Surface Water Quality Modeling of a watershed in the north of Rio Grande do Sul

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Abstract—The water crisis and the degradation of surface water resources through pollution, combined with the progressive increase in consumption has made it necessary to search for alternative sources of supply.. Because it is a finite natural resource, water is a public good that needs to be allocated among different uses and has its integrity compromised by factors such as industrial development, rapid urbanization and population growth. Considering these issues recognize and evaluate the potential of local water resources is necessary, since the River Inhandava is inserted in the north-northeastern state of Rio Grande do Sul, in the Uruguay river basin and watershed belongs to Apuaê-Inhandava. The objective of this research was to perform the modeling of surface water quality of the River Inhandava-RS. The data were inventoried quality of studies conducted in Rio were considered diffuse agricultural loads, animal waste and sewage. To assess the water quality of the Rio Inhandava, the computer model was used QUAL2Kw. The water quality has been shown, for most parameters, according to Resolution CONAMA 357/2005. The calibrated model QUAL2Kw, became an instrument to in the management of water resources, since the analysis of the results showed the selfpurification in downstream river study.

Keywords—Water Resources, Environmental Quality, Modeling.

I. INTRODUCTION

Water availability represents one of the limiting factors for a region's socioeconomic development. Water, which is a finite natural resource, is also a public domain asset, which needs to be allocated between different uses and whose integrity is compromised by factors such as industrial development, accelerated urbanization and demographic growth. Considering these issues, recognizing and evaluating the potential of local water resources is necessary, since the Inhandava River is inserted in the north-northeast region of the state of Rio Grande do Sul, in the Uruguay hydrographic region and belongs to the Apuaê-Inhandava hydrographic basin, being an important source of public supply for the municipality of Sananduva and a place of leisure in at least eight points along the river. According to the Environmental Secretariat of Rio Grande do Sul State, the largest polluting loads in the basin, where the river is located, are from domestic effluents and pig farming.

The management of water resources is the way in which it is intended to equate and resolve issues of relative scarcity of water resources, as well as to make the appropriate use, aiming at the optimization of resources for the benefit of society, which is carried out through integrated planning and management procedures. administration [1].

The water quality models are essential links to management, since they aim to predict a concentration of a certain pollutant in the water body as a function of a specific polluting load or not [2].

The use of water quality modeling can be considered as an important tool to be used in studies of framing rivers, especially with regard to meeting progressive goals, according to what is established by CONAMA Resolution No. 357/05 [3].

For the modeling of surface water quality, it is necessary to identify the sources of pollution and their launch points in the water bodies. In addition to, the

knowledge of the forms of interaction existing between the processes that take place in the basin, with the physical, chemical and biological processes that occur in the rivers. With the modeling of certain water quality variables, it is possible to estimate the acceptable limit of self-purification of these rivers, in order to guarantee the necessary quality for the use for which they are destined and, therefore, their real condition of framing [4].

The modeling of water quality emerged in order to provide useful information on mechanisms and interactions that justify the varied dynamic behaviors of water, constituting a rational basis for decision making in the management of water resources. Where it is possible to explain some properties of the system, mainly to quantify the self-cleaning capacity of the water body, thus anticipating the impacts resulting from a possible polluting discharge.

The objective of this research was to perform the modeling of water quality parameters (Biochemical Oxygen Demand (BOD); Dissolved Oxygen (DO) and Total Coliforms) of the Inhandava River - RS.

II. METHODOLOGY

The Inhandava River microbasin includes the municipalities of Lagoa Vermelha, Caseiros, Ibiaça, Santo Expedito do Sul, Sananduva, Cacique Doble, São João da Urtiga, Paim Filho, Maximiliano de Almeida, Machadinho, São José do Ouro, Capão bonito and Tupanci do Sul (Fig. 1). The river rises in the municipalities of Lagoa Vermelha and Caseiros and flows into the Uruguay River.

Melo and Astolfi [5], monitored the water quality of the Inhandava River at 16 points along the river, and in this study only twelve points were considered. Table 1 shows the geographical coordinates of the inventoried points.

