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**Environment**

# Impact of urbanization on the water quality of the Uberaba River and tributaries

## Impacto da urbanização na qualidade da água do Rio Uberaba e afluentes

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## ABSTRACT

This paper evaluated the quality of the water in Uberaba River and tributaries. Seven sites were sampled, in a 12-km under the influence of the urban area. The sampling site started upstream the raw-water catchment station, passing through the urban perimeter, upstream and downstream the discharge of the effluent treated by the Sewage Treatment Plant. Benthic macroinvertebrates were collected using a Surber net and, after identification, the indices of BMWP, diversity, equitability and dominance were calculated, besides functional group analysis. In each sampling site, it was analyzed microbiological and physicochemical parameters in order to identify possible domestic and/or industrial pollution sources. A rapid assessment protocol (RAP) was also applied, and land use and occupation aspects were mapped. The water collected in the furthest sampling site from the urban area and with vegetation in the surroundings, presented good quality, based in BMWP index. However, this quality dropped to very poor as the river water crossed the urban perimeter. The land use and occupation map showed a predominance of agriculture/pasture and urbanization. In addition, the presence of *E. coli* and the high levels recorded for some metals (principally cooper and cadmium), suggested contamination of the water with domestic and industrial effluents.

**Keywords**: Biomonitoring; BMWP; Water quality, Land use and occupation

## RESUMO

Este trabalho avaliou a qualidade da água do rio Uberaba e de seus afluentes. Sete locais foram amostrados, em um percurso de 12 km sob influência da área urbana. O local de amostragem teve início a montante da estação de captação de água bruta para abastecimento público, passando pelo perímetro urbano, a montante e a jusante do lançamento do efluente tratado pela Estação de Tratamento de Esgoto. Os macroinvertebrados bentônicos foram coletados utilizando um amostrador do tipo *Surber* e, após a identificação, foram calculados os índices de BMWP, diversidade, equitabilidade e dominância, além da análise de grupos funcionais. Em cada local de amostragem, foram analisados parâmetros microbiológicos e físico-químicos. Também foi aplicado um protocolo de avaliação rápida (PAR) e mapeados os aspectos de uso e ocupação do solo. A água coletada no trecho de captação de água bruta do Rio Uberaba, ponto de amostragem mais distante da área urbana e com vegetação no entorno, apresentou qualidade satisfatória, com base no índice BMWP. No entanto, essa qualidade caiu para muito ruim quando o rio cruzou o perímetro urbano. O mapa de uso e ocupação do solo mostrou predomínio da agricultura / pastagem e urbanização. Além disso, a presença de E. coli e os altos níveis registrados para alguns metais (principalmente cobre e cádmio), sugeriram contaminação da água com efluentes domésticos e industriais. Os dados indicaram os impactos negativos do perímetro urbano sobre as águas do rio Uberaba e afluentes e apontaram os impactos deletérios nas comunidades de macroinvertebrados bentônicos.

**Palavras chaves**: Biomonitoramento; BMWP; Qualidade da água; Uso e ocupação

## 1 INTRODUCTION

The pollution of surface water bodies is one of the most severe environmental issues in the world, with negative impacts on environmental health and decreases of water quality used for different purposes. The release of domestic and industrial effluents in water bodies and the use of pesticides and agrochemicals in agricultural systems are the main causes of pollution in aquatic ecosystems (DELLAMATRICE; MONTEIRO, 2014; QUEIROZ; SILVA; TRIVINHO-STRIXINO, 2008). These impacts can be based on physicochemical and biological parameters (ANA, 2017). Physicochemical monitoring evaluates parameters such as dissolved oxygen (DO), biochemical oxygen demand (BOD), hydrogenionic potential (pH), temperature and turbidity (ANA, 2017). CONAMA Resolution nº 357/2005 addresses the limits of such parameters and classifies in quality water bodies, besides setting guidelines for their classification (BRASIL, 2005). However, this monitoring type analyzes momentary conditions in the environment without showing the effect of contaminants on the ecosystem over time (SILVA; ROSA; ALVES, 2015).

Biological monitoring, also known as biomonitoring, is complementary to physicochemical analysis and can be used to evaluate biological communities in different ecosystems. Monitoring the abundance and diversity of biological communities in a specific environment allows assessment of the effects of pollution (TSGA, 2014).

