amount of the WWTP effluent would be 42 mg.L^{-1}, that is, instead of removals in the range of 65% (S1), the ideal BOD removals would be in the order of 88% (S2). However, considering the state legislation and their authorization are present in the National Water Resources Policy (PNRH), it is suitable to guarantee 96% BOD removal, with an effluent presenting 15.7 mgBOD.L^{-1}. In some studies such as Marçal *et al.* (2017) in Rio Paraopega-MG and Moreira (2006) in Rio Ribeirão Entre Rios-MG (both in Brazil), it was concluded that in these basins the authorizations granted exceed the maximum state limit. There may be conflicts over water use, such as: water withdrawal by abstraction, irrigation by various users, and the solution would be to adopt public policies or invest in engineering projects that increase water availability for authorizations throughout the year. Grubba and Hamel (2005), in a study on the environmental problem of water resources, affirm that for good water resource management it is necessary to guarantee good water quality and quantity for present and future generations. From these studies it can be seen that in addition to these problems, there are others in regards to water management issues. In the adoption of the criteria established by the PNRH, according to S3 (Figure 3c), guaranteeing 96% BOD removal and maximum flow rate in response to authorizing multiple water uses, the BOD value remained below 5 mgBOD.L^{-1}at the mixing point and other points. Therefore, the support capacity of the Ribeirão das Botas Stream is obeyed at the release point, and its classification is not altered. According to Von Sperling (2014), in order to meet 96% BOD removal, an alternative

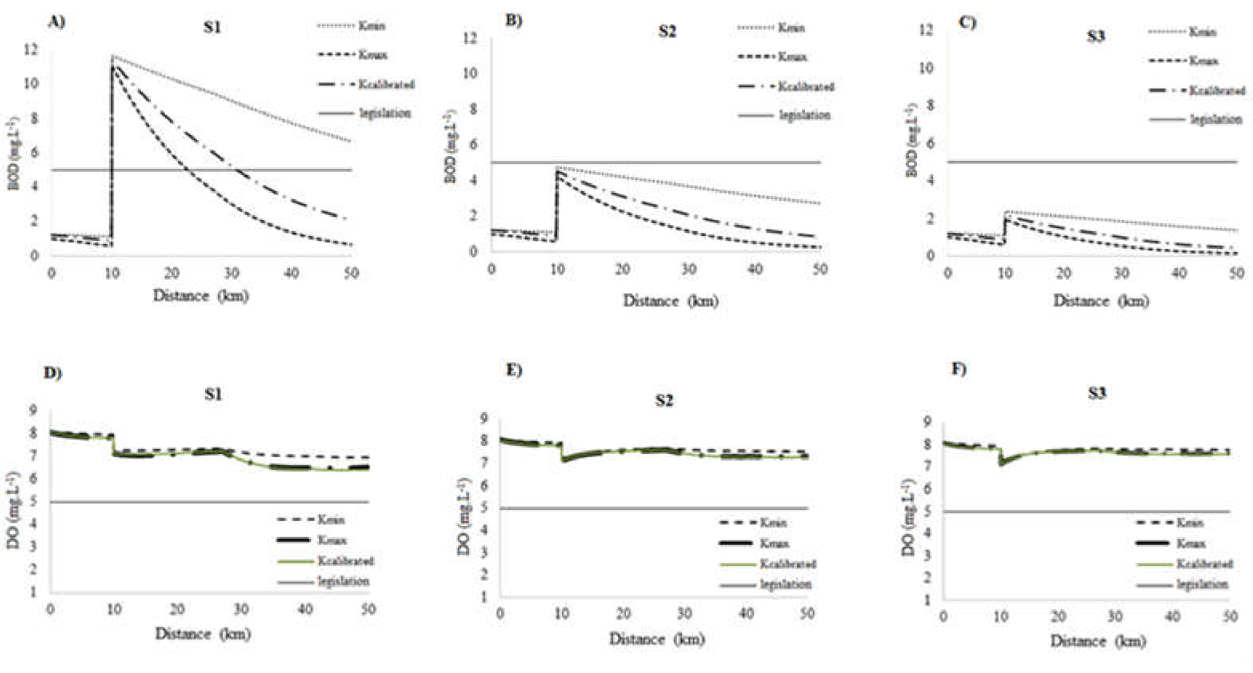

Figure 3. DBO and DO profiles of the scenarios

This is due to the hydraulic characteristics of the water body, a shallow mean depth (1.0 m) and a high mean velocity (1.0 ms^{-1}), in addition to the presence of many stones, rapids, and curves favoring oxygenation, also observed by Ide and Ribeiro (2011), Corrêa and Araújo (2015) and Carvalho *et al*. (2014). With respect to the BOD parameter in S1 (Figure 3a), with effluents being released at concentrations of 120 mg.L^{-1}, the value exceeds 5 mgBOD.L^{-1} at the mixing point. In S2 (Figure 3b), it was identified that as a function of the quantitative

