MODELING OF WATER QUALITY PARAMETERS OF DISSOLVED OXYGEN AND BIOCHEMICAL OXYGEN DEMAND IN THE SUB-BASIN OF POXIM RIVER, BRAZIL

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Abstract

The major cause of scarcity of the water resources, especially in large urban centers, is caused by the degradation of water quality; this is because of the inadequate release of industrial effluents and domestic sewage. The application of models that consider aspects of quantity and water quality are extremely important in case to understand and try to solve this problem. Thus, this paper aims are to show how computational modeling can be used to assess pollution by sewage water resources in the sub-basin of Rio Poxim, contributing in this way to solve environmental problems. To conduct the study, we employ the data monitored DO and BOD during the period from July 2009 to June 2010, which were inserted in the AcquaNet for calibration and validation. The simulations were performed for the current situation, (calibrated) with two scenarios increase of 10 thousand and 20 thousand inhabitants in the area of influence. The results of parameter calibration and validation of OD showed a good correlation between the observed and calculated data, the same can not be observed for the parameter BOD. The results show that the parameters DO and BOD present critical situations at Station E4 mainly for the month of May where they were observed DO and BOD concentrations of 0.0 mg L-1 and 16.52 mg .L-1 with respective population increases. Computer modelings allows monitoring of water quality parameters in rivers and seek some solutions for that serious problems related to the quality of life and environmental health in areas where the risk of contamination by sewage is higher. For those reasons it is recommended to study what are the best treatment solutions or launch strategy and develop specific levels of monitoring for future situations.

Key words: Environmental simulation, calibration and validation, AcquaNet program.

1. Introduction

All activity developed by man, bring on directed or undirected ways impacts in watershed. Nowadays, the intense population growing and the technological development have been causing an intense degradation in the natural resources, mainly the water. For those reasons, water resources management has been emphasizing as a manner for planning and administrates in a sustainable way the multiple uses of the water. Giving assistance to this management, the protection and the control of the water resources is also important the use of some tools that make possible to analyze the physical, chemical and biological processes that happen in a watershed, in a way we can anticipate a scenario and prognosis about the uses of the water resources. The math models about water quality can be used as useful tools for watershed management, and also as a support for choosing the best method to be used. Those tools are used for simulating self - purification processes of the river and in consequence, helps to take decisions about the intervention and management measures in the watershed.

The mathematical modeling in the water quality emerge in this context as a tool of extremely importance in the watershed management process, once this can help choosing of management alternatives, with a view to answering of the model to a different kinds of residual discharges (RODRIGUES, 2005).

Originally developed to help in the solution of problems, besides been used to minimize the pollution problems, the simulation problems enable a better understand of the environment and visualize in an integrated way, whereas the math models associate the physical, chemical and biological information. In spite of the city's growth in the last decade has been responsible for the increasing of the pressure in the anthropic activities related with natural resources like, the pollution caused by the introduction of organic matter (NAGALLI; NEMES, 2009).

With the launching of human effluent in the water resources, in spite of the unpleasant visual aspect, the exhalation of putrescence gas and also the possibility of contamination, for its use or contact. There is a reduction in the concentration of the oxygen solved in the phase, put at risk the survival of the aquatic organisms (SARDINHA et al., 2008).

The evaluation of the water pollution effects providing of the launching of sewage can be done through the monitoring of some chemical parameters related with the water quality for example (Dissolved Oxygen) (DO), Biochemical Oxygen Demand (BOD). To this end the water quality computational models which contemplates source/ sink in these parameters, the transportation all through the water resource and its reaction with other substances, are important tools for the environment monitoring, which has as a main way of pollution the domestic sewage(BachBACH et al., 1995).

The present article has the objective of analyzing the water quality in the Poxin River drainage sub basin using the (DO) and (BOD) parameters relating them with the domestic effluents generated for both simulated scenarios, the main reason for it is contribute with useful information for management of the resources in this drainage sub basin.

2. Methodology

The Poxin River drainage sub basin is located between the geographical coordinates 11°01' and 10°47' of south latitude, and 37°01' and 37°24' of longitude west and it is inserting in the metropolitan region of the capital Aracaju. Nowadays about 20% of the water is consumed by people in the city is from that drainage sub basin, emphasizing the importance of this study in the region.