Benthic macroinvertebrates are widely used as aquatic bioindicators. They are invertebrate species, visible to the naked eye, which live associated with the substrate in aquatic ecosystems. They are considered as good bioindicators because they have relatively long life cycle and are easy to screen and identify. The life cycle of macroinvertebrates is affected by environmental disturbances, fact that enables the easy identification of adverse effects caused by such disturbances on the environment (BUSS, BAPTISTA; NESSIMIAN, 2003). Several researchers have recently used benthic macroinvertebrates as water-quality bioindicators (BLAKE; RHANOR, 2020; CHAGAS *et al.*, 2017a; MEZGEBU; LAKEW; LEMMA, 2019; NASCIMENTO; ALVES-MARTINS; JACOBUCCI, 2018; OCHIENG; ODONG; OKOT-OKUMU, 2020, PEREIRA *et al.*, 2020; SUDARSO *et al.*, 2021).

The Rapid Assessment Protocol (CALLISTO *et al.*, 2002) assesses qualitative parameters of the physical conditioners of water resources in an integrated manner and has often been used as complementary tool to monitoring procedures (CHAGAS *et al.*, 2017b; MACHADO *et al.*, 2015).

Other analyzes are carried out in order to verify the quality of the water resources and to investigate possible polluting sources, such as microbiological and toxic metal analyzes. Microbiological analysis seeks, among other microorganisms, the intestinal bacteria Escherichia coli, whose presence confirms fecal contamination in water (MOURA; ASSUMPÇÃO; BISCHOFF, 2009). Toxic metals from agriculture, mining and industries are carried to water bodies from leaching sediments. High concentrations of heavy metals cause considerable damage to the environment due to the effectiveness of accumulation in the environment, as in sediments, plants and animals (CORBI *et al.*, 2006; CORBI *et al.* 2018). Thus, the analysis of the concentration of metals shows the degree of contamination of the aquatic environment (LUOMA; RAINBOW, 2008).

The present study evaluated the impact of urbanization on water quality of the Uberaba river and its tributaries using benthic macroinvertebrates as bioindicators, in addition to physical-chemical and microbiological analyzes and the application of a Rapid Assessment Protocol.

## 2 MATERIAL AND METHODS

### 2.1 Study area

The study was carried out in Uberaba County (Triângulo Mineiro planning region, Minas Gerais State), whose population comprises approximately 328,000 inhabitants; 96% of them living in urban areas (IBGE, 2018). The county territory is located in Grande River basin; its main water body is Uberaba River, which crosses the county in the East/West direction.

Data were collected in seven different sites of Uberaba River and tributaries, in a 12-km stretch starting upstream of the water catchment station for public supply (A), passing through the urban perimeter (B and C), upstream (F) and downstream (G) of the discharge of the effluent treated by the Sewage Treatment Plant, and included two tributaries, Saudade (D) and Juca (E) streams. The QGis software was used to map land use and occupation and to evaluate the effects of vegetation on water bodies.

### 2.2 Collection data and analysis

#### 2.2.1 Benthic macroinvertebrates

Benthic macroinvertebrates were sampled during the dry season, in triplicate. A Surber net (900 $cm^2$ area and 250 μm nylon screen) was used (SILVEIRA; QUEIROZ, BOEIRA, 2004). It was positioned against the current and the entire substrate was transferred to plastic bags with 70% ethanol and identified. In the laboratory, the sediment was washed under running water using a 250μm mesh. Afterwards, previous screening was performed with the naked eye, in order to collect larger organisms, separating them from the debris. The collected material was transferred to a supersaturated salt solution, with the objective of the lighter macroinvertebrates to float, as they are less dense than the supersaturated solution, facilitating and optimizing the screening in the stereoscopic magnifying glass (BRANDIMARTE; ANAYA, 1998). After screening, taxa were identified (COSTA; IDE; SIMONKA, 2006; MUGNAI; NESSIMIAN; BAPTISTA, 2010).

Collection procedures were previously authorized by the Biodiversity Authorization and Information System (SISBIO - Sistema de Autorização e Informação em Biodiversidade, protocol number 43382-1).

The quality of water in Uberaba River and in its tributaries was evaluated with the BMWP (Biological Monitoring Working Party System) index. This index divides macroinvertebrates into nine groups; the higher the sensitivity to pollution, the higher the score. BMWP score suggested by Junqueira and Campos (1998) was used, adapted through the inclusion of some taxa as ecological equivalents due to the similarity in their level of tolerance to pollution. The sum of all scores classifies each site from very bad to excellent quality.

The diversity in the macroinvertebrate community was evaluated with the Shannon-Wiener index (H'), equitability was assessed with the Pielou Index (J') and dominance with the Berger-Parker index (d) (KREBS, 1989). The macroinvertebrates were sorted into functional feeding groups, shredders, scrapers, filters, collectors and predators (MERRIT; CUMMINS, 1996).

