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Response of Epilithic Diatom Communities to Downstream Nutrient Increases in Castelhano Stream, Venâncio Aires City, RS, Brazil

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ABSTRACT

The Castelhano Stream Hydrographic Basin, located in the city of Venâncio Aires, RS, Brazil, shows an area of 675.3 km^2, highlighting the Castelhano Stream as their main water course. The stream is the main responsiblity for the local water supply; however, there are no published studies in the literature regarding their water quality. In this context, the present research aimed to assess the water quality of Castelhano Stream in terms of organic pollution and eutrophication, applying the Biological Water Quality Index (BWQI), which uses epilithic diatoms communities as bioindicators. Biological samples were collected at three sampling stations along the stream in the months of September, November and December 2012. The results showed 81 identified species, distributed in 30 genera. The water pollution levels detected ranged from "strong" (66.7%) and "very strong" (33.3%), with differences in species composition between sampling stations. The sampling station S1 in the upper reaches was characterized by the presence of indicative species of acidophilus and lentic environments with large amounts of organic matter. The sampling stations S2 and S3, in the intermediate and lower reaches, respectively, showed a substitution of species in the community, with the presence of highly tolerant taxa to organic pollution and eutrophication. The high pollution levels detected along the basin are related to the nutrients and high organic load originating from livestock, domestic and industrial waste, as well as excess fertilizers and agricultural inputs used in farming. The results demonstrate the necessity to implement mitigation measures to contain the processes of organic pollution and eutrophication detected due to the dangers offered to public health and the environment.

Keywords: Castelhano Stream Hydrographic Basin; Biological Water Quality Index (BWQI); Epilithic Diatoms; Organic Pollution; Eutrophication

1. Introduction

At highly industrialized regions in which water demand has increased, most part of domestic and industrial effluents, as well as chemical fertilizers and pesticides used in agriculture, are dumped directly into water bodies, reducing further the possibility of use water resources and drastically modifying the characteristics of aquatic ecosystems. This damage has been demonstrated in two ways: through the introduction of toxic substances into groundwater and through the phenomenon of artificial eutrophication that, besides reducing the water quality, produces significant changes in the metabolism of whole ecosystem [1].

Eutrophication is the increased concentration of nutrients in the aquatic ecosystems, especially phosphorus and nitrogen, which causes an increase in their productivity, characterized as a complex phenomenon because of their ecological basis. This increase in nutrients required for primary producers results in a massive increase of algae growth, which prevents the light penetration to the submerged vegetation, resulting in a massive amount of dead biomass. As a consequence, bacteria need large amounts of oxygen to decompose this material, reducing the oxygen concentration of the water [2,3].

Environmental monitoring studies in freshwater bodies at central region of Rio Grande do Sul have been demonstrated that these systems already show fairly advanced conditions of eutrophication [4-14]. Furthermore, accord-

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ing to Tundisi (2006), this condition characterizes the watercourses throughout southern Brazil [15]. Such problems highlight the importance of adoption criteria aimed to assess the pollution levels in aquatic ecosystems, through the use of bioindicators. In this context, epilithic diatoms have been recommended by researchers to assess the water quality due to the sensitivity of this group in relation to a variety of environmental conditions [16].

The city of Venâncio Aires, located at Taquari-Antas Hydrographic Basin, RS, Brazil, has a main source of supply for human consumption the Castelhano Stream; however, there are no published studies in the literature regarding their water quality. In this context, the present research aimed to assess the water quality of Castelhano Stream in terms of organic pollution and eutrophication, applying the Biological Water Quality Index (BWQI), which uses epilithic diatoms communities as bioindicators.

2. Materials and Methods

Venâncio Aires city is located in the central depression of Rio Grande do Sul state (**Figure 1**), in the northeast mountain range (29˚39'30"—South latitude and 52˚8'41" —North latitude). Inserted at Taquari-Antas hydrographic basin (98%), has an area of 773,239 km^2 and a population density of 65,964 inhabitants [17]. Their main water course is the Castelhano Stream, which has a watershed of 675.3 km^2 and a length of over 100 km [18]. This stream is the main responsible for the local water supply, the most part it's surrounded by small and medium rural farms, with subsistence crops (rice, tobacco, corn), livestock activities, as well as areas of forest remnants.

