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Research paper

Quantitative and qualitative analysis of water from the basin of the Mutum stream in Uberaba, Brazil

Análise quantitativa e qualitativa da água da microbacia do córrego Mutum em Uberaba, Brasil

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ABSTRACT: *The morphometric analysis of basins is a complementary way to explain the interactions between landscape elements and water quality. This study aimed to analyze the morphometry, quality, and quantity of water in the Mutum stream basin in the municipality of Uberaba, Brazil. The morphometric analysis, water flow through the float method, and water microbiological analysis were performed. The results indicated that the stream flow increased parallel to rainfall increase in October. The total area of the microbasin is 8.60 km², with a perimeter length of 12.73 km and 12.35 km of the main course. The microbasin has elongated, where the water flows easily and has the possibility of floods in the area. The water stream was contaminated by 2.20 NMP 100 mL^{-1} of fecal and thermotolerant coliforms, making it unfit for human consumption during the evaluated period.*

Keywords: *environmental diagnosis, environmental preservation area, hydric flow, potability*

RESUMO: A análise morfométrica das microbacias hidrográficas constitui-se num meio complementar para explicar as interações que ocorrem entre os elementos da paisagem e a qualidade da água. Neste estudo objetivou-se analisar a morfometria, a qualidade e quantidade da água da microbacia do córrego Mutum, no município de Uberaba, Brasil. Foi feita a análise morfométrica, mediu-se a vazão através do método do flutuador e fez-se a análise microbiológica da água. Os resultados indicaram que a vazão do córrego aumentou paralelamente ao aumento da precipitação a partir do mês de outubro. A área total da microbacia é de 8,60 km², perímetro de 12,73 km e comprimento do curso principal de 12,35 km. A microbacia tem formato alongado, onde a água escoa com facilidade e não tem a possibilidade de ocorrer enchentes na área. A água do córrego encontrava-se contaminada por de 2,20 NMP/100 mL de coliformes fecais e termotolerantes, tornando-a imprópria para consumo humano no período avaliado

Palavras-chave: diagnóstico ambiental, área de preservação ambiental, vazão hydrica, potabilidade.

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INTRODUCTION

The association of quantitative and qualitative methods in the study of basins has been fundamental in investigating the factors that influence the various forms of relief and the identification of homogeneities in a given geographical area. Different methods may reveal specific physical, chemical, and biological indications for a given location to qualify environmental changes and to support the determination of the natural fitness of each case (VIEIRA; TOWERS; SANTOS, 2018; SUKRISTIYANTI et al., 2018).

Several studies prove the importance of performing morphometric analysis in defining parameters that reveal physical indicators for a given location and qualify the environmental changes due to land use or occupation. Some of those studies were implemented in the microbasins of the environmental protection area (EPA) of the Uberaba River (ABDALA; NISHIYAMA; TORRES, 2011; VIEIRA et al., 2012a; TOWERS; VIEIRA, 2013; TOWERS; SCALLOP; BARRETO, 2018); other studies were implemented in other basins (RODRIGUES; PISSARA; CAMPOS, 2008; MELO et al., 2010; VALLE JR et al., 2011; ZANATA et al., 2011; COUTINHO et al., 2011; WOULD; BANKS; SOUZA, 2012; MANI et al., 2022).

All these studies have brought relevant information on the soil-surface relationship because these address pedology, relief, and hydrographic network, with the consequent environmental processes and describe the dynamics of surface drainages and topographic forms, analyzing several geomorphological issues (COUTINHO et al., 2011). However, Zanata et al. (2011) highlight the importance of the scale in the morphometric analysis of microbasins because increased scales and terrestrial references alter the number of hydrological compartments and increase the length of the drainage network, which reflect in changes in the physical parameters studied.

The water quantity and quality in a region are determined by the intensity of precipitation, weathering, and crops and by the influence of agriculture, urban concentration, industrial activity, and excessive water use (ANDRADE et al., 2007). The water quality reflects the combined effects of processes that occur along the watercourse. Additionaly, such water quality is not only explained by its biological characteristics but by the quality of the entire basin ecosystem functioning.