### 2.2.2 Rapid Assessment Protocol

The Rapid Assessment Protocol (RAP) was applied (CALLISTO *et al.*, 2002) to evaluate, in an integrated way, qualitative parameters of the physical conditioning factors of water resources (RODRIGUES; CASTRO, 2008). A score within the range pre-established by the RAP, based on environmental stress gradient, was given for each protocol parameters, such as occupation of the banks, presence of erosion, anthropic changes, odor and transparency of the water, among others. Scores attributed to each parameter evaluated in each sampling site were summed and the sites were classified as natural (above 60), altered (41 to 60) and impacted (0 to 40) sections.

### 2.2.3 Physicochemical parameters

The YSI Professional Plus Multiparameter meter was used to measure the following parameters in situ: temperature, pH, dissolved oxygen and electrical conductivity. Approximately 500 mL of sediment and water were collected in random areas around the sampling sites for analysis of the concentration of metals (cadmium, copper, iron, nickel and zinc). Samples were placed in plastic bottles with nitric acid and analyzed according to APHA (2012).

The physical-chemical parameters were analyzed according to CONAMA Resolution nº 357/2005 (BRASIL, 2005) for class 2 rivers.

### 2.2.4 Microbiological parameters

Chromogenic and fluorogenic substrate Colitag® were used to investigate total coliforms and Escherichia coli in order to assess fecal contamination. Field samples were collected in sterile glass vials and transported to the laboratory in a polystyrene box filled with ice. At the laboratory, a 100 mL aliquot of each sample was transferred to sterile Erlenmeyer flasks in aseptic conditions. Next, the Colitag® substrate was added to each sample, homogenized and the vials were incubated in a BOD oven at 44°C (DA SILVA *et al.*, 2017). After 24h, the reading was performed observing the yellow color capture (presence of total coliforms) and / or fluorescence presentation under ultraviolet light (confirming *E. coli*, that is, fecal contamination).

2.2.5 Statistical analyses

Data from biological indexes and physicochemical parameters were normalized through z-score technique, with a mean value of 0 and variance equals to 1, to reduces the influence of parameters with high variability. Zinc and copper values were removed from the multivariate analyzes, as for most points they were below the detection limit. The variables equitability (J') and dominance (d) were also removed because they have a high (> 0.98) positive and negative correlation with the Shannon diversity index (H'), respectively.

So principal component analysis (PCA) was calculated using the correlation matrix in order to identify potential sources that influence on water quality.

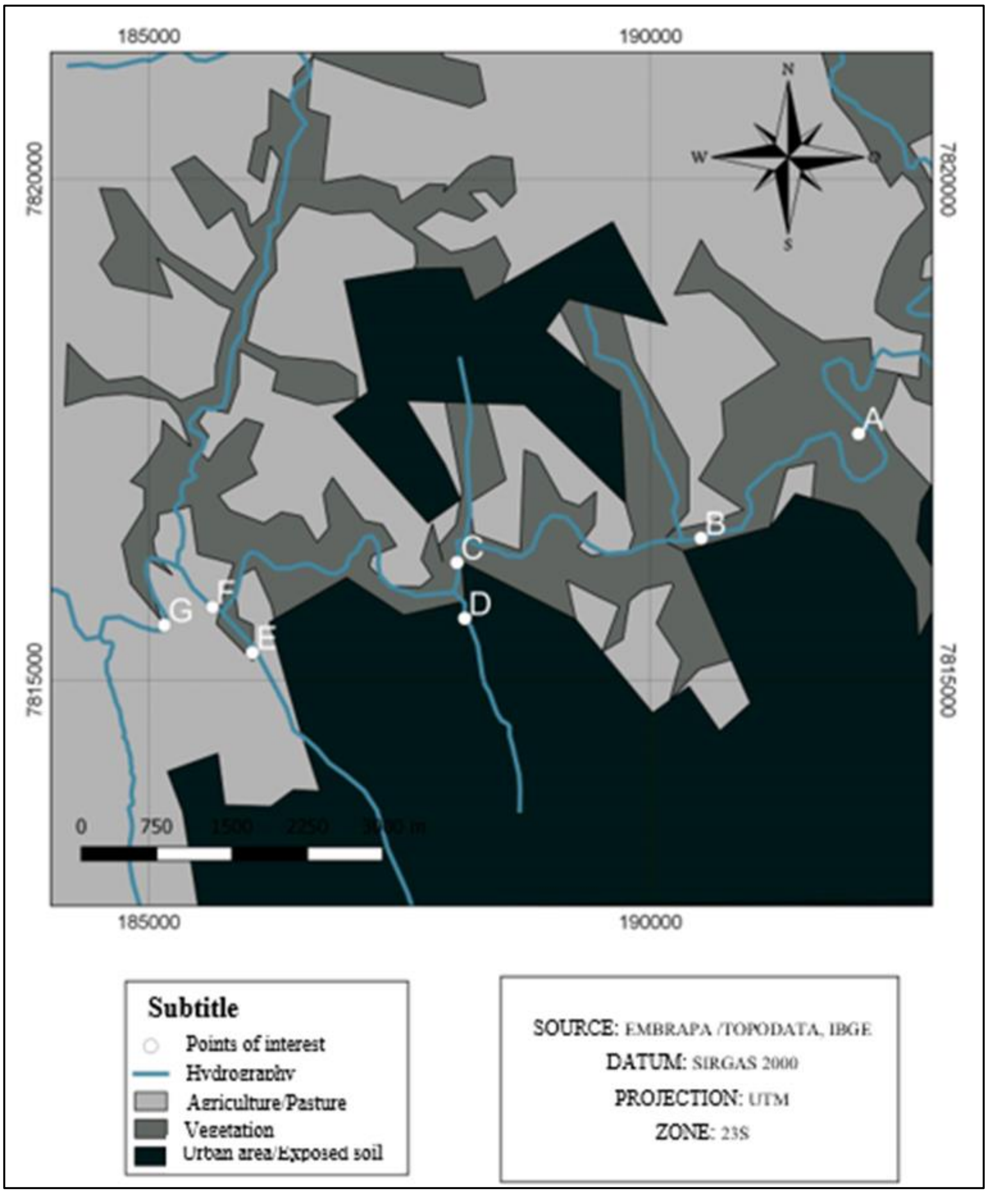
The hierarchical cluster analysis (HCA) was calculated using Ward's method and Euclidean distance as a measurement of similarity, to investigate similarities between sampling sites. Results were presented in a dendrogram.

