Biological and chemical oxygen demand in the Uraim River and the urbanization process. Paragominas-Pará

Demanda biológica e química do oxigênio no rio Uraim e o processo de urbanização. Paragominas-pará

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ABSTRACT
The preservation and reuse of water resources require the adequacy of the physical-chemical and biological parameters of the water to the current environmental legislation. In this sense, this research aimed to quantitatively analyze the biological oxygen demand - BOD and the chemical oxygen demand - COD, in an extension equivalent to 4,250 meters, from the point of water collection in the Water Treatment Station (area of less urbanization) to the left side of the PA 125 bridge (area of greater urbanization),
Paragominas-PA, as well as relating the variation of these parameters to the number of inhabitants in these two places. The methodology employed was observational, systematic, direct, and laboratory analysis protocols established for Brazilian waters were observed. Statistical analysis of data after laboratory analysis was performed using the BioEstat 5.3 software, based on descriptive statistics (calculations for: mean, standard deviation and coefficient of variation) and use of Pearson's linear correlation. The data obtained and analyzed indicated that both BOD (≤ 20, unpolluted waters) and COD (< 200, polluted waters) remained within the maximum permitted limits, in the two guidelines used in the six points analyzed (BOD = 0.9±1.1; COD =1.7±0.3). However, the BOD, between P3 (0.9mg/L of O2) and P6 (1.1 mg/L of O2), more urbanized places, there was a variation for more, in the two analyzed parameters, which indicated the entry of organic matter from domestic effluents, which is harmful to aquatic ecosystems, due to the absence of adequate basic sanitation in the municipality, which could determine a higher cost for the treatment of water captured in the Uraim river, which will increase the cost of cubic meter to the community that is supplied with water distributed by the company SANEPAR.

**Keywords:** river, physical-chemical parameters, Pearson's correlation.

1 INTRODUCTION

It is stated in the Global Agenda 2030, involved with Sustainable Development, drawn up by the United Nations (UN), that water quality should be available, as well as
be managed in a way that guarantees the quality of this natural resource, but this is not yet possible in the Brazilian territory because of the deficiency of basic sanitation (SCARLATTI et al., 2019). About this activity, Soares et al. (2020), state that this is an activity considered critical, since urban care for effluent collection and treatment are still incipient: 51.9% and 59.7%, respectively.

These delays jeopardize the preservation and reuse of natural resources, especially water resources, are recurrent themes nowadays. In this context, the proper management of these resources is necessary in order to ensure that environmental legislation is complied with and that the water environment is not damaged. Despite this, waste and/or effluents from urban activities are discharged into water bodies. Moreover, the high rate of urbanization causes the increase of the waterproof area of the city, which intensifies the leaching of organic matter towards the watercourse (SHARMA; KANSAL, 2010).

In this context, the quality of the waters of the so-called "urban rivers" is affected by two types of sources: the point and the diffuse one. The former has faster identification than the latter because these diffuse waters occur in undetermined locations. This type of discharge is recurrent in urban rivers (PEREIRA et al., 2021).

When excess organic matter is dumped, the population of microorganisms that feed on it increases and, therefore, the oxygen it consumes for metabolic activities. These activities are biological or biochemical in nature. For this reason, the consumption of this element is called biochemical demand for oxygen (BOD). This concept is essential for pollution analysis because it allows to evaluate the "polluting force" of a waste (BRANCO, 2010).

In addition to BOD, chemical oxygen demand (COD) determines the amount of oxygen required for organic matter degradation. However, it is made through chemical oxidation, capable of oxidizing both biodegradable and non-biodegradable organic matter (LAZZEREIS, 2013). Both are quantified from the oxygen consumed in the decomposition of organic matter.