The microbasin area of the Mutum stream has about 8.6 km^2 and correspondes to 1.63% of the Uberaba River EPA. The length of its watercourses is about 11.9 km, and 5.6 km for the main watercourse. About 126.1 hectares are of native forest, containing seven headwaters and corresponds to 1.5% of the total Mutum strem EPA. Mutum stream has a $Q_{7/10}$ flow at the river mouth of 30 L s^{-1}, and as an affluent of the Uberaba River, it supplies water to Uberaba city, in Minas Gerais state, Brazil (SEMEA, 2004).

In Brazil, surface water quality is determined according to its uses and intentions, and its classification is ranked according to some physical and chemical attributes (BRASIL, 2021). The physical, chemical, and biological attributes indicate the water quality for human consumption, which cannot contain pathogenic microorganisms and be free of bacteria from fecal contamination (LIMA; SILVA, 2008). Among the physical and chemical parameters analyzed to evaluate the water quality of watercourses, there are color, turbidity, flavor, odor and temperature, pH, alkalinity, acidity, nitrogen, phosphorus, dissolved oxygen, and organic matter present in water; the biological parameters are intended to monitor the presence of microorganisms (DANELON; RODRIGUES, 2013). In this context, this study

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aimed to analyze the morphometry, quality, and quantity of water from the microbasin of Mutum stream, a tributary of the Uberaba River in Uberaba city, Minas Gerais state, Brazil.

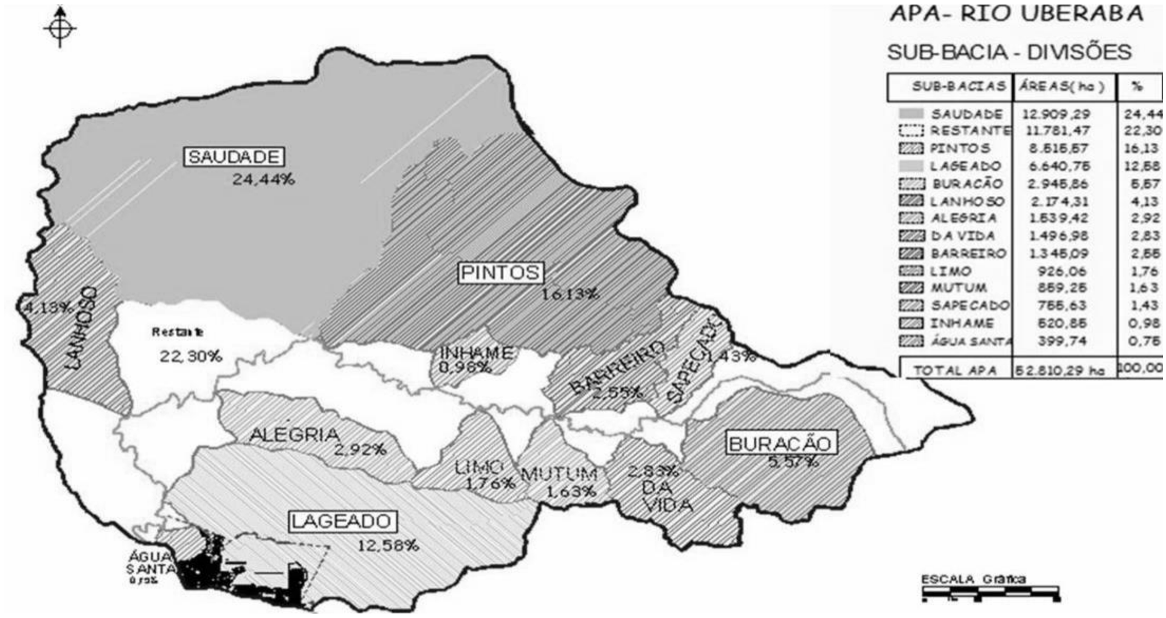
MATERIAL AND METHODS

The study was carried out in the municipality of Uberaba, located in the microregion of Triângulo Mineiro, in Minas Gerais state, Brazil. The area has about 4.537 km^2 and is located between the South latitude 19º 45' 27" and West longitude 47º 55' 36". The data collection occurred between October and November 2011.