The two multivariate tests were performed by the free software PAST (Paleontological Statistics), version 4.03.

## 3 RESULTS

The land use and occupation map showed a predominance of agriculture/pasture and urbanization (Figure 1). The first sampling site (A) was the furthest from the urban perimeter and showed the largest extension of riparian vegetation. In B and C, the river run through the city, reducing the riparian vegetation. At sites F and G, the river moved away from the urban perimeter and, showing, respectively, a predominance of agriculture and pasture and vegetation. Affluent D was within the urban perimeter, with no vegetation, while E was surrounded by agriculture / pasture.

Figure 1 - Land use and occupation map of Uberaba River, with the sampling sites from upstream of the water catchment station for public supply (A) to downstream the Sewage Treatment Plant (G)




Fonte: Authors (2020)

By the analysis of principal components, the PC1 accounts for 62.6% of total variance and has positive correlation with cooper, iron, dissolved oxygen and BMWP, and negative correlation with cadmium. PC2, with a total variance of 18.2%, presented positive correlation with electric conductivity and negative correlation with species diversity (H’) (Figure 2).

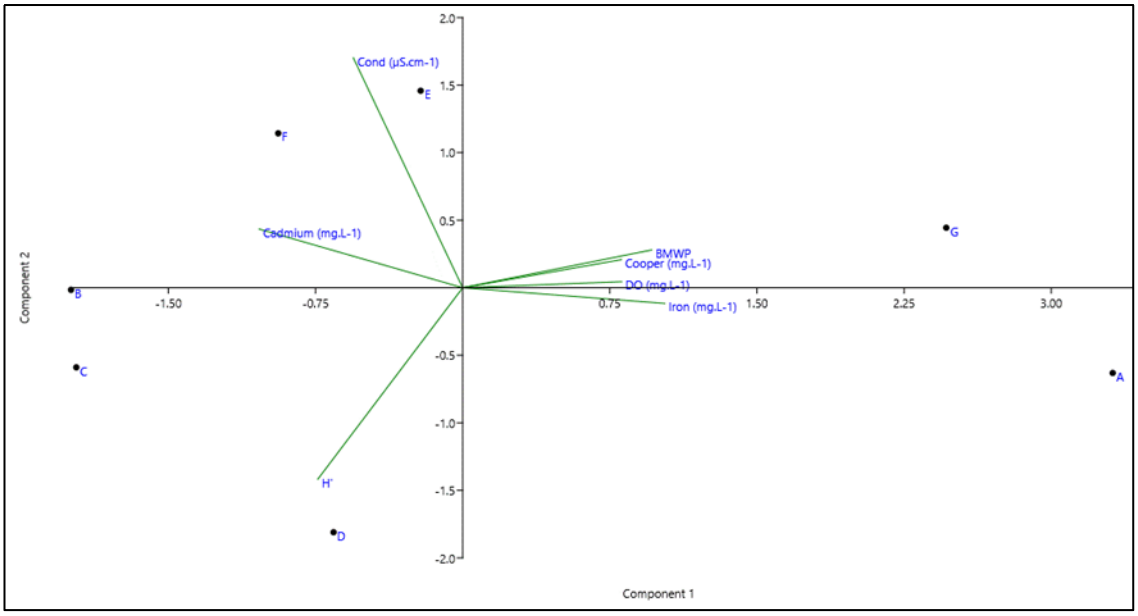
There was high similarity between the most distant sampling sites from the urban perimeter (A and G), based on biological indexes and physicochemical parameters (Figure 3), mainly due to the high values of BMWP, dissolved oxygen, cooper and iron, and lower cadmium (Figure 2). Despite having some evidences of degradation resulting from anthropic actions, such as waste deposition on the river banks, the both sites showed riparian vegetation, which contributed to the diversification of habits for macroinvertebrate communities (CORBI; TRIVINHO-STRIXINO, 2008; SANTOS; MELO, 2017).