The data for this study were provided through 12 sample swabs in 4 monitoring places, during the period of July in 2009 to same month in 2010, totalizing one year of data. The water samples were collected in the superficial phase, respecting the swab and storing procedures, following the hygiene standard and the sample control described by AGUDO (1987) and MACÊDO (2003). The analysis respected the methodology obeys the Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

2.1 Modelling using the AcquaNet program

The version 3.16.00 of the AcquaNet program used in this work is divided in 6 modules. Two of them were applied for calibration and simulation in the Poxim River drainage sub basin and in the Poxim-Mirim, Poxim-Açu and Poxim River: The allocation module (AlocaLS) and the quality module (QualityLS). The mentioned modules will be described in the nest topic.

2.2 Characteristics of the Quantity and Quality modules.

The quality module (QualityLS) integrated with the AcquaNet program, used to simulate the water quality in the rivers, is a unidimentional and considered a permanent flux system. It is possible to be considered the punctual launching (the entrance of industrial and domestic effluents), simulating the concentrations of DO and BOD total coliform bacteria, total phosphorus, algae, organic nitrogen, ammonia, nitrite and nitrate (PORTO et al., 2004; TEIXEIRA et al., 2005).

The rivers or artificial canals which compound the studied water system are segmented in some of their parts, those ones are considered by the model as a computational element where the transportation mechanisms cargo and also where the concentration of components responsible for the quality water are mixed. The hydraulic parameters (area section, speed, outflow and the medium height of the waterline) should be constants in each part. Each segment represents a controlled volume about what the equations that coordinates the mass balance will be applied.

2.3 The entrance of the quantitative and qualitative data

The aquanet model requires as entrance the data of outflow and the parameters of the water quality. In this present study the simulated parameters were DO and BOD. The data used were obtained through the collecting of water samples and the outflow measurement in the sub basin Poxim River, made between July 2009 to July 2010.
The first step for the utilization of AcquaNet software was to build a flux network in which we could represent the system of the water resource formed by “nós” and “arcos”. The “nós” represent the elements of location in the system like (reservoir, demand and confluences) while the “arcos” symbolize the connections among the “nós” (the stretch of the river, water supply network, natural or artificial canals and other similar elements). After building the network, the quantitative data was inserted for the monitoring stretch.

After that, the entrance of a suitable quantitative data, the next step was the entrance of the hydraulic data of each stretch of the rivers, indicated at Table 1. The needed data were obtained in the “Atlas de Recursos Hídricos de Sergipe” (SERGIPE, 2011).

TABLE 1: Entrance data in the AcquaNet software about the hydraulic conditions in different stretch of Poxim-Mirim, Poxim-Açu and Poxim Rivers.

Hydraulic characteristics adopted				
Attribute	Trecho 1	Trecho 2	Trecho 3	Trecho 4
Stretch Length (km)	4	3	4	4
smaller base (m)	3	6	15	15
Canal declivty ($m.m^{-1}$)	0,0002	0,0003	0,0001	0,0001
Number of Manning	0,03	0,03	0,03	0,03
River Classification	Classe 2	Classe 2	Classe 2	Classe 2
Altitude da bacia(m)	11	11	10	10

3. Results and Discussion

3.1 Calibration parameters

It was adopted K1, K2, K3 and K4 variables which better adjusted the relation between the DO and BOD observed and calculated by the model. The Table 2 presents the variable concentration used in the calibration of the drainage sub basin of the Poxim River in different studied stretch.

TABLE 2: Calibrated values for the different parameters used for simulation of DO and BOD in AcquaNet software.

Trechos	K1(day^{-1})	K2 (day^{-1})	K3 (Manual)	K4 (g O_2.m^2 day^{-1})
1	1,2	0,12	10	0,50
2	1,2	0,15	10	0,50
3	1,2	0,12	11	0,50
4	2,9	0,70	6	0,25

(a) Parameter BOD decay rate, (b) Parameter BOD sedimentation, (c) Parameter reaeration DO and (d) Sediment Oxygen Demand

3.2 The validation for calibration

The validation was verified according to the correlation between the variable of the DO and BOD coefficients observed and calculated by the model, according to Santos' (2007) classification. The Figure 1 presents the analyzed data. In the months of September 2009 to April 2010 wasn't observed the DO data and these variables were not taken in consideration. In the months of July and September in 2009 were not observed BOD data and like the previous variable were not taken in consideration too.

In figure 1 is presenting the correlations between the OD variables observed and calculated by the model. The linear correlation coefficients were classified as moderate according to Santos (2007).