The Uberaba River basin has an area of approximately 2,346 km^2, and covers the municipalities of Uberaba (24%), Veríssimo (50%), Conceição das Alagoas (70%), and Planura (1%) (CRUZ; PATERNIANI; OAK, 2003). The lowest point (mouth of the Uberaba River) is at an altitude of 811 m, and the highest point is at 885 m.

The municipality of Uberaba created the environmental protection area (EPA) of the Uberaba River through state law (n° 13,183 of 21/01/1999) and located the area at the head of the Uberaba river basin and has a total area of 528 km². The Uberaba River EPA was subdivided into microbasins larger than 4 km^2 (**Figure 1)** (SEMEA, 2004).

Figure 1. Main streams that make up the Environmental Preservation Area (APA) of the Uberaba River



Source: SEMEA (2004).

The Mutum Stream microbasin composes the EPA of the Uberaba River and is located between the South latitude coordinates 19º40'12.8'' and West longitude 47º47'35.8''. This microbasin has a total area of 859.25 ha corresponding to 1.63% of the Uberaba River EPA area, and bout 126 ha of covered area with native vegetation. This means that about 14.7% of this microbasin area is covered with native vegetation according to Landsat-7 satellite image in October 2003 (**Figure 2**) (SEMEA, 2004).

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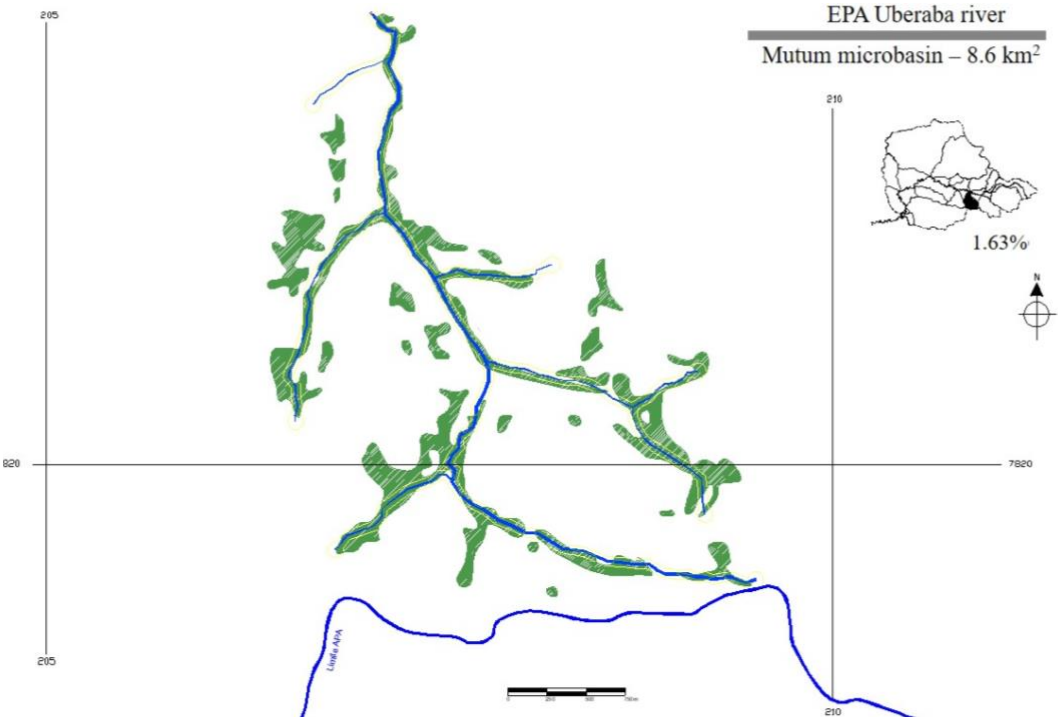
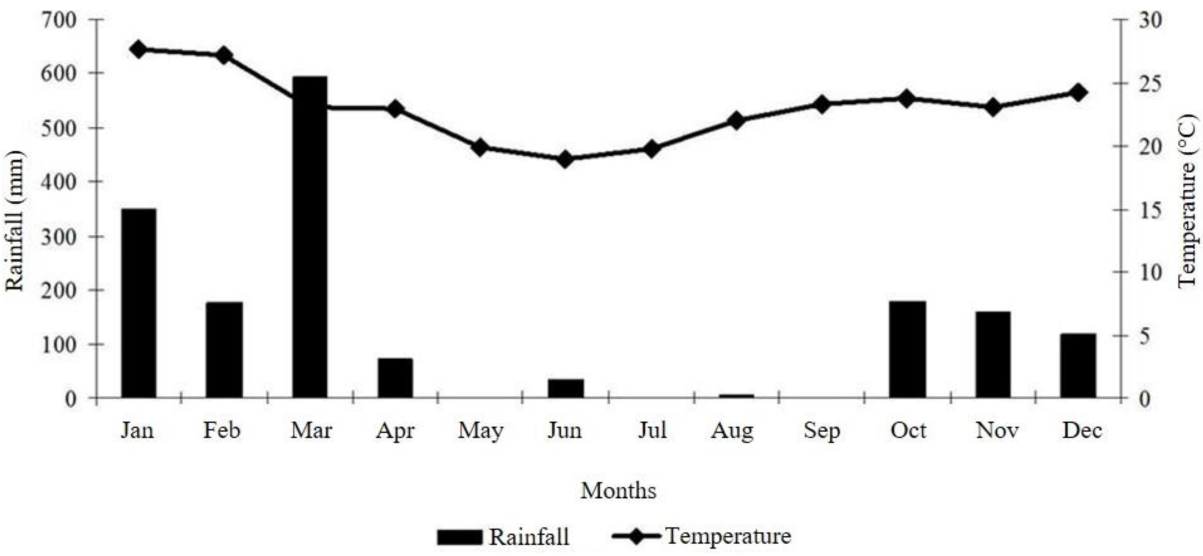
Figure 2. Microbasin of the Mutum stream, which makes up the EPA of the Uberaba River



Source: SEMEA (2004).