would be to adopt activated sludge systems - extended aeration or conventional activated sludge + tertiary filtration, with values in the order of 90 to 98% BOD removal. However, it is worth emphasizing that in order to choose the right system, it is necessary to take into consideration aspects other than efficiency, such as its operational, financial and executive advantages and disadvantages. An alternative would be the use of constructed wetlands (CWs), as a nature-based system by simulating natural wetlands and green treatment technologies

(Hernandéz-Crespo *et al*., 2017). CWs remove various contaminants (over 90% removal for BOD, COD, nitrogen) and improve water quality, and have been widely used to treat various kinds of wastewater such as domestic sewage (Kadlec& Wallace, 2009; Saeed & Sun, 2012). Thus, with the increase of trace pharmaceutical patterns in water environments in recent years, CW technology has also been studied for the removal of pharmaceuticals. In rural and urban areas CWs have been used to treat domestic sewage and agro industrial wastewater (Matamoros *et al*., 2008; Matamoros *et al*., 2009). The efficiency of CWs studies has shown removals between 82 and 97% for compounds such as ibuprofen (Zhang *et al.*, 2012b). These low-cost systems demonstrate good removal percentages for emerging compounds and removal parameters for physical-chemical treatment area possible complementary technology for removing compounds with advanced oxidation processes.

Conclusion

For adequate water resource management, it is essential to combine two pillars: quality and quantity, while also considering legislative evolution that seeks to solve conflicts between users when assuring diverse water use in a basin. In addition, it is important to understand that more efficient and adequate wastewater treatment would fulfill a role in environmental and water resource policies in an integrated manner. The physical-chemical and biological analysis shows negative impacts from anthropic actions in the Ribeirão Botas Stream, caused by inadequately treated urban effluent discharge and agricultural activities, from the presence of *E.coli* and total phosphorus in disagreement with current standards, both at local and federal levels. The application of water quality modeling as a tool in the self-purification study in the receiving body reveals that BOD and DO in the scenario in which the BOD concentration released is the maximum recommended by the oldest legislation, caused DO to remain below 7 $mgO_2.L^{-1}$ and BOD to be out of the classification (class 2), exceeding 5 $mgBOD.L^{-1}$. This reveals that the river basins that chose wastewater treatment systems based on the old legislation must undergo a new evaluation in order to improve treatment performance of these pollutants. The other scenarios, which respected the river's support capacity, presented DO above 7 $mgO_2.L^{-1}$ and BOD below 5 $mgBOD.L^{-1}$.For the support capacity of the stream to be met without changing its classification, the wastewater treatment system to be implemented must have a maximum flow rate in accordance with the water resource use authorization (0.43 $m^3.s^{-1}$) and have a minimum of 96% efficiency. Thus, the presented methodology highlights the importance of using mathematical models through computational tools to assist the water resource management council with decision making in the face of multiple use conflicts. In addition, this would help the water distribution and waste water collection and treatment concessionaire, regarding new project designs and the feasibility of implementing, operating and maintaining WWTPs, aiming at the support capacity of the receiving body.

Glossary of Abbreviations

ANA	National Water Agency
APA	Environmental Protection Area
CD	Coefficient of determination
CECA	State Environmental Control Council
CONAMA	National Environment Council
TC	Total coliforms
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
WWTP	Wastewater treatment plant
TP	Total phosphorus
EWI	Equal-Width-Increment
K1	Deoxygenation rate (d^{-1})
K2	Reaeration coefficient (d^{-1})
Kd	Decomposition coefficient
km²	Square kilometers
Ks	BOD removal by sedimentation coefficient
m³	Cubic meters
TN	Total nitrogen
DO	Dissolved oxygen
PNRH	National Policy of Water Resources
Q95	Minimum expected flow in 95% of the time
Qdil	Diluted flow
S1	Scenario 1
S2	Scenario 2
S3	Scenario 3
TDS	Total dissolved solids
SEMADUR	Environment and Urban Development Municipal Secretary
SNIS	National Sanitation Information System
SS	Sedimentable solids
T	Temperature
Tu	Turbidity
UASB	Upflow Anaerobic Sludge Blanket Reactor
UPG	Planning and Management Unit

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