ARTIGO | *ARTICLE*

Water quality of urban streams, *Santa Cruz do Sul*, *Rio Grande do Sul*, Brazil, based on physical, chemical and biological analyses

Qualidade da água de arroios urbanos de Santa Cruz do Sul, Rio Grande do Sul, Brasil, com base em análises físicas, químicas e biológicas

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A B S T R A C T

The purpose of the study was to evaluate the water quality of urban streams in *Santa Cruz do Sul*, in the Brazilian state of *Rio Grande do Sul*, using physical, chemical and microbiological parameters. Eight sampling sites were distributed over the upper and lower reaches of four streams. Four sampling campaigns were carried out, two in 2007 and two in 2008. The parameters analyzed were: temperature, pH, turbidity, dissolved oxygen, biochemical oxygen demand, nitrate, ammonia nitrogen, phosphate, total dissolved solids and thermotolerant coliforms. Simultaneously, epilithic diatom samples were collected, the species identified and the respective relative abundance determined. The assessment of water quality was performed applying resolution 357/2005 of the National Environment Council, and the Biological Water Quality Index. The results indicated that the streams are polluted by organic contamination and show advanced stages of eutrophication, mainly in the lower reaches, and are classified according to the National Environment Council resolution as "Class 4", corresponding to poor water quality. The results of the Biological Water Quality Index ranged from "strong" to "very strong" in most sampling sites, highlighting Cyclotella meneghiniana, *Fallacia monoculata, Nitzschia palea* and *Sellaphora pupula* as the species most tolerant to eutrophication. Two sampling groups were separated by using cluster analysis, one containing the points in the upper reaches and the other the points in the lower reaches, having 38% quantitative similarity in diatom community composition. This similarity can be explained by the fact that some of the abundant species

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tolerant to organic pollution and eutrophication, occurred in both the upper and lower reaches.

Key words: Urban streams. Epilithic diatoms. Organic pollution. Eutrophication.

RESUMO

Este estudo objetivou avaliar a qualidade da água de arroios urbanos, em Santa Cruz do Sul, Rio Grande do Sul, Brasil, utilizando parâmetros físicos, químicos e microbiológicos. Oito sítios de amostragem distribuíram-se nos trechos superiores e inferiores de quatro arroios. Duas amostragens foram realizadas em 2007 e duas em 2008. Foram analisados: temperatura, pH, turbidez, oxigênio dissolvido, demanda bioquímica de oxigênio, nitratos, nitrogênio amoniacal, fosfato, sólidos totais dissolvidos e coliformes termotolerantes. Simultaneamente, amostras de diatomáceas epilíticas foram coletadas, as espécies identificadas e as abundâncias relativas determinadas. Fez-se a avaliação da qualidade da água utilizando-se como parâmetro a resolução nº 357/2005 do Conselho Nacional do Meio Ambiente e aplicando-se o índice biológico de qualidade da água. Os resultados indicaram que os arroios estão poluídos por contaminação orgânica apresentando avançados estágios de eutrofização, principalmente nos trechos inferiores, enquadrando-se na "Classe 4" de acordo com a resolução do Conselho Nacional do Meio Ambiente, correspondendo a águas de má qualidade. Os resultados do índice biológico de qualidade da água variaram do nível "forte" a "muito forte" na maioria dos pontos de amostragem, destacando-se: Cyclotella meneghiniana, Fallacia monoculata, Nitzschia palea e Sellaphora pupula como as espécies mais tolerantes à eutrofização. Dois grupos de amostras foram separados através da análise de agrupamento, um contendo os pontos dos trechos superiores e o outro os pontos dos trechos inferiores, havendo 38% de similaridade quantitativa na composição da comunidade de diatomáceas. Tal similaridade pode ser explicada pelo fato de algumas das espécies abundantes e tolerantes à poluição orgânica e eutrofização ocorrerem tanto nos trechos superiores quanto inferiores.

Palavras-chave: *Arroios urbanos. Diatomáceas epilíticas. Poluição orgânica. Eutrofização.*

INTRODUCTION

Concerns about water are of particular interest, given its fundamental role in regulating biological processes and the health of human populations. Currently, however, the idea that water treatment can solve all problems has changed to a more efficient management of water sources, thus reducing the costs of treating and preserving the resources for the future. Within this framework, the monitoring of water quality is currently an important tool for environmental evaluation (Tundisi, 2000).

The assessment of water quality encompasses the physical, chemical and biological approaches (Lobo & Callegaro, 2000). Physical and chemical monitoring only permits snapshot measurements, therefore restricting the knowledge of water conditions to the period when the measu-rements were taken. These limitations take on even more gravity when the object of the study is a lotic system where the current promotes the continuous renewal of water in each location. Biological monitoring provides a direct measure of ecological integrity by using the response of biota to environmental changes. This allows long-term environmental effects to be detected because of the capacity to reflect conditions that are not present at the time of sample and analysis. Moreover, studies of these communities provide a continuous record of the environmental quality, showing changes in the natural or anthro-pogenic processes (Gold *et al.,* 2002). Physical and chemical methods are, however, complimentary to biological methods, contributing to the correct assessment of the quality of running waters (Lobo *et al.,* 2004a).