In this perspective, this research aimed to quantify the BOD and the COD in 4,250 meters of the course of the river Uraim, in the upstream direction - downstream, in urbanized area of the municipality of Paragominas-PA, as well as to relate the variation of these parameters to the degree of urbanization of the area of both banks of this body of water. To better design this research, it was structured in: 1. INTRODUCTION; 2. MATERIAL
2 MATERIAL AND METHODS

2.1 PHYSIOGRAPHY OF THE MUNICIPALITY

The survey was carried out in the municipality of Paragominas, southeast of the state of Pará (Figure 1), with an estimated population of 108,547 inhabitants (IBGE, 2016). The local climate is hot and humid, with an average annual temperature of 26ºC and relative air humidity of 81% (BASTOS et al., 2010).

Figure 1. The municipality of Paragominas and the four neighboring municipalities: Nova Esperança do Piriá, Ipixuna do Pará, Ulianópolis and Dom Eliseu.


The hydrography consists of the catchment areas of the Gurupi River and the Capim River. The Uraim River flows into the Gurupi River, and both make up the Capim River Integration Hydrographic Region. But only the rivers Uraim, the streams of the 54, of the seven, and the Paragominas. It crosses the urban area, from the highway of the Pioneers and empties into the right bank, upstream-downstream, in the river Uraim. All of them constitute hydrographic microbasin of the Uraim river (Figure 2), they cross the urban perimeter (PINTO et al., 2009).
2.2 FIELD OF STUDY

The Uraim River, which has an annual average flow of 268,423.35 m³/h, is essential for the city's sanitation services, since it houses the water abstraction point for public supply (SANEPAR, 2014). Of the total length of 202 km, 4,250 meters were studied, starting at the water abstraction point of the Water Treatment Station - ETA of Paragominas-PA (area of least urbanization) and ending near the bridge of PA 125 (area of greatest urbanization), limit of the Industrial district (Figure 3). The study was carried out in the month of April, the rainy season of the region.
2.3 CHARACTERIZATION OF RESEARCH  

The research methodology employed followed the one described by Santos (2021): systematic structured observatory because data were used to observe the phenomenon (in this case, the pollution of the Uraim river), direct (with water sampling, and laboratory analysis) associated with the collection of documentary data with temporal cut-off between 2005 and 2023. With the exception of this cut-off, the legislation already promulgated and published: Chapman and Kimstach (1996), NBR ABNT (BRAZIL, 1989;1992; 2005).

2.4 DATA COLLECTION  

The six collection points of the water samples were selected under the condition that they were located in areas with smaller (Point 1) and greater urbanization (Point 6): at the water collection site of the Paragominas Water Treatment Station (ETA) and on the left side of the bridge of PA 125, respectively. Among them, points P2, P3, P4 and P5 were located, and all of them are 850 m apart (Figure 4).

Figure 4. Location of the six collection points. Paragominas - Pará.

Source: Google Earth (2016)
To better locate the six points, the geographical coordinates were identified, using the Global Positioning System - GPS (Table 1).

Table 1. Geographical coordinates of the six collection points. Paragominas - PA.

<table>
<thead>
<tr>
<th>Point</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S 3°00'24.68&quot;</td>
<td>O 47°22'52.83'</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>S 3°00'11.62&quot;</td>
<td>O 47°22'34.17'</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>S 2°59'56.31&quot;</td>
<td>O 47°22'18.15'</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>S 2°59'38.05&quot;</td>
<td>O 47°22'01.12'</td>
<td>4</td>
</tr>
<tr>
<td>5*</td>
<td>S 2°59'17.36&quot;</td>
<td>O 47°21'48.05'</td>
<td>5*</td>
</tr>
<tr>
<td>6</td>
<td>S 2°58'57.34&quot;</td>
<td>O 47°21'40.16'</td>
<td></td>
</tr>
</tbody>
</table>

Subtitles: ^1At the entrance to area 5; ^2At the exit of area 5.
Source: Authors (2017)

To verify whether urbanization acts on the values of BOD and COD, five areas were delimitated that are crossed by the six points of water collection, observed the course of the river that has the direction of P₁ to P₆, always marginal the extension of the water bodies studied (Figure 5).

Figure 5. Definition of the areas of influence at the six collection points. Paragominas - Pará.