Three scientific expeditions were performed along the stream, in September, November and December of 2012, where samples of epilithic diatoms were collected. Three sampling stations were selected along the stream (**Figure 1**), station 1 located upper reaches, station 2 in an intermediate reaches, and station 3 in the low reaches.

For qualitative and semi-quantitative diatom analyses, samples were scrubbed off the upper surface of submerged stones about 10 - 20 cm in diameter using a toothbrush and fixed with formalin [19]. Diatom samples were cleaned with sulphuric and hydrochloric acids and mounted on microscopic slides with Naphrax. All individuals found in random transects under light microscopy across each permanent slide were identified and counted, up to a minimum of 600 valves, using an Olympus BX-40 microscope. The taxonomic references Metzeltin & Lange-Bertalot (1998, 2007), Metzeltin & García-Rodríguez (2003), Metzeltin *et al.* (2005) and Rumrich *et al.* (2000) were used for species identification [20-24]. Following the criterion of Lobo & Leighton (1986) the quantitatively important species (abundant species), were indicated [25]. Voucher samples were stored in the DIAT-UNISC Herbarium at the University of Santa Cruz do Sul, RS, Brazil. Based in the classification of diatoms for southern Brazilian rivers proposed by Lobo *et al.* (2004*a*) the Biological Water Quality Index (BWQI) was calculated for all sampling sites and dates [6].

Descriptive statistics was used to tabulate the data and its graphical illustration [26]. In order to assess quantitatively the similarity between the sampling stations, from abundant species, the hierarchical clustering method of Ward was used (minimum variance method) to identify homogeneous groups [27]. The data were processed using the statistical program PAST [28,29].

3. Results and Discussion

In relation to epilithic diatom composition, 81 species were identified belonging to 30 genera, 27 taxa, distributed in 17 genera were considered abundant. The results obtained from the Biological Water Quality Index (BWQI) indicated that the water pollution levels ranged between "strong" (66.7%) and "very strong" (33.3%), in the three sampling stations.

As illustrated in **Figure 2**, the sampling stations S1 and S3, corresponding to the upper and lower reaches of the stream, respectively, showed a "strong" pollution level in 100% of the samples collected. The sampling station S2, in the intermediate section, was characterized by having the highest contamination levels, since 100% of the samples showed a "very strong" pollution.

These high pollution levels observed are due to the presence in high percentages of tolerant species to organic pollution [16] and eutrophication [6], for example *Achnanthidium minutissimum* sensu lato, *Achnanthidium exiguum* var. *constrictum* (Grunow) Anderson, Stoermer e Kreis, *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck, *Diadesmis contenta* (Grunow ex V. Heurck) Mann, *Eolimna minima* (Grunow) Lange-Bertalot, *Fallacia monoculata* (Hustedt) Mann, *Geissleria aikenensis* (Patrick) Torgan & Oliveira, *Gomphonema gracile* Ehrenberg, *Gomphonema parvulum* (Kützing) Kützing, *Luticola goeppertiana* (Bleisch) Mann, *Mayamaea atomus* (Kützing) Lange-Bertalot, *Navicula cryptotenella* Lange-Bertalot, *Navicula rostellata* Kützing, *Navicula symmetrica* Patrick, *Nitzschia palea* (Kützing) Smith, *Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot, *Sellaphora pupula* sensu lato *e Surirella angusta* Kützing.