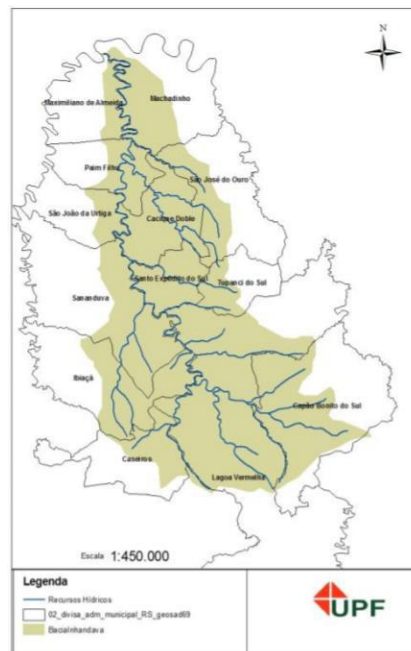Figure 2 shows the Inhandava River microbasin delimited by the Ottocodified form.

Fig. 1: Location of the municipalities of the Inhandava River watershed.

Table.1: Geographic coordinates of collection points in Rio Inhandava-RS

| Spot	Longitude	Latitude	Elevation (m)	Location (km)
1	-51,3994188	-28,1914137	842	26,7
2	-51,4526527	-28,1888668	729	33,6
3	-51,5246755	-28,1424544	686	48,3
4	-51,6343324	-28,0475590	675	64,6
5	-51,6433833	-28,1817566	632	84,3
6	-51,6448763	-27,9934335	596	97,3
7	-51,7109516	-27,9589900	588	106,3
8	-51,7348512	-27,9333331	577	116,9
9	-51,7541818	-27,8778018	576	152,0
10	-51,7486111	-27,7125231	574	162,7
11	-51,7366667	-27,6783333	564	171,7
12	-51,7266000	-27,6525000	504	181,7
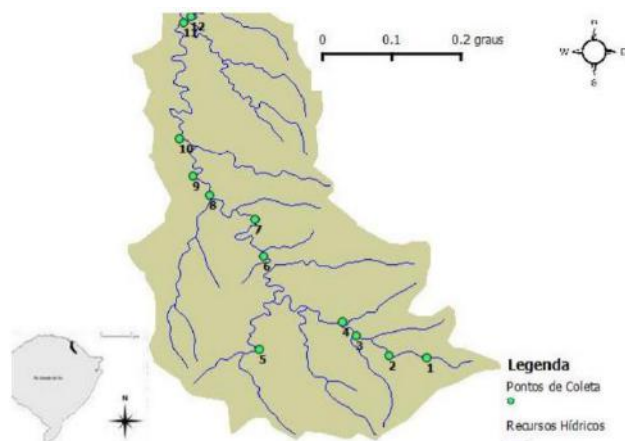
Fig. 2: Location map of the studied points.

In order to support the evaluation and modeling of water quality, it was necessary to determine the flow, in which values were determined only for the points 1, 7 and 10. For point 1 (km 26.7), which symbolizes the spring conditions, the flow was determined according to the conventional method (area-velocity), internationally certified by the European standard ISO 748 [6], which involves measuring velocity in several verticals (sections) of the river and in several depths for each of these.

The other points 7 (106.3 km) and 10 (162.7 km) were inventoried according to information provided by CORSAN (data referring to the water supply station for the municipality of Sananduva) and by ANA (Passo do Granzotto station), there are no other flow measurement stations along the route of the Inhandava River.

The model used for the present work was the QUAL2Kw regulated by the North American Environmental Protection Agency (U.S. - Environmental Protection Agency - EPA) [7]. The QUAL2Kw program is one of the modeling programs for surface water quality with great complexity, however its modeling of water quality is a valuable tool in Environmental Engineering, providing foreseeing and evaluating for different scenarios such as the changes in water quality of the river under study in this work.