Source: authors (2017)

The population of each area was estimated with the help of the interactive map, made available by the IBGE, which allows the user to delimit any area on the screen and obtain the approximate amount of total population in it, using data coming from the 2010 Demographic Census (IBGE, 2010).

2.5 WATER SAMPLING AND CHEMICAL ANALYSIS

The volume of surface water collected at each point was two liters, in polyethylene bottles with screw caps, previously sterilized. Sampling was performed on three
consecutive days, always at the same time (09:00), with one sampling per day at each point, totaling 18 samples collected. After the samples, they were sent to the Water Analysis Laboratory of the Paragomin Sanitation Agency (SANEPAR), where the physico-chemical parameters analyzed were the DBO, with the use of an aerator and incubator with a thermostat, and the DQO, with the use of a water bath, magnetic stirrer, and chemical thermometer. The analysis protocol used to determine the oxygen consumed in the water was that established by NBR 10.739. For the determination of DBO_{5;20}, the instructions contained in NBR 12.614 (BRAZIL, 1989;1992) were followed.

2.6 STATISTICAL PROCESSING OF DATA

The laboratory data obtained were treated statistically with the use of the BioEstat 5.3 software (AYRES et al., 2007), in which descriptive statistics were used (mean: used for general analysis of the water quality of the river with respect to the parameters analyzed in relation to the limits established for this research; standard deviation: homogeneity of the values of BOD and COD; in the points analyzed and coefficient of variation, expressed this deviation in percentage form, and confirms a low dispersion). Simple linear regression was applied to check the relationship between DBO x DQO; DBO x Urbanization; DQO x Urbanization, from the analysis of the termination coefficient value (R^2).

3 RESULTS

3.1 VALUES FOR BOD AND COD AND THE PARAMETERS SET OUT IN THE BASE PROTOCOLS.

The analysis of the data obtained for BOD and BQO indicated that both values are within the maximum allowed limits (Table 2).

Table 2. Values obtained from BOD and COD analyzes. River Uraim, Paragominas, Pará.

<table>
<thead>
<tr>
<th>Points</th>
<th>DBO</th>
<th>WFD</th>
<th>DBO</th>
<th>WFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>0.6</td>
<td>1.0</td>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Q2</td>
<td>0.7</td>
<td>1.2</td>
<td>0.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Q3</td>
<td>0.9</td>
<td>1.6</td>
<td>0.9</td>
<td>1.6</td>
</tr>
<tr>
<td>Q4</td>
<td>1.0</td>
<td>1.8</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Q5</td>
<td>1.0</td>
<td>1.9</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Q6</td>
<td>1.1</td>
<td>1.9</td>
<td>1.1</td>
<td>1.9</td>
</tr>
<tr>
<td>( \bar{x} \pm \sigma )</td>
<td>0.9±1.1</td>
<td>1.7±0.3</td>
<td>0.9±1.1</td>
<td>1.7±0.3</td>
</tr>
<tr>
<td>( p ) value</td>
<td>0.4413</td>
<td>0.2224</td>
<td>0.4413</td>
<td>0.2224</td>
</tr>
</tbody>
</table>

Source: authors (2023)
In Table 2, the data obtained on BOD and COD for P1 and P2, show lower MO reception. This is an indication that the entry of domestic effluents occurs more actively and more frequently, starting from P3, since the two parameters of water quality have risen. However, in P5 and P6, both located in area 5, presented a stability for both parameters analyzed. In the statistical comparison for the values for mean and standard deviation, the value for COD (1.7±0.3) was high. When compared to the mean value of the BOD (0.9±1.1), there is an almost 100% growth (Table 3).

Table 3. Descriptive statistics (maximum, minimum, mean, standard deviation (SD), for the Biochemical Oxygen Demand (DBO) and Chemical Oxygen Demand (DQO) of the six points analyzed. River Uraim. Paragomins - PA.