Different taxonomic groups have been used in the assessment of water quality, especially the epilithic diatom community which is recognized as a potential indicator of contamination and has been recommended as particularly suitable in assessing water quality, due to the sensitivity of the species in relation to a variety of ecological conditions such as pH, salinity, organic matter and eutrophication (Round, 1991; Kelly & Whitton, 1995; Lobo *et al*., 2002, 2004a; Ector & Rimet, 2005). In Brazil, however, only a few studies have been carried out using this group of algae as bioindicators, and mainly in the Southern region (Oliveira *et al*., 2001; Lobo *et al*., 2002; Lobo *et al*., 2004a; Lobo *et al*., 2004b; Lobo *et al*., 2004c; Lobo *et al*., 2010; Wetzel *et al.*, 2002; Hermany *et al*., 2006; Salomoni *et al.*, 2006; Dupont *et al*., 2007; Schneck *et al.*, 2007).

In this context, the main purpose of the present study was to evaluate the water quality of streams located in the urban area of *Santa Cruz do Sul*, in the Brazilian state of *Rio Grande do Sul*, using physical, chemical and biological methods.

MATERIAL AND METHODS

Study Area

The city of *Santa Cruz do Sul* is located in the *Pardinho* River Sub-basin, one of the main tributaries that make up the *Pardo* River Hydrographic Basin, in the state of *Rio Grande do Sul*. Inside the urban area, four main streams were selected and eight sampling sites were distributed along the streams; they were named *Lajeado* (S1 and S2), *Preto* (S3 and S4), *Pedras* (S5 and S6) and Lewis-Pedroso (S7 and S8), where S1, S3, S5 and S7 were located on the upper reaches and S2, S4, S6 and S8 in the lower reaches (Figure 1).

Data collection

Four seasonal sampling campaigns were carried out in these streams, two in 2007 (August and November) and two in 2008 (February and May). The physical, chemical and microbiological parameters analyzed were: water temperature, pH, turbidity, dissolved oxygen, biochemical oxygen demand after five days, nitrates, ammonia nitrogen, phosphate, total dissolved solids and thermotolerant coliforms. The water temperature was measured in the field using a mercury thermometer. For other parameters, samples were collected at the surface using glass bottles, with a capacity of between 300mL and 1000mL, and packed in coolers. The techniques used in the collection and sample analyses for physical, chemical and microbiological measurements are described in American Public Health Association (2005).

Simultaneously, epilithic diatoms were collected at the eight sampling sites. For qualitative and quantitative analysis, diatom samples were scrubbed off the upper surface of between three and five submerged stones, 10 to 20cm in diameter, using a toothbrush, and were fixed with formalin following the method employed by Kobayasi & Mayama (1982). Diatom samples were cleaned with sulfuric and hydrochloric acids and mounted on permanent slides with Naphrax. All specimens found in random transects under light microscopy through the prepared permanent slides were identified and counted up to a minimum of 600 valves using an Olympus BX-40 microscope. For the identification of species, the following taxonomic references were used: Metzeltin & Lange-Bertalot (1998, 2007), Rumrich *et al.* (2000), Metzeltin & García-Rodríguez (2003) and Metzeltin *et al*. (2005). To determine the abundant and dominant species, the Lobo & Leighton (1986) criterion was used. Voucher samples were stored in the DIAT-UNISC Herbarium at the *Universidade de Santa Cruz do Sul* (RS), Brazil.

Data analysis

Based on the physical, chemical and microbiological data, the assessment of stream water quality was performed applying resolution 357 of the National Environment Council (Brazil, 2005). With