Among these, *G. parvulum* was abundant in 6 of the 9 samples, equivalent to 66.7% (**Figure 3**). This species showed the higher abundance at the sampling station S1, corresponding to the upper section, reaching the maximum percent of relative abundance of 71.4% in September. This specie is tolerant to organic pollution, being

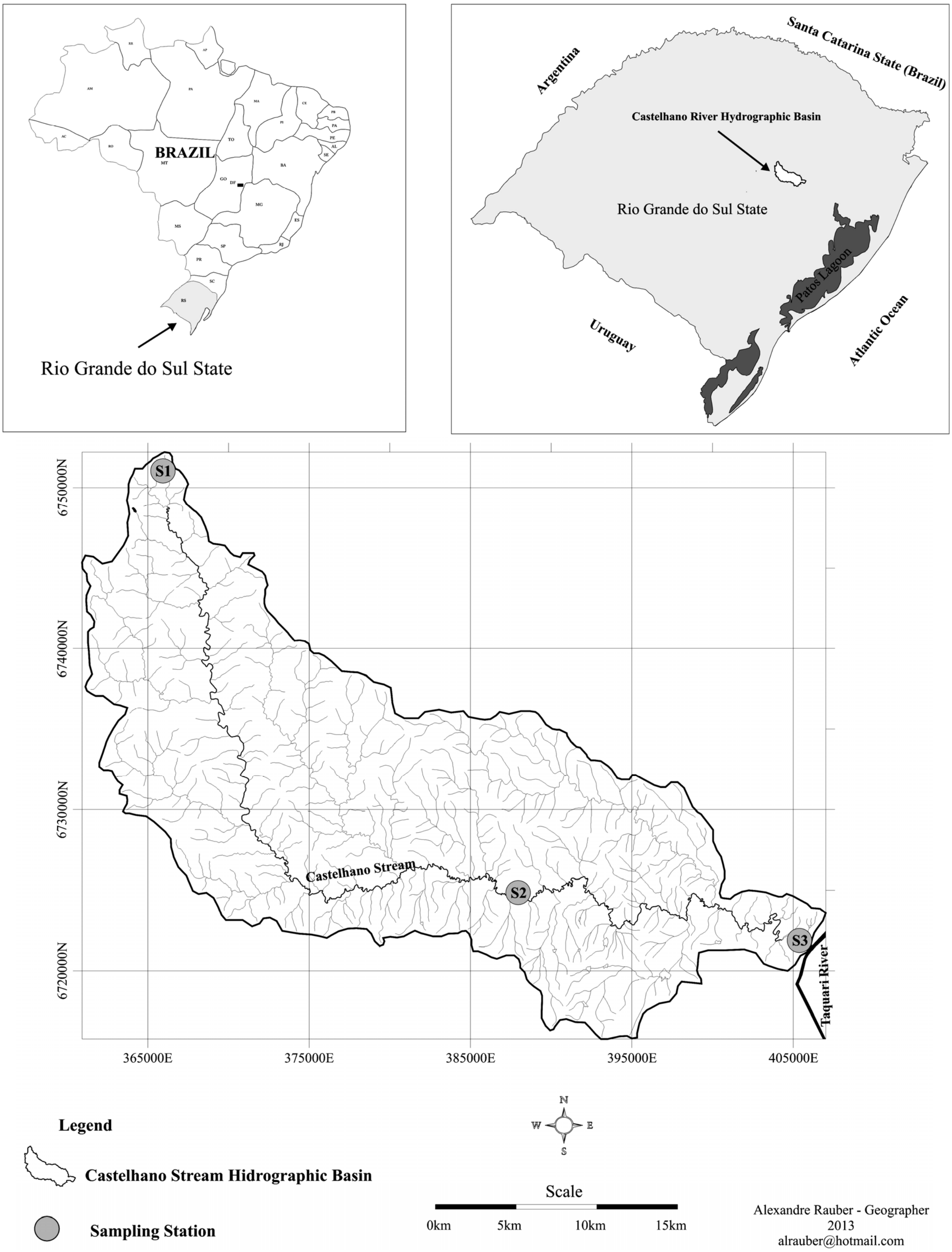

Figure 1. Map of the study area and localization of the Castelhano Stream Hydrographic Basin, in the state of Rio Grande do Sul, Brazil, and the three sampling stations (S1 - S3) along the stream.