<table>
<thead>
<tr>
<th>Environmental Variable analyzed</th>
<th>BOD (mg/L O₂)</th>
<th>COD (mg/L O₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>1.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.7</td>
<td>1.2</td>
</tr>
<tr>
<td>( \bar{x} \pm \sigma )</td>
<td>0.9±1.1</td>
<td>1.7±0.3</td>
</tr>
</tbody>
</table>

Source: authors (2023).

For verification and identification of the points where pollution is already a fact, the \( p \) value was more significant for COD (\( p > 0.05; = 0.8396 \)) when compared to DBOp >0.05; = (0.4413). As the WFD indicates the chemical fraction of water or effluent, and that the decomposers act in an acid medium. So polluted water. The value of \( R^2 \), i.e., the termination coefficient, in linear regression, it was found that between these two parameters, there is a strong relationship (R²=0.9735; 97.3%), and that one acts on the other in a directly proportional way (Figure 6).

Figure 6. Linear correlation between DQO and DBO, River Uraim and Igarapé Paragominas, in urban stretch. Paragomins - PA.

\[ y = 1.9469x - 0.1331 \]
\[ R^2 = 0.9735 \]

Source: authors (2023).
3.2 DBO VS. POPULATION DENSITY RATIO AND COD VS. POPULATION DENSITY RATIO

The analysis of the data obtained for these two relationships indicated that starting from P3, the number of inhabitants tends to grow, which may generate greater production of domestic effluents and, consequently, a pollution load destined to the Uraim river, urban stretch (Table 4).

Table 4. Statistical data for BOD, COD, and inhabitants. River Uraim, Paragominas, Pará.

<table>
<thead>
<tr>
<th>Points</th>
<th>DBO—mg/L O₂—</th>
<th>WFD</th>
<th>Estimated number of inhabitants</th>
<th>F(i)</th>
<th>fr(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>0.6</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Q2</td>
<td>0.7</td>
<td>1.2</td>
<td>9,842</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Q3</td>
<td>0.9</td>
<td>1.6</td>
<td>23,186</td>
<td>12.9</td>
<td></td>
</tr>
<tr>
<td>Q4</td>
<td>1.0</td>
<td>1.8</td>
<td>40,064</td>
<td>22.3</td>
<td></td>
</tr>
<tr>
<td>Q5</td>
<td>1.0</td>
<td>1.9</td>
<td>49,225</td>
<td>27.4</td>
<td></td>
</tr>
<tr>
<td>Q6</td>
<td>1.1</td>
<td>1.9</td>
<td>57,081</td>
<td>31.8</td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>5.3</strong></td>
<td><strong>9.4</strong></td>
<td><strong>179,398</strong></td>
<td><strong>100</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: Prepared from data collected by the authors (2023).

To verify the influence of population growth on the concentrations of BOD, we analyzed the dispersion of it in the water medium in the six points analyzed, we found that the population growth generates a greater quantity of effluents containing organic matter, and that the decomposition of this, requires greater consumption of dissolved oxygen, which raised the concentrations of BOD, since the value of the coefficient of determination was equal to 94.8%, that is, identifies a strong relationship between these two variables (Figure 7).

Figure 7. Analysis of the relationship between population growth and the concentration of DBO, Uraim River, Paragominas, Pará.

\[ y = 113.45x - 70.316 \]
\[ R^2 = 0.948 \]

Source: Authors (2023).
For the relationship between COD and population growth, the data obtained and analyzed indicated that the degree of relationship between these two variables, based on the coefficient of determination ($R^2 = 93.8\%$), is strong (Figure 8).

Figure 8. Analysis of the relationship between population density and the concentration of the DQO, Uriam River, Paragominas, Pará.

\[ y = 57.201x - 59.716 \]
\[ R^2 = 0.9384 \]

Compilation: authors (2023).