The sites most impacted by urbanization (B, C and D) were clustered together (Figure 3), mainly due to high values of cadmium and lower dissolved oxygen (Figure 2). Uberaba River presented virtually no riparian vegetation in the section crossing the urban area, and it presented waste deposition in the river banks and bed, as well as sites receiving the discharge of domestic effluents, among other anthropic changes (CURADO *et al.*, 2018).

The greater similarity between E and F sites (Figure 3) was due, mainly, to the high percentages of the benthic community dominance by chironomids (98%), consequently low equitability and diversity, and to the higher values of electrical conductivity (Figure 2).

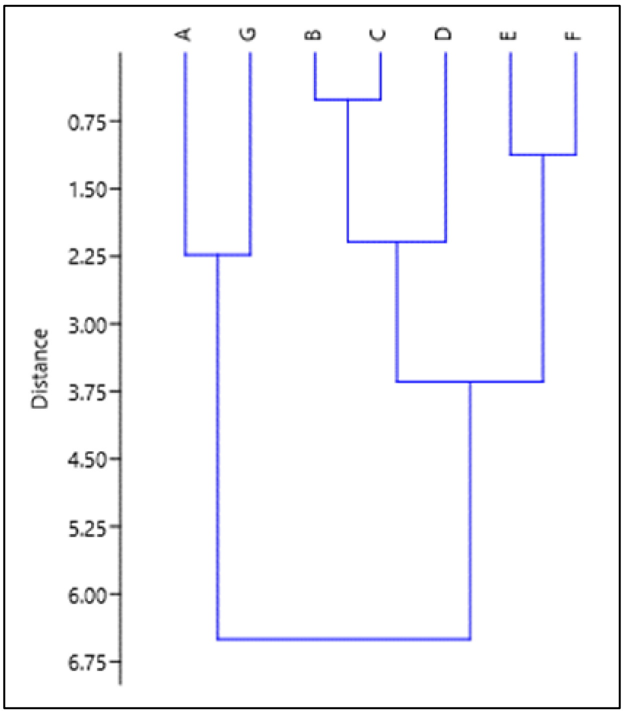
The biological indexes and physicochemical parameters will be better discussed later in the text.

Figure 2 - Principal component analysis (PCA) for all sampling sites. The variables are represented by vectors and the sites by points




Source: Authors (2020)

Figure 3 - Dendrogram presenting the sampling stations clusters (HCA)




Source: Authors (2020)

## 3.1 Benthic macroinvertebrate community's analysis

In total, 46,470 organisms of benthic macroinvertebrate belonging to 28 taxa were identified (Supplementary Table). The sampling site A recorded the highest score in the BMWP index, with good water quality, showed the greatest richness of macroinvertebrate taxa and presented pollution-sensitive taxa such as Ephemeroptera and Trichoptera (Supplementary Table). Despite the good quality of the water and the RAP classification as a natural section, the community was dominated by chironomids with low diversity and, equitability and high dominance (Table 1).

Table 1 - Benthic macroinvertebrate metrics: BMWP indices and water quality, H', J, d, RAP and land use and occupation classifications

| Sampling Sites | BMWP | Water Quality | H' | $H'_{max}$ | J' | d | RAP | Land use and occupation analysis |
|---|---|---|---|---|---|---|---|---|
| A | 73 | Good | 0.10 | 2.77 | 0.03 | 0.99 | Natural | Native vegetation |
| B | 19 | Bad | 1.20 | 1.79 | 0.67 | 0.39 | Impacted | Vegetation/Urban area – exposed soil |
| C | 17 | Bad | 1.25 | 1.79 | 0.70 | 0.47 | Impacted | Vegetation/Urban area – exposed soil |
| D | 18 | Bad | 1.47 | 1.79 | 0.82 | 0.37 | Impacted | Urban area – exposed soil |
| E | 50 | Satisfactory | 0.17 | 2.71 | 0.06 | 0.98 | Altered | Native vegetation/agriculture – pasture |
| F | 14 | Very bad | 0.17 | 1.61 | 0.11 | 0.97 | Impacted | Vegetation/agriculture – pasture |
| G | 48 | Satisfactory | 0.17 | 2.64 | 0.07 | 0.97 | Altered | Native vegetation/agriculture - pasture |