indicative of α-mesosaprobic conditions [16]. At streams located in Mato Leitão, RS, Lobo *et al.* (1999) classified this species as belonging to both *α*-mesosaprobic and polysaprobic conditions [30]. In the same study area, Rodrigues & Lobo (2000) reported the occurrence of this species in *β*-mesosaprobic environments [31]. Kobayasi & Mayama (1989) and Lobo *et al.* (1995) classified this taxa as highly tolerant to organic pollution in rivers stud-

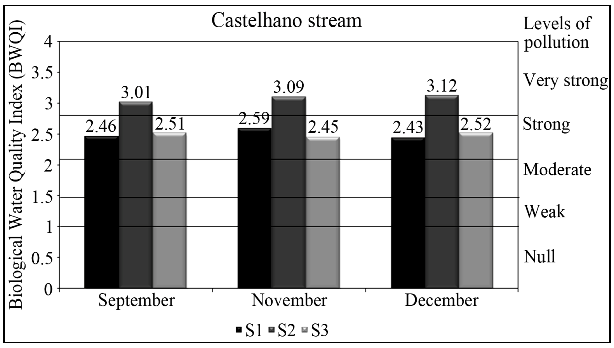

Figure 2. Water quality assessmentin three sampling stations (S1, S2, S3) along the Castelhano Stream, using the-Biological Water Quality Index (BWQI).

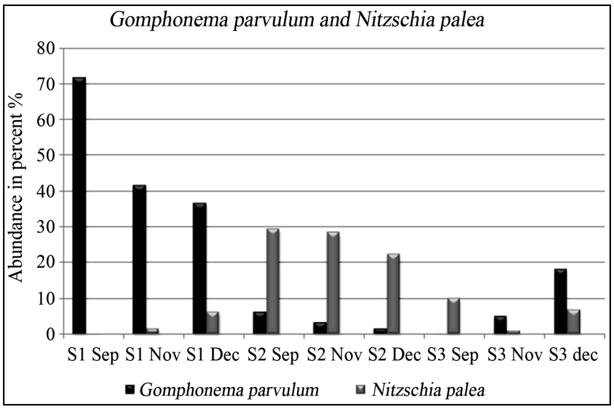

Figure 3. Relative abundance (%) of G. *parvulum*and N. *palea* species insamples collectedin Castelhano Stream, Venâncio Aires, RS.

ied in Japan [32,33].

N. palea was equally abundant in 6 of the 9 samples, equivalent to 66.7% (**Figure 3**). This species showed the higher abundance at sampling stations S2 and S3, corresponding to the intermediate and lower sections, respectively, reaching the maximum percent of relative abundance of 29.4%, at the sampling station S2, in September. This species is considered tolerant to organic pollution, being indicative of *α*-polisaprobic conditions [16]. Moreover, Van Dam *et al.* (1994) stated that *N. palea* corresponds to polysaprobic taxa, indicating hypereutrophic conditions [34]. At Gravataí River, this species was found in all samples collected from the upper reaches to the lower section, however, the highest densities were recorded in the lower section highly polluted [12].

Differently, Souza (2002), in a study realized at Monjolinho River, São Carlos, Brazil, *G. parvulum* was found in places where the physical and chemical characteristics of the river were considered oligosaprobic (negligible pollution), with a highly abundance of 95.1%, while in polysaprobic conditions the abundance was low, about 10.6% [35].

Salomoni *et al.* (2011) analyzing epilithic diatoms at Gravataí River, RS, highlighted *G. parvulum* as the most abundant species in the sampling stations 1, 2 and 3, corresponding to the upper reaches of the river, with a relative abundance of 37%, 78% and 48%, respectively, condition which led to the classification of this taxa in Group C, characterizing oligotrophic/mesotrophic environments [36]. The authors argue that the species morphology may change as a result of genetic variability, as well as the ecological variation may result in different ecotypes, which would explain the many responses assigned to the same species [13]. Clearly, a more detailed study of ecology, physiology and morphotypes of *G. parvulum* in Southern Brazilian Rivers is required.