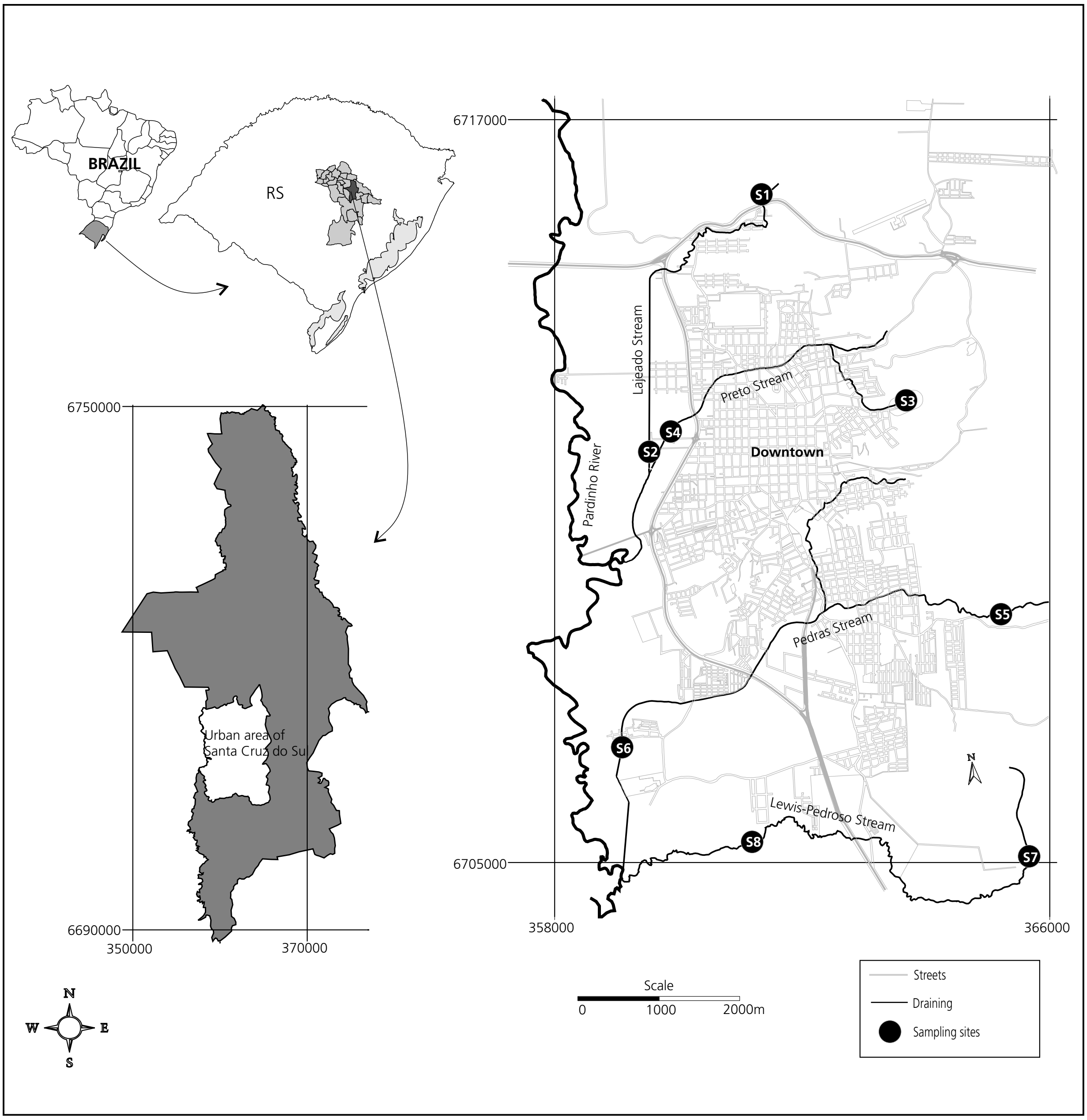

Figure 1. Location of the study area and the eight sampling sites (S1 - S8), in *Santa Cruz do Sul* county, RS, Brazil, were S1, S3, S5 and S7 are sampling stations of the upper reaches and S2, S4, S6 and S8 of the lower reaches.

regard to the biological analyses, the assessment of water quality was performed applying the Water Quality Biological Index (WQBI), based on the diatom classification for southern Brazilian rivers proposed by Lobo *et al*. (2004a). The environmental and biological data were standardized, utilizing the mathematical transformation (ln + 1), in order to make a distinction between groups, based on the quantitative similarity of sampling sites in different sampling periods. The Bray-Curtis index was utilized as the distance coefficient for Cluster analysis, following Ludwig & Reynolds (1988). All the analyses were calculated using the Past software application, version 1.81 (Hammer *et al*., 2008).

RESULTS AND DISCUSSION

Physical, chemical and microbiological variables

Overall, high values of phosphate, BOD_5 and thermotolerant coliforms were observed, these being the main parameters used to classify stream water quality. As can be seen in Figure 2(A), the results for phosphate concentration showed that almost all sampling sites were classified in "Class 4" (Brazil, 2005), corresponding to the poorest water quality level, used only for navigation and harmonizing landscapes, ranging between 0.28 and 8.31mg L^{-1}, except the points S1, S3 and S7, which were classified as "Class 3", in the May sampling (values ranged between 0.12 and 0.15mg L^{-1}). The high phosphate values were found at sampling stations in the lower reaches. Phosphorus is recognized as the main reason for eutrophication caused by diffuse or point sources that deteriorate the water quality, making it even unsuitable for human consumption (Tundisi & Tundisi, 2008). The high phosphate concentrations observed are probably related to the discharge of untreated domestic sewage and diffuse loads emanating from the rural and industrial areas of *Santa Cruz do Sul*.

The results for biochemical oxygen demand after 5 days (Figure 2B) indicated that S2 and S8 were classified in "Class 4", in the February sampling, as well as the points S2, S4 and S8, where the values obtained for dissolved oxygen (1.9 ± 1.0mg L^{-1}) corresponded to the same quality classification, indicating that these points contain high loads of organic pollution.

The results for thermotolerant coliforms (Figure 2C) indicated that points S8 in November and S4 in May, were also classified as "Class 4". The high values of thermotolerant coliforms indicate fecal contamination by domestic sewage and may also indicate the presence of pathogens that can affect the health of the population (Magalhães-Junior, 2007).

The results showed that the urban streams of the city of *Santa Cruz do Sul* are heavily polluted by organic contamination and show advanced stages of eutrophication, particularly the sampling sites S2, S4 and S8, all of which are in the lower reaches, as indicated mainly by high values of phosphate, BOD_5 and thermotolerant coliforms.