4 DISCUSSIONS

4.1 THE SIX POINTS SAMPLED

The data obtained and analyzed for the six points at which the samples were collected indicated that the marginal urbanization of lotic water bodies, when associated with the deficiency of basic sanitation, becomes a polluting source of the diffuse kind and that contributes directly to the alteration in the quality of the water. About this pollution, Sodré (2012), states that diffuse pollution occurs worldwide, and that in these cases, they occur in large areas, and that in general, this pollution arises where there are frequent anthropic operations such as soil sealing. In the Uriam river, this has similarity from the points P3 to P6.

It is worth noting that P\(_1\) does not suffer from urbanization influence, as it is located before the urban area. Population interference in the concentration of the parameters analyzed occurs as a function of the reception of domestic effluents that are discharged by the community into the body of water that is the object of this research. The problem is that this dumping does not only affect surface water, since there is infiltration into the soil and the carrying of contaminants that may be present in wells, whether artesian or Amazonian (water pipes).
About these wells, Castro (2020) warns that the contamination or pollution of these water supply sites, their quality can be altered by other anthropic activities such as industry, agriculture, or even septic tank leakage. The consequence of the loss of water quality, especially for human consumption, was the subject of research by Matos et al. (2020). These authors concluded that "water safety" involves both the availability and quality of water, and that, when ingested, it maintains the health of consumers.

In terms of comparison with the Water Legislation, the analysis of the data obtained, after laboratory analysis, indicated that the values found, in the six points analyzed, for the first variable analyzed (DBO), are in accordance with CONAMA Resolution, No. 357 (BRAZIL, 2005), which establishes a maximum value equal to 3 mg/L O₂ in Class 2 fresh waters. When these limits are exceeded, the cost of water treatment rises. Ribeiro e Moura (2021) wrote about this that surface waters are in direct contact with atmospheric air (in the open air), which increases the operational cost of treating the water captured before distribution to the final consumer.

4.2 BIOLOGICAL OXYGEN DEMAND

The values for this parameter were increasing, starting from P1. Two observations were made at this point: 1. The maintenance of ciliary vegetation; 2. Low urbanization, therefore, low reception of domestic effluents, low load of organic matter (MO). About this MO, Matos et al. (2013), they claim that the quantification of DBO makes it possible to establish, even indirectly, how much of MO has been degraded. For this reason, they say that the use of this parameter in the quality of the water is essential for the elaboration of the monitoring and the dimensioning of biological treatment systems.

In the view of Pinheiro et al. (2015), the BOD is aggravated whenever it becomes an effluent receptor body whose predominance is linked to organic matter because there will be a high consumption of oxygen in this place, and this will bring as consequences: the mortality of fish, the proliferation of anaerobic bacteria, among others. All this is already evident in the Uraim River.

4.3 CHEMICAL OXYGEN DEMAND

When the concentrations of the Chemical Demand for Oxygen (COD) are analyzed in surface waters, it is necessary because the values found are indicators of the pollution load contained in that place, and the higher this value, the greater the degree of
water pollution. In this research, the values showed increasing between P3 and P6, with slight stability in the A5, where points 5 and 6 were concentrated. About the Longuine COD (2014), in analyzes carried out in the Campos Stream, Ribeirão Preto-SP, concluded that the highest values are the indications of water pollution and, in general, highlights the presence of biodegradable effluents. So, from P3 to P6, this kind of material is being deposited in the Uraim River.

To better understand and identify the state of pollution of the Uraim river, the values obtained after laboratory analyzes were compared with those recommended by Chapman and Kimstach (1996). Such a comparison was necessary because both claim that the observed concentrations of COD in surface waters not receiving effluents are 20 mg/L O$_2$ or less. The result of this comparison made it possible to state that the quality of the water, in comparison with the base values, proved to be adequate.

5 CONCLUSIONS AND RECOMMENDATIONS

The Biochemical Demand of Oxygen suffers influence from the process of urbanization, therefore, population and rural growth, are mechanisms that contribute to the loss of water quality.

Therefore, it is recommended that monitoring of potential river polluting activities should be frequent and effective, with analysis of BOD and COD concentrations. In addition, public roads must be kept clean, to prevent leaching of organic matter and other waste towards the river, in addition to the use of agrochemicals.
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