The climate of the Uberaba River basin is classified as Aw (warm tropical) according to the updated Koppen's classification (BECK et al., 2018) (hot, rainy summer and cold, dry winter). Average annual precipitation and temperature are 1600 mm and 22.6 ºC, respectively (INMET, 2021). The accumulated precipitation during 2011 was 1,680 mm, while in the period evaluated (October to December/2011), it was 336 mm (**Figure 3**) (INMET, 2021).

Figure 3. Average precipitation (mm) and temperature (ºC) obtained at the IFTM Campus Uberaba-MG Meteorological Station in 2011



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The topography of the Uberaba River basin is characterized by flat or slightly wavy surfaces, where Latosols and Argisols with different degrees of soil fertility can be found (EMBRAPA, 1982). The IBGE (Instituto Brasileiro de Geografia e Estatistica) topographic chart (Folha Uberaba) used was in the 1:100,000 scale, with curves distant every 50 m, in digital format (IBGE, 2004). To determine the areas and drainage networks, the water dividers were identified, the highest altitude line of the basin was quantified, and all measurements were performed with the aid of the AutoCAD 2010 program. The indexes presented in CARDOSO et al. (2006), SANTOS; SOBREIRA (2008), RODRIGUES, PISSARA; CAMPOS (2008), FLORÊNCIO; ASUNCIÓN (2010), VIEIRA et al. (2012b), VIEIRA, TORRES; SANTOS (2018) are highlighted:

The basin area (A) is defined as that which is drained by the whole of the river systems, and the length of the basin (L) is evaluated based on the main watercourse. Through the relationship between A and L, the geometric length of the watercourse can be calculated (Equation 1).

$$L = 1{,}5\ x\ A^{0{,}6} \tag{1}$$

where: L = length of the basin (km); A = basin area (km^2).