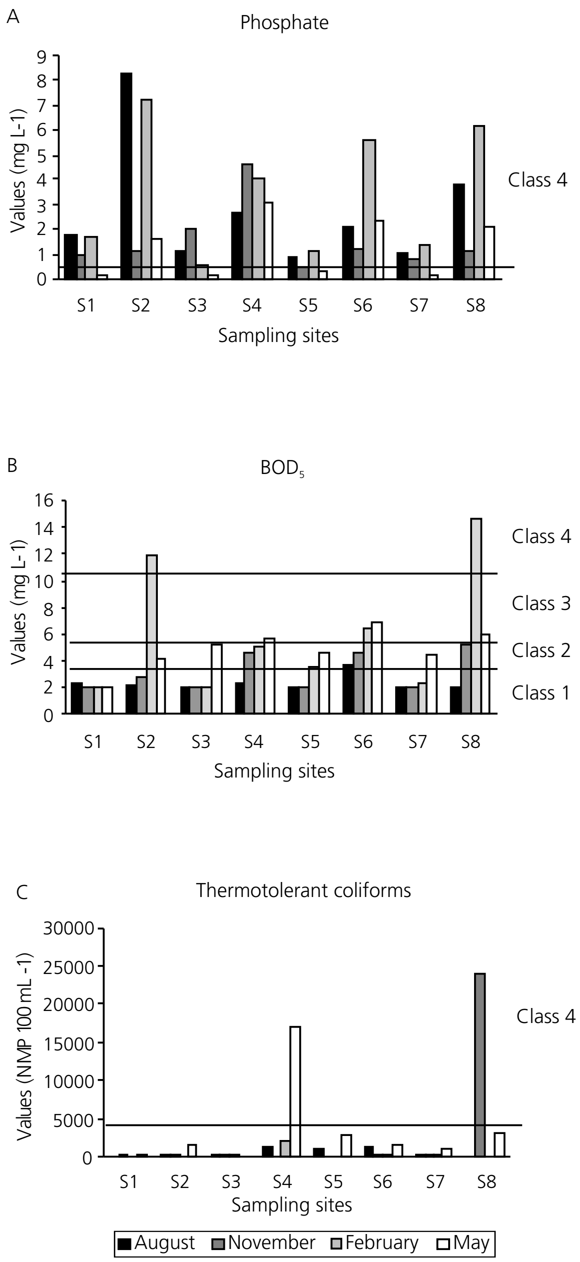

Figure 2. Values for total phosphate (A), BOD_5 (B) and thermotolerant coliforms (C), in the eighth sampling sites (S1 - S8), in *Santa Cruz do Sul* county, RS, Brazil, at four seasons, two in 2007 (August and November) and two in 2008 (February and May), were S1, S3, S5 and S7 are sampling stations of the upper.

These results corroborate studies of environmental monitoring in regional water systems in the state of *Rio Grande do Sul*, Brazil, which have demonstrated that they already have very advanced states of eutrophication and organic pollution (Torgan *et al*., 1999; Rodrigues & Lobo, 2000; Oliveira *et al.*, 2001; Lobo *et al.*, 2002, Lobo *et al.*, 2003; Lobo *et al.*, 2004a; Lobo *et al.*, 2004b; Lobo *et al.*, 2004c; Lobo *et al.*, 2004d; Lobo *et al.*, 2010; Wetzel *et al.,* 2002; Hermany *et al.*, 2006; Salomoni *et al.*, 2006; Dupont *et al*., 2007; Schneck *et al*. 2007).

Biological composition

As for the composition of the epilithic diatom community, 203 species were identified to specific and infra-specific levels, distributed across 45 genera. A total of 53 taxa were considered to be abundant species (Lobo & Leighton, 1986). The BWQI results (Figure 3) indicated that the water quality levels range from "strong" (25.0%) to "very strong" (53.1%) in all sampling sites, except at the points S1, S3 and S8 where the pollution level was considered "moderate" (15.6%) in November and May. Point S3, in August and February, showed a pollution level considered "weak" (6.3%).

The highest pollution levels were found at the sampling sites S2, S4, S6 and S8, all of these located in the lower reaches, corroborating the results obtained through the physical, chemical and microbiological variables. These samples showed strongly to very strongly polluted waters. According to Lobo *et al.* (2004a), the high pollution levels determined using the BWQI are due to the occurrence of species tolerant to organic pollution and eutrophication, which showed high percentages of relative abundance such as *Achnanthidium exiguum* var. *constrictum* (Grunow) Andresen, Stoermer and Kreis, *Adlafia drouetiana* (Patrick) Metzeltin and Lange-Bertalot, *Cyclotella meneghiniana* Kützing, *Eolimna minima* (Grunow) Lange-Bertalot, *Fallacia monoculata* (Hustedt) Mann, *Gomphonema parvulum* (Kützing) Kützing, *Luticola goeppertiana* (Bleisch) Mann, *Mayamaea atomus* (Kützing) Lange-Bertalot, *Navicula cryptotenella* Lange-Bertalot, *N. symmetrica* Patrick, *Nitzschia palea* (Kützing) Smith*, Sellaphora pupula* (Kützing) Mereschkowsky in the strictest sense and *S. seminulum* (Grunow) Mann.

Among these taxa, *C. meneghiniana*, *F. monoculata*, *N. palea* and *S. pupula* were regarded as the species most tolerant to eutrophication according to Lobo *et al.* (2010), in a study carried out in the Pardo River Hydrographic Basin. *F. monoculata* was also considered by Souza & Senna (2009) as extremely tolerant to eutrophication and organic pollution.

According to Lobo *et al.* (2004*a*), *N. palea* is classified as one of the most tolerant species to organic pollution and eutrophication, indicative of polysaprobic conditions. This taxon has been recognized as a cosmopolitan species extremely tolerant to pollution (Watanabe *et al*., 1988; Kobayasi & Mayama, 1989; Round, 1991; Gomez, 1998). Moreover, van Dam *et al*. (1994) argue that *N. palea* corresponds to a polysaprobic species indicative of hypereutrophic conditions, and Bruno *et al*. (2003), working with planktonic diatom communities in the region of the *Quarto* River, *Argentina*, confirmed the validity of *N. palea* as an indicator of waters impacted by a high nutrient load.