In the next sampling sites (B, C, F), besides the reduction of riparian forest, the analysis revealed decreasing of water quality by BMWP index (bad or very bad) and characterized them as impacted by RAP (Table 1). Only five or six macroinvertebrate taxa resistant to pollution were sampled (Supplementary Table), indicating the negative impact of the county on Uberaba River. When the three sites were compared, F was the furthest from the city, was surrounded by agriculture, but presented the lowest BMWP index. This apparent worsening in the quality of the water - due to high turbidity, foam, and strong and unpleasant odor – results from the constant discharge of untreated effluents, whenever the effluent treatment capacity of the STP was exceeded. The negative effects of domestic sewage on the benthic macroinvertebrate community had also been reported by other authors, who observed dominance of resistant taxa, such as Oligochaeta, alteration of diversity, the sensitive species were replaced by opportunistic ones, among others (CABRAL-OLIVEIRA *et al.*, 2014; GUSMÃO *et al.*, 2016; XU *et al.*, 2014).

The last site in Uberaba River (G) showed improved water quality as the river moved away from the city (Figure 1), even after the release of treated effluent. 14 macroinvertebrate taxa were collected and observed the reemergence of Coleoptera, Odonata, Tricoptera, as well as the presence of Hemiptera and Collembola (Supplementary Table). However, the high dominance of chironomids (97% to 99%) in this site led to low species richness, diversity and equitability indices (Table 1). Studies of the benthic community, analyzing land use and occupation, showed similar results, pointing out that diversity is higher in environments with the presence of riparian vegetation (CORBI; TRIVINHO-STRIXINO, 2008; SANTOS; MELO, 2017).

Similar results were observed in the tributaries Saudade (D) and Juca (E). Site D, located within urban perimeter with no riparian forest (Figure 1), was characterized as impacted by RAP (Table 1). It revealed just 6 macroinvertebrate taxa and water was classified as bad quality (Supplementary Table). However, site E was surrounded by agriculture/pasture, showed 15 taxa, including some sensible to pollution. This site presented the second highest BMWP, which classified water as satisfactory quality. Thus, the impacts caused by the urban area were greater than those of agriculture (SANTOS; MELO, 2017).

Chironomidae was the most abundant family representing (69.5% of all individuals), and prevailed in most sampling sites. These larvae are extremely resistant to pollution and can thus survive, heavily- degraded environments. This happened due to a variety of adaptive mechanisms that enable them to live under varying temperature, pH, depth, flow speed and dissolved oxygen conditions. Moreover, most of these species can synthesize a respiratory pigment similar to hemoglobin. This pigment has high affinity for oxygen and enables survival in water presenting low dissolved oxygen content (CALLISTO; ESTEVES, 1998).

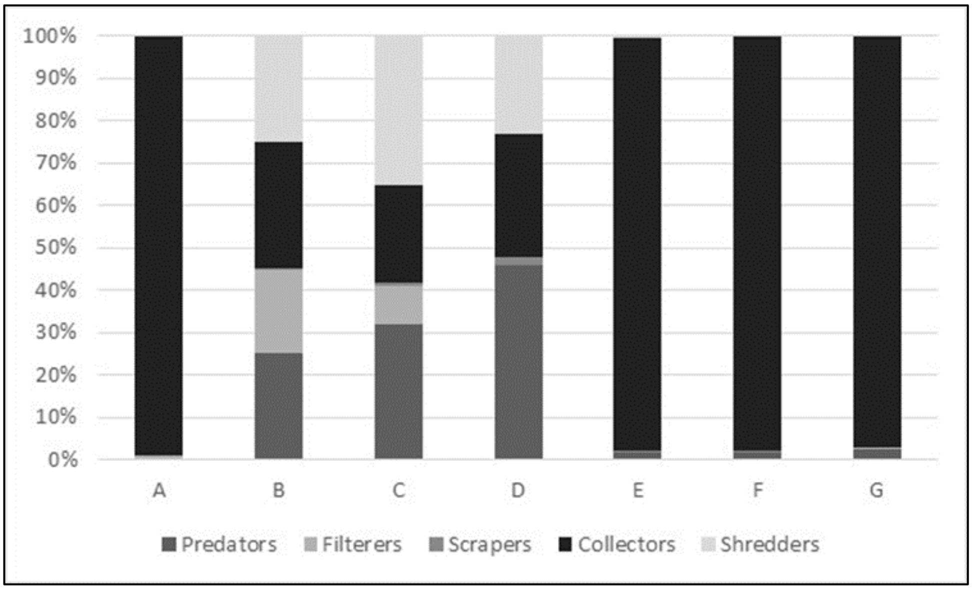
The higher indexes evidenced by the BMWP were associated with better environmental preservation of the sites and the presence of vegetation. Habitat quality is one of the most important factors in the success of colonization and establishment of biological communities in lentic or lotic environments (KOTZIAN *et al.*, 2014; MARQUES; FERREIRA; BARBOSA, 1999). In addition to protection, the riparian forest contributes with branches and leaves, which serve as food and shelter for macroinvertebrates CHARÁ-SERNA *et al.*, 2015; VAIKRE *et al.*, 2018).