The compactness coefficient (Kc) relates the shape of the basin with a circle, which is the result of the relationship between the perimeter of the basin and the circumference of a circle of area equal to that of the basin (Equation 2):

$$Kc = 0{,}28\ (P/\sqrt{A}) \tag{2}$$

where: P = perimeter (m); A = drainage area (m^2).

The form factor (Kf) relates the shape of the basin with a rectangle, corresponding to the ratio between the average width and the axial length of the basin (Equation 3):

$$Kf = A/L^2 \tag{3}$$

where: A = drainage area (m^2); L = length of the basin axis (m).

The circularity index (Ci), simultaneously with Kc, tends towards the unit as the basin shape approaches the circular shape and decreases as the shape becomes elongated(Equation 4):

$$Ic = 12{,}57 * A/P^2 \tag{4}$$

where: A = drainage area (m^2); P = perimeter (m).

The drainage density (Dd) estimates the highest or lowest speed water leaves the basin. Thus, this index indicates the degree of development of the drainage system in the referred basin (Equation 5):

$$Dd = Lt/A \tag{5}$$

where: Lt = total length of all channels (km); A = drainage area of the basin (km^2).

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The sinuosity of the main course (Sin), the mean slope of the basin (H), and the roughness coefficient (NB) were calculated using equations 6, 7, and 8.

$$Sin = Lt/Dv^2 \quad (6)$$
$$H = ((Cn * h)/A) * 100 \quad (7)$$
$$RN = Dd * H \quad (8)$$

where: A = drainage area of the basin (km^2); Lt = total length of all channels (km); Dv = distance vector from the main watercourse; Cn = sum of the lengths of all level curves (km); h = equidistance between the level curves (km); H = mean slope (%).

The roughness coefficient (RC) was calculated using the topographic chart of representative level curves of the studied area, where the total length of the basin level curves was determined. Next, the average slope and the RC coefficient of each microbasin were calculated to elaborate the database.

Rocha (1997) points out four classes of land use aptitude, established according to the relationship between the largest and the smallest RC [agriculture/urbanism (A), pasture (B), pasture/forestry (C), only forestry (D)]. The distribution of land use aptitude classes was based on the RC values found, ordering them increasingly. Subsequently, the amplitude (RC major - RC minor) and the interval (amplitude divided by four) of these roughness coefficients were calculated as described by Rocha and Kurts (2001). For this microbasin characterization, 12 other microbasins of the Uberaba River (TORRES; VIEIRA, 2013) were calculated to increase the result's amplitude and range for better representative ness.

The classification of the drainage channels was established according to Horton's laws (1945) modified by Strahler (1952), which considers every watercourse without affluent as being of the first order. The junction of two watercourses of the same order forms another of an immediately higher order which does not extend the smaller affluents and referrers only to segments of the main channel.

Four technical visits were made to the Mutum stream at intervals of 15 days to estimate the water flow between October and November 2011. The float method estimated the water flow at a straight and uniform point in the watercourse bed. This method used the width, length, and depth of the watercourse section to mark the water level. Piles were placed to mark the beginning and end of the 8 meters section traveled by the float. A rope was used to mark the measurements every 0.2 m in the width of the section to determine the wet area of the watercourse (**Figure 4**). For flow calculation, equation 9 was used (HERMES; SILVA, 2004):

$$V = A \, x \, D \, x \, C \, / \, T \quad (9)$$

where: V = flow (m^3); A = cross-section area of the stream (m^2) being: A = stream width (m) × average stream depth (m); D = distance used to measure the speed of the stream (m); C = correction coefficient (used 0.8 for streams with a rocky bottom, or 0.9 for streams with muddy bottom); T = time(s) spent by the float to cross distance D.