The Qual2Kw model requires some data to be entered to perform the simulations: Coordinates and discharge coefficients in the stretches, distance between the mouth of the main river and the stretch; Altitude and slope of the stretches; Concentrations of Biochemical Oxygen Demand, Dissolved Oxygen, Water Temperature and Total Coliforms and Flow at Collection Points; Kinetic coefficients, such as the global BOD removal coefficient, re-coefficient, bacterial decay rate. Along the route, the river may receive contributions from tributaries and the

discharge of sewers, or abstractions, which may contribute to the increase or decrease in the volume of water in the source.

For the calibration of the model, it is necessary to insert monitored data, which include hydraulic data (flow) and water quality (BOD, DO, total coliforms).

III. RESULTS

The flow is determined by the amount of water that passes through a certain section of a free conduit, in this case the river under study, for a unit of time. As shown in Figure 3, the average flow increases downstream of the river. The river channel also increases, being at first a small stream and at 162.7 km a river expressive in size and flow. With the increase in flow from 8.00 m³/s to 50.60 m³/s, the effluent loads are more dispersed, facilitating the self-cleaning of the river and consequently increasing its aeration power.
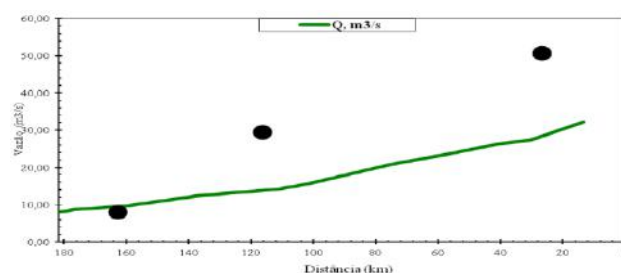

Fig. 3: Flow simulation along the longitudinal axis of the Inhandava River

The increase in flow rates may have a beneficial character, as a greater dilution of pollutants may occur. However, if this increase in flow occurs during periods of rain, it may also imply an increase in the loading of solids into the bed of springs, silting up rivers and streams.

The BOD shows the amount of oxygen needed to oxidize the biodegradable organic matter in the water. The greater the amount of organic matter present, the greater the amount of oxygen needed for its decomposition and at the level that the organic matter goes down, the decomposing bacteria will need small amounts of oxygen to decompose it, so the BOD will be low. The simulation of the BOD concentration for the stretch under study is shown in Figure 4.
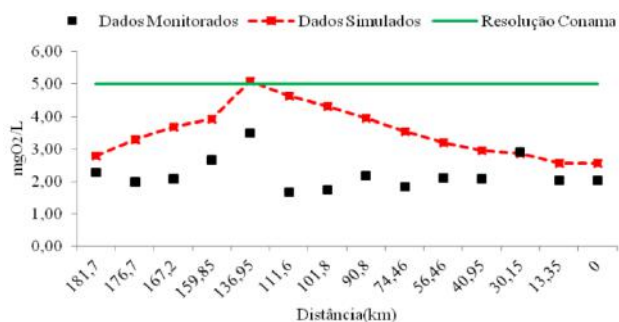
Fig. 4: Monitored and simulated data on the Biochemical Oxygen Demand

Fig. 5: Simulation of Dissolved Oxygen

In the analysis of the results of the water of the Inhandava River, the BOD varied considerably in several points, due to the diverse uses occurring in the river plains and climatological variations mainly in the pluviometric quantity. In the analysis of the BOD simulation, a reduction is observed along the simulated segment, going from 2.78 mg/L to 2.56 mg/L. This reduction may be directly related to the river's self-cleaning capacity. When there is no change in the degradation rate according to Silvino [8], possibly the reduction in BOD is due to the dilution of the organic load with the increase in the flow from the upstream to the downstream.

Dissolved oxygen (DO) is the most important parameter to express the quality of an aquatic environment, since it is fundamental for the maintenance of aerobic aquatic organisms [9] [10]. Normally, natural waters have a concentration around 8.0 mg/L at 25ºC, with the minimum concentration for maintaining aquatic biota in the range of 2.0 mg/L to 5.0 mg/L.