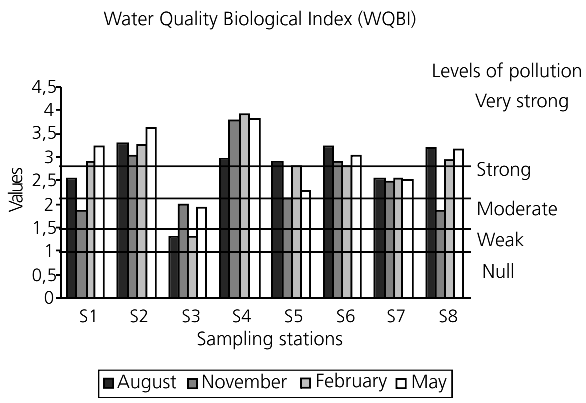

Figure 3. Assessment of water quality using the Water Quality Biological Index (WQBI), with the respective levels of pollution, in the eighth sampling sites (S1 - S8), in *Santa Cruz do Sul* county, RS, Brazil, at four seasons, two in 2007 (August and November) and two in 2008 (February and May), were S1, S3, S5 and S7 are sampling stations of the upper reaches and S2, S4, S6 and S8 of the lower reaches.

The sampling point S3 showed the lowest pollution level "Weak", although limited to August and February, and representing only 6.3% of the total pollution levels detected. In this case, most of the species that were considered abundant are sensitive to pollution (Lobo *et al.* 2004a), thus being responsible for the low BWQI values obtained. They are *Achnanthes rupestoides* Hohn, *Cocconeis placentula* var. *acuta* Meister, *Gomphonema pumilum* (Grunow) Reichardt and Lange-Bertalot, *Nupela lesothensis* (Schoeman) Lange-Bertalot, *N. praecipua* (Reichardt) Reichardt, *Planothidium biporomum* (Hohn & Hellerman) Lange-Bertalot and *Placoneis ovillus* Metzeltin, Lange-Bertalot and García-Rodríguez.

Some of these taxa have been classified as sensitive to organic pollution and/or eutrophication. According to van Dam *et al.* (1994), *A. rupestoides* has a preference for oligotraphentic and oligosaprobic environments, as well as *P. biporomum* for oligotraphentic conditions. *C. placentula* var. *acuta* showed high relative abundance in oligotraphentic and mesotraphentic environments (Schneck *et al.*, 2007).

The dendrogram in Figure 4 clearly shows this biological condition, separating by cluster analysis the sampling station S3, highlighting *A. rupestoides* as abundant taxa in all periods and *P. ovillus* as dominant in February, from other stations which were separated into two groups; the stations of the upper reaches (S1, S5, S7), and the stations of the lower reaches (S2, S4, S6, S8), in all sampling periods.

The environmental and biological data were analyzed together by Cluster analysis, as shown in the dendrogram in Figure 5. Again, two groups of sampling sites are separated, one containing the points