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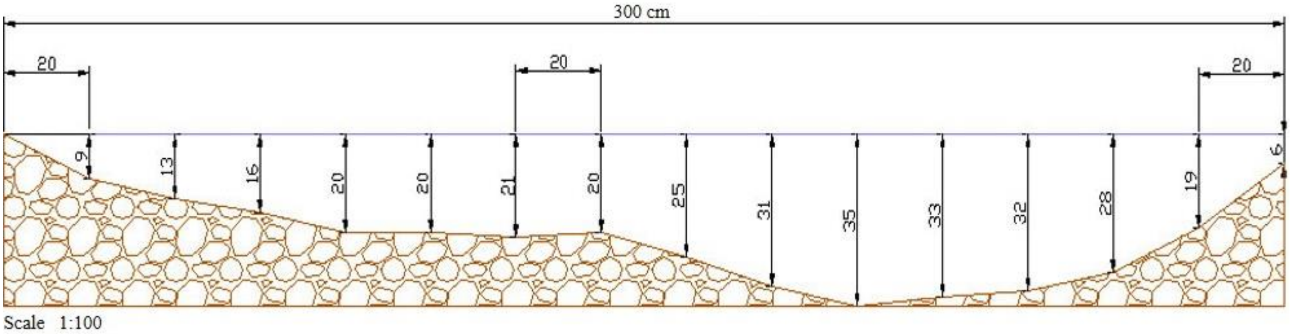
Figure 4. Scheme for determining the wet area of the channel, where the values 9, 13, 16, and others are the stream's depth measures



The water sampling for analysis was performed according to the standards established by the Microbiology Laboratory of the IFTM campus Uberaba, which is based on current legal standards, according to the Ministry of Health, ordinance n° 888 of 05/Apr/2021, which establishes that the presence of total and thermotolerant coliforms are determined in water to ascertain their potability (BRASIL, 2004).

The method of analysis used to determine the presence of total and fecal coliforms in water samples was the multiple tubes technique (APHA, 2012). This technique consists of two procedures, one presumptive (I) and one confirming (II). Procedure I is used to determining the presence or absence of coliforms. This procedure uses 10 mL of Lactose-Bouillon in test and inverted Durham tubes. The tubes containing the Lactose-Bouillon were autoclaved at 1 kgf cm^{-2} of pressure and 121 °C for 15 minutes. After cooling, the sterilized tubes were inoculated with water from the Mutum river with dilution replicas from 10^{-1} to 10^{-4}. Fifteen tubes for each dilution were incubated in a greenhouse at 35.5+0.5 °C for 24 hours. The results are simple to interpretate: if there is gas formation and cloudy coloring of the solution in the Durhan tube, then there are bacteria of the coliform group, which will only be confirmed in Procedure II.

In Procedure II, 10 mL of Brillangrum-Galle-Lactose-Bouillon, or Brilliant-Green Bile Lactose Broth, were used in separate test tubes for total coliform analysis; 1 mL of the sample where cloudy gas formed was incubated for 24 to 48 hours at 35.5+0.5 °C. If gas production has not been detected, if the solution does not become cloudy, the test concludes negative for this coliform group. For fecal coliform confirmation, EC broth medium is used in test tubes and Durham tubes, where 1 mL of the positive sample from Procedure I was transferred. The fecal coliform group is confirmed if gas was formed in the Durham tube. This method of analysis is quantitative, which allows for determining the most probable number (MPN) of the microorganisms surveyed.