The comparison between the BMWP scores (Table 1) and the land use and occupation (Figure 1) evidenced the negative effects of the urban perimeter on water quality: there was abrupt decrease in the BMWP index from site A, with riparian vegetation, to site B, the (urban area), and the score increased again in sites E and G located in (vegetated areas). Sites near the urban area recorded lower quality of the water than sites presenting forest and agricultural systems. This outcome emphasized the negative impact of the urban area on water quality (SANTOS, CORREIA; SANTOS, 2016) and the importance of riparian forests (MANGADZE; BERE; MWEDZI, 2016; VAIKRE *et al.*, 2018), which, besides protecting the river banks, provided food and shelter to macroinvertebrates. Storey and Vowley (1997) showed the key role played by riparian forests in increasing the richness and number of taxa as different streams flow into forest fragments. Several studies also showed the importance of riparian forest to macroinvertebrate communities (CUMMINS *et al.*, 1989; DUDGEON, 1988; FERREIRA-PERUQUETI; FONSECA-GESSNER, 2003; GOULART; CALLISTO, 2005; SPONSELLER; BENFIELD; VALETT, 2001).

The reduction of riparian forest causes an increase in the periphyton biomass, due to the greater availability of light in the river, and decreases the litter debris. The benthic community of these rivers was less diverse when compared to forest areas (BOJSEN; JACOBSEN, 2003). Corbi and Trivinho-Strixino (2008) observed that in environments with riparian forest presented a greater diversity of species and the presence of species sensitive to pollution, such as the Trichoptera. Santos and Mello (2017) suggested that a decrease in the number of macroinvertebrates directly proportional to the degree of land use and occupation and that the anthropic pressure showed a predominance of organisms resistant to low oxygen concentration in the water, or poor quality.

The macroinvertebrate community was in general dominated by collectors (Figure 4) due to high dominance of chironomids, which were abundant. The large number of chironomids indicated high organic matter content in the environment, as well as environmental degradation (CHAGAS *et al.*, 2017b).

Figure 4 - Relative frequency of functional groups (predators, filterer, scrapers, collectors and shredders) of benthic macroinvertebrates sampled at sites A to G




Source: Authors (2020)

Predators were the second most representative group (Figure 3). They feed on pieces of prey, or on entire preys, of other organisms belonging to other functional groups, not directly reflecting the influence of food of external origin in the lotic ecosystem (CUMMINS; MERRIT; ANDRADE, 2005).

## 3.2 Microbiological parameters

All sampling sites showed contamination with total coliforms and with E. coli in the qualitative microbiological analysis. *E. coli* bacteria are part of the intestinal microbiota of humans and of other homeothermic animals. Water samples presenting E. coli provided direct evidence of recent fecal contamination, besides suggesting the presence of enteric pathogens (POPE *et al.*, 2003). Fecal contamination could result from the discharge of untreated domestic sewage, or from feces of other homeothermic animals that reached water bodies.

### 3.3 Physicochemical parameters

Water pH and temperature values virtually did not vary between sampling sites; mean pH and temperature values were 7.7 and 23.7°C, respectively (Table 2). According to Conama 357/2005 (BRASIL, 2005), pH value must range from 6 to 9, regardless of the water-body classification.

Table 2 – Physicochemical parameters

| Sampling sites | DO ($mg.L^{-1}$) | Electrical conductivity ($\mu S.cm^{-1}$) | Zinc ($mg.L^{-1}$) | Cooper ($mg.L^{-1}$) | Nickel ($mg.L^{-1}$) | Cadmium ($mg.L^{-1}$) | Iron ($mg.L^{-1}$) |
|---|---|---|---|---|---|---|---|
| **A** | 6.88 | 75.20 | 0.550 | 0.020 | 0.040 | 0.102 | 93.20 |
| **B** | 2.00 | 369.80 | <0.002 | 0.050 | 0.020 | 1.820 | 23.51 |
| **C** | 1.54 | 279.50 | <0.002 | 0.030 | <0.015 | 1.720 | 6.05 |
| **D** | 4.53 | 128.60 | <0.002 | 0.020 | <0.015 | 0.844 | 11.07 |
| **E** | 4.76 | 438.10 | <0.002 | 0.060 | 0.020 | 1.400 | 14.55 |
| **F** | 4.50 | 416.10 | <0.002 | 0.010 | <0.015 | 1.409 | 3.94 |
| **G** | 3.75 | 290.70 | 2.770 | 1.900 | 1.030 | 0.195 | 489.10 |
| **CONAMA** | <5.00* | 100.00** | 0.180* | 0.009* | 0.025* | 0.001* | 0.30* |