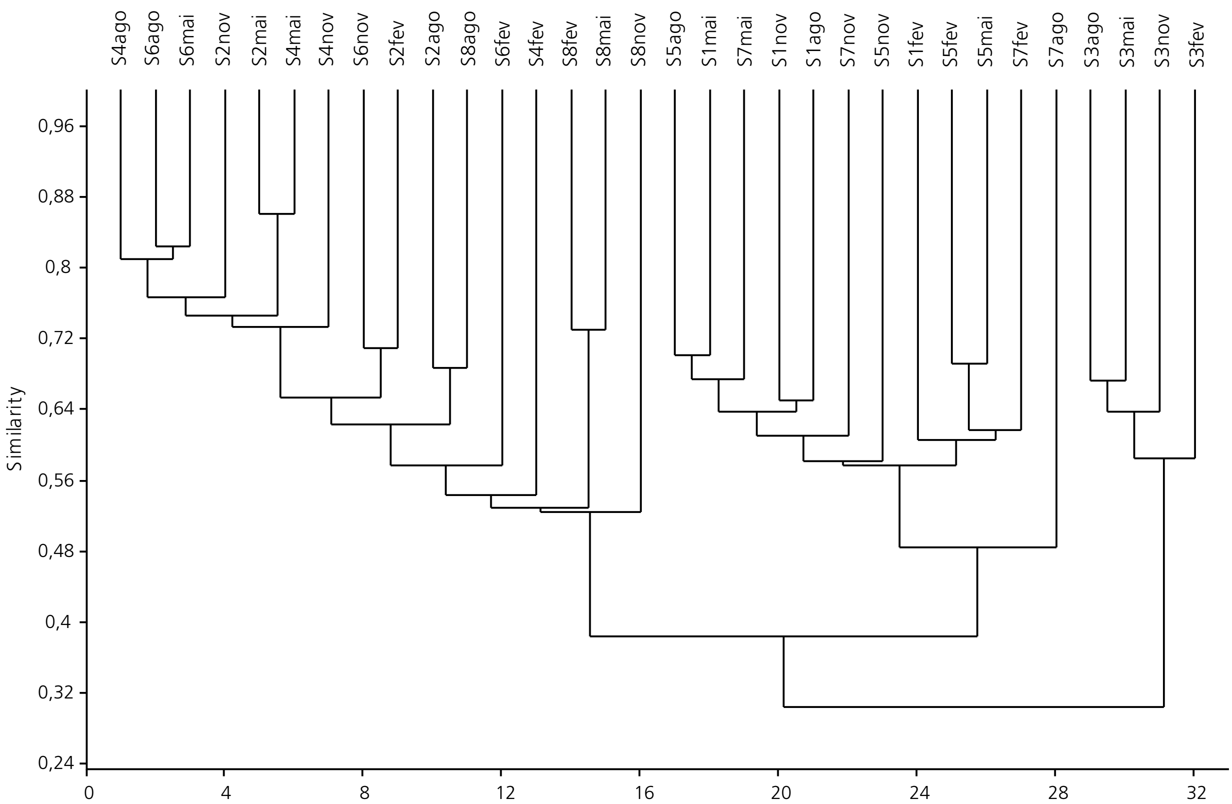

Figure 4. Cluster analysis based on biological data, in the eighth sampling sites (S1 - S8), in *Santa Cruz do Sul* county, RS, Brazil, at four seasons, two in 2007 (August and November) and two in 2008 (February and May), were S1, S3, S5 and S7 are sampling stations of the upper reaches and S2, S4, S6 and S8 of the lower reaches.

in the upper reaches in all sampling periods (S1, S5, S7), excepting S3, and the second containing the points in the lower reaches, in all periods (S2, S4, S6, S8). Similarly to the results shown in Figure 4 for biological data, the sampling site S3, in all sampling periods, was again separated, forming a single group, primarily because the diatom composition was different when compared to other sampling sites in relation to the pollution tolerance of species.

This clustering can be explained mainly by considering that the sampling sites in the lower reaches are characterized by the highest levels of pollution, as indicated by the environmental conditions, i.e. highest values of phosphate, BOD_5 and thermotolerant coliforms. The diatom composition corroborated this grouping; however, as shown in Figure 4, there is a 38% quantitative similarity between these two groups, as indicated by the Bray--Curtis index. This condition can be explained because some of the abundant species that were tolerant to highly polluted environmental conditions occurred in both the upper and lower reaches. This was the case for *C. meneghiniana*, *E. minima*, *F. monoculata. G. parvulum, N. cryptotenella*, *N. palea, S. seminulum and S. pupula* (Krammer & Lange-Bertalot 1986; van Dam *et al.,* 1994; Lobo *et al.,* 2002, 2004a).

CONCLUSION

These results highlight that, in spite of the higher pollution levels detected at the sampling sites in the lower reaches, those located in the upper reaches are also contaminated, suggesting that although the sites are located in the upper part of the streams, nowadays they are receiving a significant pollution load, probably originating from local domestic and agricultural activities. Thus, public

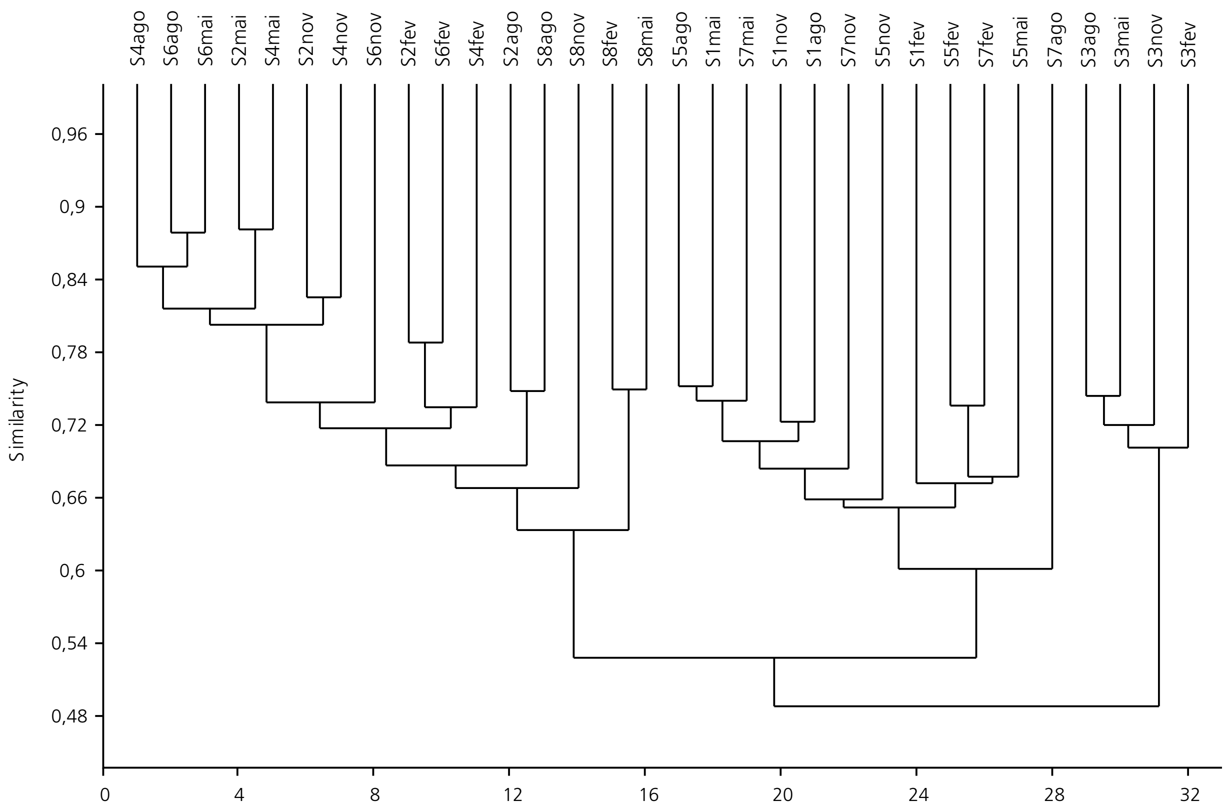

Figure 5. Cluster analysis based on the environmental and biological data, in the eighth sampling sites (S1 - S8), in *Santa Cruz do Sul* county, RS, Brazil, at four seasons, two in 2007 (August and November) and two in 2008 (February and May), were S1, S3, S5 and S7 are sampling stations of the upper reaches and S2, S4, S6 and S8.

policies must be implemented by local government to reduce the environmental impacts in the urban streams of *Santa Cruz do Sul*, since they are located in the *Pardinho* River Sub-basin, a source of water supply for this city and one of the main tributaries forming the *Pardo* River Hydrographic Basin.