RESULTS AND DISCUSSION

The analysis of the morphometric indices from the Mutum stream basin confirms the total area of 8.60 km², the perimeter of 12.73 km, and the length of the main course of 12.35 km (**Table 1**). The drainage system of the Mutum stream basin is little branched and considered of 3rd order, with a dendritic pattern, which corroborates with the classification made by ABDALA; NISHIYAMA; TORRES (2011). Tonello et al. (2006) highlight that orders

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less than or equal to four are common in basins and reflect the direct effects of land use because a more branched network of streams means more efficient drainage systems.

Table 1. Morphometric analysis of the Mutum stream basin, an affluent of the Uberaba River

Morphometric indexes	Unity	Values
Area (A)	km²	8.60
Perimeter (P)	km	12.73
Length of main stream	km	12.35
Thalweg length	km	4.11
Sinuosity of the main course (Sin)	---	3.00
Compactness coefficient (Kc)	---	1.22
First order channels	km	15.16
Second order channels	km	6.69
Third order channels	km	7.52
Fourth order channels	km	-
Total length	km	29.37
Drainage density (Dd)	km km^{-2}	3.42
Circularity index (Ci)	---	0.67
Form factor (Kf)	---	0.51
∑ level curve lengths	m	32,414
Equidistance between curves	m	50
Average slope of the basin	%	18.80
Roughness coefficient (RC)	---	64.36

The observed length of the main course (12.35 km) is higher than the 5.56 km indicated by Semea (2004). This difference may be caused by the difference in the reference image scale or the computer program used, as highlighted by Zanata et al. (2011); these authors stated that scale and software might cause changes in the length of drainage networks within the basins.

The sinuosity of the main watercourse (Sin) was 3.00. This observation, associated with the mean slope (18.80%), indicates that the water flows with increased velocity, hindering infiltration and favoring the occurrence of erosive processes along and in the stream bed. Watercourse sinuosity is a controlling factor of the natural flow rate and represents the relationship between the main watercourse's length and its thalweg (TORRES et al., 2011).

The Mutun stream compactness coefficient (Kc), circularity index (Ci), and form factor (Kf) were 1.22, 0.67, and 0.51, respectively. These results indicate that the shape of the Mutum microbasin is elongated and facilitates the water flow and consequently decreasing the risk of flooding. The drainage density (Dd) was 3.42 km km^{-2}, indicating the drainage system's high degree of development. According to Villela and Mattos (1975), the Dd can range from 0.5 km km^{-2} in a basin with poor drainage to 3.5 km km^{-2} or more in well-drained basins. The Dd is an index that cannot be solely analyzed; however, when associated with Kc (1.22) and Kf (0.51) results, it is possible to confirm that no flooding can be considered in the Mutum microbasin. These results also indicate that the susceptibility to erosive process in the microbasin is elevated.

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The Debossan River basin in Nova Friburgo (Rio de Janeiro state) was studied by Cardoso et al. (2006). The authors observed high Kc (1.58), Kf (0.33), and Ci (0.39), and drainage density (Dd) of 2.36 km^{-2} that point to an elongated basin form. Such results also indicated that the rainfall was more distributed at different points, mitigating the influence of rainfall intensity and reducing variations in the watercourse flow and flooding events.

The average slope of the basin (18.80%) can indicate the type of relief existing in the area, which was classified as wavy according to the proposal presented by Embrapa (1979). The calculated Roughness Coefficient (RC) (64.36) indicated that the Mutum microbasin is classified as Class B (presents soils suitable for livestock) (**Table 2**), as proposed by Rocha and Kurts (2001).

Table 2. Classification determined by the roughness coefficient (RC), domain interval, values found, and land uses

Class	Domain interval (RC values)	Land use	Values found
A	17.23 - 47.56	Agriculture	16.60 (Pintos). 17.23 (Ribeirão da Vida). 20.46 (Alegria).
B	47.57 - 77.90	Livestock	48.15 (Limo). 49.14 (Borá). 51.00 (Mata). 51.10 (Jacaré). 60.71 (Saudade). 62.46 (Borazinho). 64.36 (Mutum). 70.60 (Congoinhas).
C	77.90 - 108.24	Livestock/Forest	-----
D	108.24 - 138.57	Forest	111.42 (Galinha). 138.56 (Inhame).