In figure 2 is presenting the correlations between the BOD variables observed and calculated by the model. The linear correlation coefficients were classified as low according to Santos (2007). This parameter presents a big distortion between the observed and calculated data. In the months of December 2009 and January 2010 was founded the biggest differences. The difficulty of BOD calibration is the uncertainty associated with the launching of organic cargo in the point 3 from the network. The estimative of cargo in the organic effluent cannot be representative. The lapse used for each simulation was one month. This lapse undoubtedly turns the calibration process for this parameter more difficulty and also reduced the correlation coefficients. A few part of the population used in the correlation also contributed for increasing random mistakes, according what it was commented DO results. From the statistical point of view one cannot consider the calibrated model for BOD, however, even in the face of random errors exist, you can use the model for planning given that in December the model underestimates the calculation of the concentration on the order of 7.2 mg L^{-1} and overestimates the concentration in the month of January in the order of 4.45 mg L^{-1}.

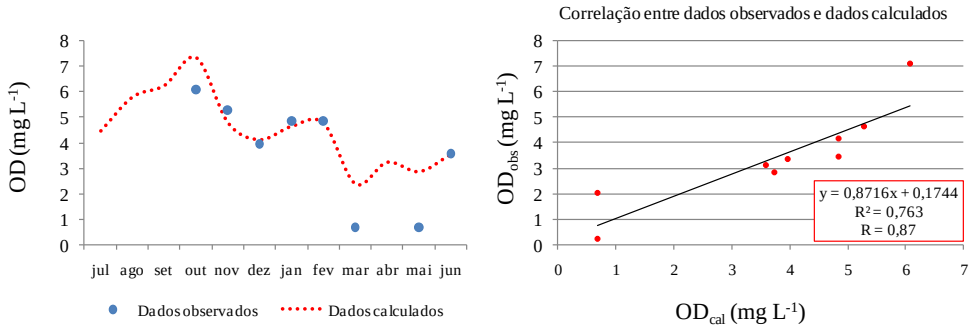

Figure 1 - Correlation between the observed and calculated parameters for the OD, the station E4 in the river basin Poxim.

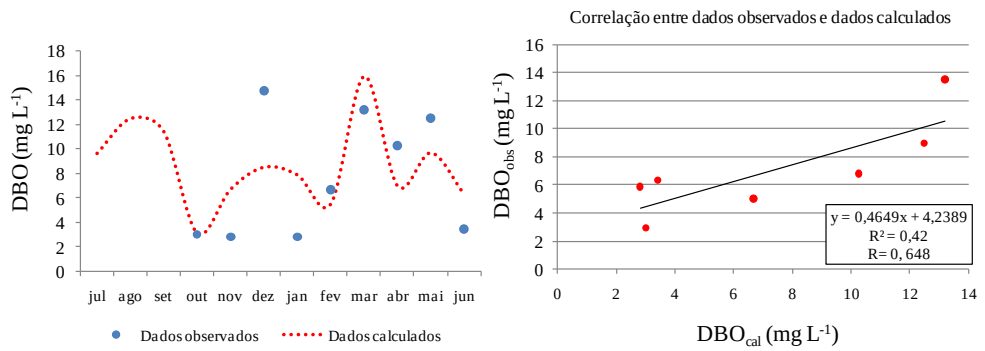

Figure 2 - Correlation between observed and calculated data for the parameter BOD at station E4, the sub-basin of the Rio Poxim.

3. 3 Simulation scenarios for effluent discharge

Once calibrated model, the water quality can simulate the AcquaNet specific conditions of launch of the effluents from the point loads. Simulations were made by assigning values of effluents (untreated sewage) launched by Elze Neighborhoods Rosa (City of São Cristovão) and Parque dos Faróis,Tijuquinha and Pai André (City of Nossa Senhora do Socorro) together, for two different scenarios where were taken loads "per capita", taking into account an increase in the overall population of 10 000 and 20 000 inhabitants in all neighborhoods. The values for volume of effluent released were determined using data in the literature (VON SPELING 2006), in that the volume of organic effluent (drain) of the population can be estimated by the product of the per capita consumption of water (q) and coefficient return drain (c), as shown in Table 3

TABLE 3: Typical values of consumption "per person" for people endowed with household connections according to population size.

Porte da comunidade	Faixa da população (hab.)	Consumo per capita- q (l/hab.dia)	Coeficiente de retorno de esgoto (c)**
Povoado rural	< 5.000	90-140	0,80
Vila	5.000 -10.000	100-160	0,80
Pequena localidade	10.000 - 50.000*	110-180	0,80
Cidade média	50.000 - 250.000	120-220	0,80
Cidade Grande	>250.000	150-300	0,80

* Value adopted for the region; ** Value recommended by the NBR 9649 (ABNT, 1986) when there are no data from local research. Source: Von Sperling (2006).