A C K N O W L E D G E M E N T S

The authors would like to express their thanks to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (Brazilian National Research Council - CNPq) for the scholarship granted to the first and second-named authors (PIBIC/CNPq) during their undergraduate studies.

R E F E R E N C E S

American Public Health Association. (2005). *Standard methods for the examination of water and wastewater*. 21nd ed. Washington: APHA.

Bruno, E.; Martinez de Fabricius, A. & Luque, M.E. (2003). Fitoplancton en un tramo del Río Cuarto con influencia antrópica. *Boletin de La Sociedad Argentina de Botánica*, 38(1-2):1-13.

Brasil. Conselho Nascional de Meio Ambiente. (2005). Resolução CONAMA nº 357 de 2005. *Diário Oficial da União,* 17 março 2005.

Dupont, A.; Lobo, E.A.; Costa, A.B. & Schuch, M. (2007). Avaliação da Qualidade da Água do Arroio do Couto, Santa Cruz do Sul, RS, Brasil. *Caderno de Pesquisa Série Biologia*, 19(1):56-74.

Ector, L. & Rimet, F. (2005). Using bioindicators to assess rivers in Europe: a overview. In: Lek, S.; Scard M.; Verdonschat, P.F.M; Descy, J.P. & Park, Y.S. (Ed.). *Modelling community structure in freshwater ecosystems.* Berlin: Heidelberg. p.7-19.

Gold, C.; Feurtet-Mazel, A.; Coste, M. & Boudou, A. (2002). Filed transfer of periphytic diatom communities to assess short-term structural effects of metals (Cd, Zn) in rivers. *Water Research*, 36(14):3654-64.

Gomez, N. (1998). Use of epipelic diatoms for evaluation of water quality in the Matanza-Riachuelo (Argentina), a Pampean plain river. *Water Research*, 32(7):2029-34.

Hammer, O.; Harper, D.T. & Ryan, P.D. (2008). Past: paleontological statistics version 1.81. Norway: Paleontological Association. Available from: <http://folk.uio.no/ohammer/past>. (cited 10 Aug. 2008).

Hermany, G.; Schwarzbold, A.; Lobo, E.A. & Oliveira, M.A. (2006). Ecology of the epilithic diatom community in a low-order stream system of the Guaíba hydrographical region: subsidies to the environmental monitoring of southern Brazilian aquatic systems. *Acta Limnologica Brasiliensia,* 18(1):25-40.

Kelly, M.G. & Whitton, B.A. (1995). Comparative performance of benthic diatom indices used to assess river water quality. *Hydrobiology*, 302(3):79-188.

Kobayasi, H. & Mayama, S. (1982). Most pollution tolerant diatoms of severely polluted rivers in the vicinity of Tokyo. *Japanese Journal of Phycology*, 30:188-96.

Kobayasi, H. & Mayama, S. (1989). Evaluation of river water quality by diatoms. *The Korean Journal of Phicology*, 4(2):121-33.

Krammer, K. & Lange-Bertalot, H. (1986). Bacillariophyceae. 1. Teil: Naviculaceae. In: Ettl, H.; Gerloff, J.; Heynig, H. & Mollenhauer, D. (Ed.). *Süsswasserflora von Mittleeuropa*, *Bd. 2/1*. New York: Gustav Fischer Verlag Stuttgart.

Lobo, E.A. & Leighton, G. (1986). Estructuras comunitarias de las fitocenosis planctónicas de los sistemas de desembocaduras de rios y esteros de la Zona Central de Chile. *Revista Biologia Marina*, 22(1):1-29.

Lobo, E.A. & Callegaro, V. L. (2000). Avaliação da qualidade de águas doces continentais com base em algas diatomáceas epilíticas: enfoque metodológico. In: Tucci, C.E.M. & Marques, D.M. (Org.). *Avaliação e controle da drenagem urbana*. Porto Alegre: UFRGS. p.277-300.

Lobo, E.A.; Callegaro, V.M. & Bender, E.P. (2002). *Utilização de algas diatomáceas epilíticas como indicadores da qualidade da água em rios e arroios da região hidrográfica do Guaíba, RS, Brasil.* Santa Cruz do Sul: EDUNISC.

Lobo, E.A.; Wetzel, C.E. & Bes, D. (2003). Avaliação da qualidade da água dos arroios Sampaio, Bonito e Grande, Município de Mato Leitão, RS, Brasil. *Revista Tecno-Lógica*, 7(2):39-53.

Lobo, E.A.; Callegaro, V.L.; Hermany, G.; Bes, D.; Wetzel, C.E. & Oliveira, M.A. (2004a). Use of epilithic diatoms as bioindicator from lotic systems in southern Brazil, with special emphasis on eutrophication. *Acta Limnologica Brasiliensia*, 16(1):25-40.