Source: Torres e Vieira (2013) modified.

Torres and Vieira (2013) calculated the RC of twelve microbasins in the same environmental protection area (EPA) of the Uberaba River and observed that three basins fall into class A (Agriculture), 7 in class B (Livestock), and 2 in class D (Forest). These values were used to calculate the amplitude (RC major - RC minor) and the interval (amplitude divided by 4) of these roughness coefficients, as described by Rocha and Kurts (2001).

In a similar study in the Uberaba River basin, in the Mata and São Francisco microbasins, in Campo Florido city, Minas Gerais state, the morphometry of the areas determined similar indices and observed values of 41.08 for amplitude and 10.27 of interval (VALLE JR et al., 2011). The authors concluded that the analysis of potential land use should be performed in each region because morphometric characteristics are specific among soil units, according to the differences between soil formation, relief topography, and land occupation.

The stream flow is fundamental to evaluating the water volume available at a given point or stretch of a river which also influences water quality. Water quality tends to worsen with the flow decrease and dilution effect due to the concentration of pollutants (TORRES; VIEIRA, 2013). Stream flows of 25.78, 34,44, 34.21, and 54.11 L s^{-1} were reported in the evaluations performed. From the first to the last collection, the stream flow doubled, an expected increase for the period, and precipitation was reported in the region (Figure 3).

Water to be considered drinkable should not contain pathogenic microorganisms and be free of bacteria from fecal contamination. Ordinance n° 518/2004 of the Ministry of Health recommends that the standard count of heterotrophic bacteria must not exceed 500 Colony Forming Units (CFU) per 1 mL of sample (500 CFU mL^{-1}). The same ordinance also indicates that total and thermotolerant coliforms must be absent in 100 mL for human consumption

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(VIEIRA; TOWERS; SANTOS, 2018). The water analysis data (**Table 3**) indicated contamination with total and thermotolerant coliforms of 2.20 MpN 100 mL^{-1}, making it unfit for human consumption during water sampling.

Table 3. Results of the physical-chemical and microbiological analysis of water from Mutum stream

Parameters	Values	Units	Method	Detection Limit	MAV (3)
			Physical - Chemical		
Apparent color	10.00	Hu (1)	Photometric	0.100	15
pH	7.60	---	Potentiometric	---	6-9.5
Turbidity	5.50	TU (2)	Turbidimetric	0.100	5
			Microbiologic		
Total coliforms	2.20	MLN/100 mL(4)	ABNT	1.100	Absent
Thermotolerant coliforms	2.20	MLN/100 mL(4)	ABNT	1.100	Absent

(1)Hu = Hazen unity (mg Pt-Co/L); (2)TU = Turbidity Unit; (3)MAV = Maximum Allowable Value; (4)MLN = Most Likely Number. Analysis performed at Labfert Analyses (Uberaba, MG. Brazil).

The Mutum microbasin contamination probably occurred due to the presence of cattle in the studied area. The access of the animals to the studied area could be verified by the trails on the banks of the watercourses. Such areas should be protected to preserve riparian forests. Regarding the physical-chemical properties of the water, some important alterations were observed, where water turbidity (5.50 turbidity unit) was above the maximum allowed value, which is 5.00 turbidity unit. The water pH was 7.60 (quite alkaline), characterizing pollution by pesticides and, or fertilizers, which was probably caused by the bean and corn crops observed in the region.

CONCLUSION

The total area of the microbasin is 8.60 km^2, with a perimeter of 12.73 km and a length of the main course of 12.35 km.

The stream is elongated in shape, where water flows easily, and does not have flooding area risks.

The water was contaminated by 2.20 NMP 100 mL^{-1} of fecal and thermotolerant coliforms, making it unfit for human consumption in the evaluated period.

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