The volumes of effluent organic "calculated" for scenarios 1 and 2, whereas increases of 10 and 20 thousand inhabitants (0.014 and 0.028 m3 s-1, respectively) were inserted every month throughout the evaluation period the program AcquaNet. Thus we could analyze the behavior of the concentrations of DO and BOD during the year, the control point (station S4). Simulations of the concentrations of DO and BOD, as parameters to evaluate the environmental pollution at station S4 show the impacts on water quality considering the population growth and its implications for pollutant loads. A summary of RE and BOD concentrations simulated can be seen in Figure 3

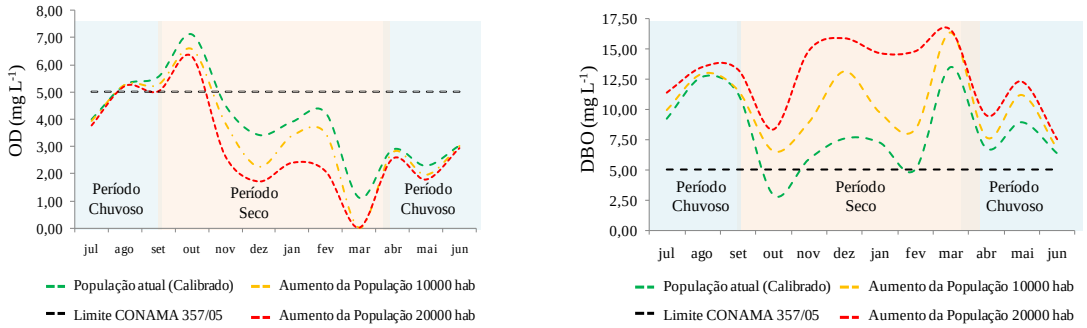

Figure 3: Concentration of the parameter OD simulated for two scenarios for release of organic effluent in the river basin Poxim.

Through the figure 3 we can infer that the current condition of water resources at the station S4 was crucial for the parameters DO and BOD, more specifically between the months of November 2009 to June 2010 where concentrations were below the minimum value for OD and above the maximum value for BOD, as defined in the Resolution CONAMA 357/2005, reflecting a major problem in maintaining water quality in Class 2 frame. The presence of organic sewage water triggers processes organic matter decomposition, and proliferation of microorganisms and oxygen depletion (BRANCO, 1993; Pelczar JR. et al., 1996; VON SPERLING, 2005). According to the CONAMA Resolution 357/2005 laying down the limits of parameters or indicators for water intended for domestic supply and primary contact recreation, the DO concentrations should not be less than 5 mg L^{-1} O2 and should not be more than 5 mg L^{-1} BOD. From these limits can be set by the responses obtained by the model, which months are more problem with the water quality and also check the influence of the increased release of effluent (untreated), associated with increased population, water quality. It was observed that the end of the dry season, specifically in the month of March, had the lowest DO concentrations (0.0 mg L^{-1} to March) and higher concentrations of BOD (16.39 and 16.62 mg L^{-1} for scenarios 1 and 2, respectively).

The influence of sewage discharge commits more steeply (greater amplitude between the different scenarios) the water quality in the dry season, this can be explained, as understood in this period is the lowest flow rates causing a higher concentration of these parameters in place. The model indicates that the increase in population further compromises the quality of water. Knowing the magnitude of the impact caused by the increased organic load effluent is essential to the planning of collection systems and treatment of domestic sewage since this population should be achieved in a short time interval. The amount of investment and time of development of infrastructure to be made in the basin may be indicated by the simulation model of water quality.

4. Conclusions

The model of analysis of water quality program AcquaNet was adequate as a tool to aid decision making for management and planning of water resources. Despite the short series of data obtained, it was considered that the model was successfully calibrated for the parameters DO and BOD in the drained basin of Poxim River.

The simulations indicated that degradation of water quality in the basin was influenced by the organic loading point releases. The DO and BOD concentrations were higher in the dry season probably due to less dilution effect.

The simulation results showed that there is a decrease in water quality with population increases, the month of March being the most critical parameters for DO and BOD at station S4.

The simulated values show that the parameters DO and BOD did not meet the standards of CONAMA 357/2005, 2009 to June 2010.

From the results obtained with the simulation of water quality of the basin Poxim River, one can say that immediate investment is needed in collecting and treating sewage in order to be improved sanitary conditions in the watershed.

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