Another important factor is the relationship between diatom communities, pH and conductivity of the basin. The pH causes a physiological stress directly on the diatoms, and also strongly influences other chemical variables of the water. The high conductivity, in turn, is related to the emergence of species known to be resistant to heavy metal pollution and have been frequently recorded in eutrophized waters with high organic pollution and low dissolved oxygen levels [37].

These authors, studying urban streams at São Paulo, SP, Brazil, observed diatom communities continuously distributed along the gradient of conductivity and pH. Moderately polluted regions, characterized by low conductivity, showed species like *Eunotia bilunaris* (Ehrenberg) Mills, *Fragilaria capucina* Desmazieres, *Gomphonema angustatum* (Kützing) Rabenhorst, *Pinnularia gibba* (Ehrenb.) Grunow and *Ulnaria ulna* (Nitzsch) Compere, while heavily impacted sites, characterized by a high conductivity and pH slightly acidic, showed species such as *G. parvulum*, *S. pupula* and *N. palea*. These species that have a great development in polluted areas can also occur in relatively clean waters, once the species show the upper limits of tolerance to pollution and not the lower limits [38].

The dendrogram of **Figure 4** clearly shows the biological condition of the sampling stations studied, separating the upper reaches, of the intermediate and lower reaches. At upper reaches it was observed that the algal community was predominantly composed by species from genera *Eunotia*, highlighting *E. pseudosudetica*, Metzeltin, Lange-Bertalot & Garcia-Rodriguez, *E. subarcuatoides* Alles, Nörpel & Lange-Bertalot and *E. cf. veneris*, besides taxa such as *Achnanthes microcephala* (Kützing) Grunow, *L. goeppertiana* (Bleisch) Mann, *N. cryptotenella* Lange-Bertalot and *G. parvulum* (Kützing) Kützing. The genera *Eunotia* has been referred in literature as acidophilus, and characteristic of lentic waters [37,39].

In relation to the species composition of the middle and lower reaches, it was observed the replacing of algal