The concentration values of dissolved oxygen in the monitored points of the Inhandava River are above 5.0 mg/L established by Conama Resolution 357/2005, reaching high values in some samples, due to a period of river flooding, which is when the dilutions of the contaminants occur and there is a greater incorporation of oxygen by the waterfalls over the period of the river. Figure 5 expresses the values corresponding to the monitored DO data and the calibrated data in the Qual2kw model over space.
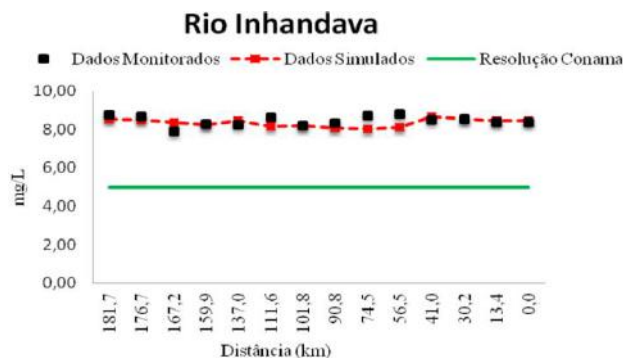
According to Vong Sperling [11], shallower and faster bodies of water tend to have a higher reaction coefficient, around 1,15 d-1 due to the ease of mixing along the depth and the greater turbulence on the surface. For the Inhandava River, a 3,0 d-1 reaeration coefficient was obtained, with a better calibration adjustment in the DO concentration.

The DO concentration is considered one of the most important variables when defining the condition of the watercourse and assessing whether it is within the limits of the class of its environment, making it a good indicator of the capacity that a water body has to promote the self-purification of organic matter discarded in its course.

The DO concentration decreases over the segment under study, varying from 8.55 mg/L to 8.47 mg/L, and the maximum concentration of this parameter did not exceed the value of 8.67 mg/L. According to Bárbara [12], the reduction in the DO concentration can be directly related to the temperature variation, knowing that these parameters are inversely proportional, the higher the temperature the lower the DO concentration in the water.

Determining the concentration of coliforms is an important indicator of the possibility of pathogenic microorganisms that are responsible for the transmission of waterborne diseases, such as typhoid fever, paratyphoid fever, bacillary dysentery and cholera.

The concentrations of total coliforms showed increases from upstream to downstream, which may be due to the presence of an urban perimeter, showing the strong influence of urban sewers in the contribution to the increase of the levels of this variable in the river. Figure 6 shows the concentration of total coliforms along the longitudinal axis of the 181, 7 km in study of the Inhandava River.
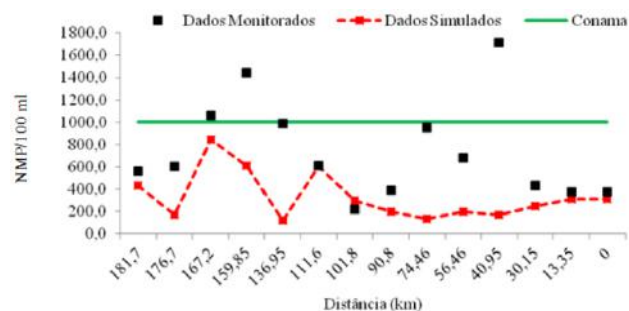
Fig. 5: Concentration of total coliforms along the longitudinal axis of the Inhandava River

IV.   CONSLUSION

The water quality, from the analyzed parameters, showed variations in the results, but without any visible spatial behavior, this is due to the use of the hydrographic micro basin being mostly agricultural and livestock, being diffuse sources of pollution, where contamination by these activities depends a lot on climatic factors. The river framework based on CONAMA Resolution 357/05, for the purpose of comparisons, showed results of high parameters of Coliforms demonstrating a possible pollution by swine manure.

The flow determined at the point one was 8 m³/s, reaching 50.60 m³/s at the point ten, thus increasing downstream of the river, this increase in flow facilitates the self-purification of the medium and consequently the aeration power of the river.

With the evaluation of the quality and calibration data, it is clear that the Inhandava River does not have critical levels of pollution, since extreme levels of concentrations have not been reached, but it must be emphasized that its monitoring have relevant importance in order to make possible the diagnosis of future impacts on this water resource, which is of fundamental importance for the northern region of the state of Rio Grande do Sul.

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