In were: * Values for class for class 2 water bodies (CONAMA, 2005); ** Limit value for no impacted environment (CETESB, 2012)

Only site A complied with the expected value for DO in class 2 (above 5 $mg.L^{-1}$) water bodies (Table 2) (BRASIL, 2005). Sites B and C recorded the lowest DO indices, which corroborated the exclusive presence of pollution-resistant macroinvertebrate taxa and explained the worst quality of the water in this site (Table 1 and Supplementary Table). The low DO concentration may be due to the domestic effluent load being discharged close to the sampling sites, as found by Cabral-Oliveira *et al.* (2014).

The concentration of pollutants in the medium can be evidenced, indirectly, by monitoring the electrical conductivity (EC). According to CETESB (2012), water electrical conductivity values higher than 100 $\mu S.cm^{-1}$ indicate impacted environments. Based on this parameter, only site A was not impacted (75.2 $\mu S.cm^{-1}$) (Table 2). This outcome reinforced the negative impact of the urban perimeter on the quality of the water in Uberaba River, as well as the importance of riparian forests to this ecosystem.

Site G recorded the highest concentrations of the herein analyzed metals, except for cadmium (Table 2). Sampling in this site was performed downstream the site where the sewage treated by STP is discharged, fact that may be associated with the presence of these metals in the treated effluent. Metals such as copper, cadmium and iron in all samples were also above the limit recommended by CONAMA. In general, metals are toxic to living beings, this toxicity being observed when the mortality rate increases among the most sensitive species, and / or when the presence of the pollutant alters important processes in the development of the organism, such as growth and reproduction (GUIMARÃES-SOUTO; CORBI; JACOBUCCI, 2018).Copper can result from brass pipe corrosion, from STP effluents, from surface runoff and groundwater contamination due to agricultural use, and from atmospheric precipitation of industrial sources (CETESB, 2012). In addition, it is extremely harmful to fish, much more than to man. Concentrations of 0.5 $mgL^{-1}$ are already lethal for trout, carp, catfish, red fish in ornamental aquariums, among others, while microorganisms die in concentrations above 1.0 $mgL^{-1}$. All sampling sites exceeded the limit set by CONAMA 357/2005 for class 2 water bodies, with emphasis on site G (Table 2).

Cadmium is extremely toxic to humans; this metal can lead to death even at low concentrations. It can derive from rechargeable batteries used in calculators and in similar devices, from the electrolytic coating of metals, from the discharge of industrial effluents resulting from galvanization processes or from rainwater leachate fertilizers (CORBI *et al.*, 2018). All sampling sites recorded values higher than the one recommended by CONAMA 357/2005, with emphasis on sites B, C, E and F.

All seven sampling sites analyzed in the current study recorded high iron concentrations (Table 2). However, it is necessary taking into consideration the chemical nature of the rocks in the subsoil where the water flows. The herein sampled sites are formed by basalts (FERREIRA JR; GOMES, 1999), whose composition presents iron oxides; thus, the herein recorded high iron concentrations showed how geology and pedology affected the quality of the water. Although this mineral is not classified as toxic to humans, it can lead to water supply issues such as water color and taste, and iron deposits in plumbing systems (CETESB, 2012).

## 4 CONCLUSIONS

The water collected in the raw water-catchment section of Uberaba River, the furthest sampling site from the urban area and with vegetation in the surroundings, presented good quality, based in BMWP index. However, this quality dropped to very poor as the river water crossed the urban perimeter, decreasing the benthic macroinvertebrate diversity and increasing dominance of chironomids. In addition, the presence of *E. coli* and the high levels recorded for some metals (principally cooper and cadmium), suggested contamination of the water with domestic and industrial effluents and contribute to the deleterious effect in the benthic macroinvertebrate communities.

Evaluating and maintaining water quality are fundamental actions to assure the well-being of human populations. This study allowed understanding of the benthic macroinvertebrate community living in Uberaba River, and in its tributaries, besides using such community to analyze the quality of the water in the sampled sites based on comparisons between physicochemical parameters and land use and occupation.

## ACKNOLEGMENTS

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