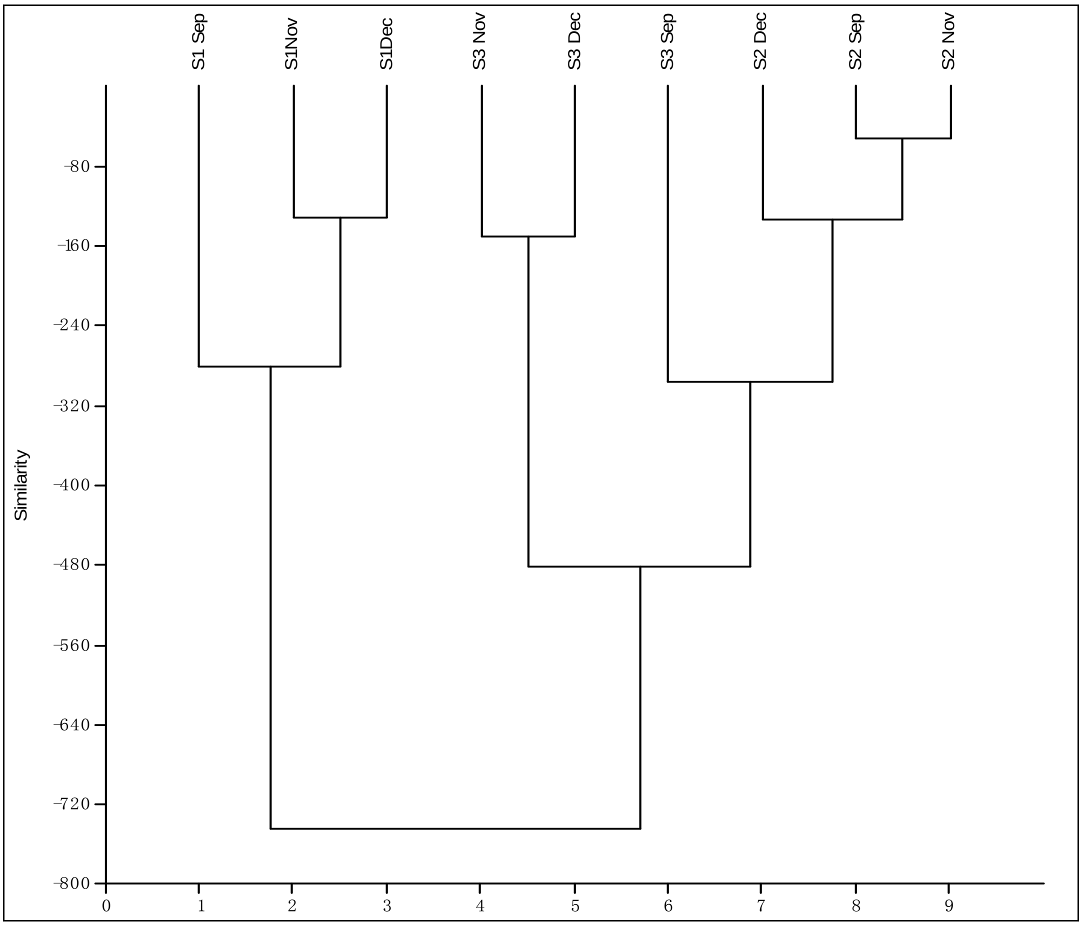

Figure 4. Cluster analysis of the three sampling stations (S1, S2, S3) along the Castelhano Stream, Venâncio Aires, RS.

community by species of bigger tolerance to organic pollution and eutrophication, such as *Nitzschia palea* (Kützing) Smith, *Gomphonema parvulum* (Kützing) Kützing, *Sellaphora pupula* sensulato, *Surirella angusta* Kützing, *Mayamaea atomus* (Kützing) Lange-Bertalot, *Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot, *Achnanthidium exiguum* var. *constrictum* (Grunow) Anderson, Stoermer e Kreis.

As referred, *G. parvulum* is a characteristic species of environments with a high degree of eutrophication [6], and is also typical from lentic waters [39]. So, their high abundance can be attributed to the large amount of organic matter in the environment from domestic animals present in the site. This condition justified the grouping of station 1, with the presence of species that reveal acidic environments, devoid of riparian vegetation, with lentic waters and excess of organic matter.

The pollution levels "very strong" and "strong" in the sampling stations S2 and S3, respectively, can be justified by the geographical location of them, since they receive many tributaries coming from the urban area, that carry domestic and industrial effluents. The pollution sources observed come from brooks tributaries of Castelhano Stream, these go through the city and are responsible for carry the diluted wastewater. The city still doesn't have absolute sewerage collection system, *i.e.*, a specific plumbing to domestic sewage. Therefore, the destination of wastewater treated or not, is mostly plumbing and galleries of rainwater, discharging in small streams and brooks causing severe environmental impacts such as eutrophication [40].

4. Conclusions

The response of epilithic diatom communities to downstream nutrient increases in Castelhano Stream Hydrographic Basin, RS, can be characterized by the presence of indicative species from acidophilus and lentic environments, with a lot of organic matter in the upper reaches, followed by the species substitution in the community in the intermediate and lower reaches, with the presence of highly tolerant species to organic pollution and eutrophication. These high pollution levels detected along the basin may be related to the nutrients and organic load originating from the livestock, domestic and industrial sewage, excess of fertilizers and agricultural inputs used in farming.

It is important to note that the city of Venâncio Aires is in progress to the establishment of a Sewage Treatment Plant, which will treat wastewater from a part of the urban area, according to the goals proposed in the Municipal Sanitation Plan of the city [40]. In this way, it's expected an improvement in the water quality at the hydrographic basin of the city, since the results obtained in this study clearly demonstrate the need to implement mitigation measures to contain the process of organic pollution and eutrophication detected, considering the potential risks in terms of public health and environment.

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