Lobo, E.A.; Callegaro, V.L.; Hermany, G.; Gomez, N. & Ector, L. (2004b). Review of the use of microalgae in South America for monitoring rivers, with special reference to diatoms. *Vie et Milieu,* 53(2/3):35-45.

Lobo, E.A.; Bes, D.; Tudesque, E.L. & Ector, L. (2004c). Water quality assessment of the Pardinho River, RS, Brazil, using epilithic diatom assemblages and faecal coliforms as biological indicators. *Vie et Milieu*, 53(2/3):46-53.

Lobo, E.A.; Callegaro, V.L.; Wetzel, C.E.; Hermany, G. & Bes, D. (2004d). Water quality study of Condor and Capivara streams, Porto Alegre municipal district, RS, Brazil, using epilithic diatoms biocenoses as bioindicatos. *Oceanological and Hydrobiological Studies,* 33(2):77-93.

Lobo, E.A.; Wetzel, C.E.; Ector, L.; Katoh, K.; Blanco, S. & Mayama, S. (2010). Response of epilithic diatom community to environmental gradients in subtropical temperate Brazilian rivers. *Limnetica*, 29(2):323-40.

Ludwig, J.A. & Reynolds, J.F. (1988). *Statistical ecology*: a primer on methods and computing. New York: John Wiley & Sons.

Magalhães Júnior, A.P. (2007). *Indicadores ambientais e recursos hídricos*. Rio de Janeiro: Bertrand Brasil.

Metzeltin, D. & García-Rodríguez, F. (2003). *Las diatomeas uruguayas*. Montevideo: DIRAC.

Metzeltin, D.; Lange-Bertalot, H. & García-Rodríguez, F. (2005). *Diatoms of Uruguay*. In: Lange-Bertalot, H. Iconographia diatomologica. Königstein: Koeltz Scientific Books. v.15.

Metzeltin, D. & Lange-Bertalot, H. (2007). Tropical diatoms of South America II. In: Lange-Bertalot, H. (Ed.). Iconographia diatomologica. Königstein: Koeltz Scientific Books. v.18.

Oliveira, M.A.; Torgan, L.C.; Lobo, E.A. & Schwarzbold, A. (2001). Association of periphytic diatom species of artificial substrate in lotic environments in the arroio Sampaio basin, RS, Brazil: relationships with abiotic variables. *Brazilian Journal of Biology*, 61(4):523-40.

Rodrigues, L.M. & Lobo, E.A. (2000). Análise da estrutura de comunidades de diatomáceas epilíticas no Arroio Sampaio, Município de Mato Leitão, RS, Brasil. *Caderno de Pesquisa Série Botânica,* 12(2):5-27.

Round, F.E. (1991). Diatoms in river water-monitoring studies. *Journal of Applied Phycology*, 3(2):129-45.

Rumrich, U.; Lange-Bertalot, H. & Rumrich, M. (2000). Diatomeen der Anden. Von Venezuela bis Patagonien (Feurland). In: Lange-Bertalot, H. (Ed.). Iconographia diatomologica. Königstein: Koeltz Scientific Books. v.9.

Salomoni, S.E.; Rocha, O.; Callegaro, V.L.M. & Lobo, E.A. (2006). Epilithic diatoms as indicators of water quality in the Gravataí river, Rio Grande do Sul, Brazil. *Hydro-biologia*, 559(1):233-46.

Schneck, F.; Torgan, L. & Schwarzbold, A. (2007). Epilithic diatom community in a high altitude stream impacted by fish farming in southern Brazil. *Acta Limnologica Brasiliensia*, 19(3):341-55.

Souza, M.G. & Senna, P.A. (2009). Diatomáceas epilíticas da subordem Sellaphorineae do rio do Monjolinho, São Carlos, SP, Brasil. *Acta Botanica Brasílica*, 23(3):618-29.

Torgan, L.C.; Becker, V. & Prates, H.M. (1999). *Checklist* das diatomáceas (Bacillariophyceae) de ambientes de águas continentais e costeiras do Estado do Rio Grande do Sul. *Iheringia Série Botânica,* 52:89-144.

Tundisi, J.G. (2000). Limnologia e gerenciamento de recursos hídricos: avanços conceituais e metodológicos. *Ciência e Ambiente*, 21:9-20.

Tundisi, J.G. & Tundisi, T.M. (2008). *Limnologia*. São Paulo: Oficina de textos.

Van Dam, H., Mertens, A. & Sinkeldam, J. (1994). A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *Journal of Aquatic Ecology*, 28(1):117-33.

Watanabe, T.; Asai, K. & Houki, A. (1988). *Numerical water quality monitoring of organic pollution using diatom assemblages.* Proceedings of the Ninth International Diatom Symposium. Koenigstein: Koeltz Scientific Books. p.123-41.

Wetzel, C.E.; Lobo, E.A.; Oliveira, M.A.; Bes, D. & Hermany, G. (2002). Diatomáceas epilíticas relacionadas a fatores ambientais em diferentes trechos dos rios Pardo e Pardinho, Bacia Hidrográfica do Rio Pardo, RS, Brasil: Resultados preliminares. *Caderno de Pesquisa Série Biologia*, 14(2):17-38.

Received: 27/7/2011
Final version re-presented: 30/11/2011
Approved: 13/12/2011