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Cientific Paper

Monitoring of water quality patterns in the Córrego Fundomicro basin, Ourinhos/SP and effects of the state plan of hydrographic micro basins

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Abstract

Hydrographic basins are territory portions where it is possible to establish the interfaces of constituent elements of landscape (climate, vegetation, soils) and how anthropic intervention modifies the environment. The water quality in hydrographic basins is intimately connected to the usage of soil and type of handling to which the cultures are subjected to. The present study aimed to quantify the water quality of the micro basin of Córrego Fundo, Ourinhos (SP), which went through interventions during the Hydrographic Micro Basin State Program (PEMBH). Through parameters such as pH, electric conductivity, temperature, turbidity and dissolved oxygen, we compared the water quality in the beginning of the program in 2008, and four years later, in 2012. The results presented differences, mostly regarding dissolved oxygen quantity in the water. Problems such as the lack of riparian forest on the surroundings of watersheds and the presence of intensive cultivation, like sugarcane and maize, potentiated the entrainment of sediment and nutrients inside the drainage channel. This ends up favoring the growth of aquatic plants, which consume most of the dissolved oxygen in the water, and consequently decreases the downstream water quality.

Keywords: hydrographic basin; soil handling; monitoring.

Monitoramento de padrões da qualidade da água na microbacia do Córrego Fundo, Ourinhos/SP e os efeitos do plano estadual de microbacias hidrográficas

Resumo

Bacias hidrográficas são porções do território onde é possível estabelecer as interfaces dos elementos constituintes da paisagem (clima, vegetação, solos) e de como a intervenção antrópica modifica o meio ambiente. A qualidade da água em bacias hidrográficas está intimamente ligada ao uso do solo e tipo de manejo a que as culturas são submetidas. O presente trabalho objetivou quantificar a qualidade das águas da microbacia do Córrego Fundo, Ourinhos (SP), que passou por intervenções durante o Programa Estadual de Microbacias Hidrográficas (PEMBH). Através de parâmetros como pH, condutividade elétrica, temperatura, turbidez e oxigênio dissolvido, comparou-se a qualidade das águas no início do programa em 2008 e quatro anos depois em 2012. Os resultados apresentaram diferenças principalmente quanto à quantidade de oxigênio dissolvido na água. Problemas como a falta de mata ciliar no entorno de mananciais e a presença de cultivos intensivos como a cana-de-açúcar e milho, potencializam o carreamento de sedimentos e nutrientes para dentro do canal de drenagem. Isso acaba favorecendo o crescimento de plantas aquáticas que consomem boa parte do oxigênio dissolvido na água e consequentemente diminuindo a qualidade das águas a jusante.

Palavras-chave: bacia hidrográfica; manejo do solo; monitoramento.

Monitoración de las normas de calidad del agua en la cuenca del Córrego Fondo, Ourinhos-SP, y los efectos del plan estatal de cuencas hidrográficas

Resumen

Las zonas de captación son porciones del territorio donde es posible establecer las interfaces entre los elementos constitutivos del paisaje (clima, vegetación, suelos) y cómo la intervención humana cambia el medio ambiente. La calidad del agua en

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las cuencas hidrográficas está estrechamente relacionada con el uso del suelo y el tipo de gestión a que las culturas son sometidas. Este estudio tuvo como objetivo evaluar la calidad de las aguas de la cuenca del Córrego Fondo, Ourinhos (SP), que pasó por intervenciones durante el Programa Estatal de las cuencas hidrográficas (PEMBH). Por parámetros como pH, conductividad eléctrica, temperatura, turbidez y oxígeno disuelto, se comparó la calidad del agua en el inicio del programa en 2008 y cuatro años más tarde en 2012. Los resultados mostraron diferencias sobre todo cuanto a la cantidad de oxígeno disuelto en el agua. Problemas como la falta de vegetación ciliar alrededor de los manantiales y la presencia de cultivos intensivos como la caña de azúcar y el maíz, potencian el arrastre de sedimentos y nutrientes par dentro del canal de drenaje. Esto termina favoreciendo el crecimiento de las plantas acuáticas que consumen gran parte del oxígeno disuelto en el agua y por consecuencia la disminución de la calidad del agua río abajo.

Palabras clave: cuencas hidrográficas; manejo de suelos; monitoreo.

Introduction

Water is an essential natural resource for the survival, ecosystem maintenance and economic activities. The demand of water resources has increased over the past few years, whether for domestic supply or for the development of industrial and agricultural activities. The need for obtaining quality water and with low treatment and distribution cost has contributed for the increasing extraction of this resource in Brazil, where fresh water is still found in abundance. In many cases the absence of planning and lack of studies in relation to quality and vulnerability of hydrographic basins lead to the compromising of small watersheds. Following this tendency, in the future, the costs for water treatment may increase and turn this resource almost inaccessible.

For the monitoring of water resources it is necessary to consider a representative area as a whole for data collect and analysis, in this case the hydrographic basins, fundamental element of environmental planning. The hydrographic basin as an unity of spatial selection of planning constitutes an fundamental element of environmental handling and management of natural resources, for it integrates soil and water, essential for the sustaining and maintenance of life. A territory where it is possible to establish the interrelations of constituent elements of landscape (climate, vegetation, soils) and the processes that act in its sculpturing (ARAÚJO and PINESE, 2006).

The National Policy of Water Resources (PNRH) (BRASIL, 1997) establishes as one of the fundaments of its first article that "the hydrographic basin is the territorial unity for the implantation of the National Policy of Water Resources and acting of the National System of Water Resources Management", therefore, the representative territorial unity for implantation of water management resources projects. Even before the promulgation of the so called Water Law (Law 9.433/97) that established the PNRH, it was instituted through the Decree number 94.076, on March 5th of 1987 the National Program of Hydrographic Micro Basins (PNMH). This project aimed to execute actions regarding handling practices and renewable natural resources conservation, with the objective of increasing in a sustainable way the agricultural productivity, as well as the revenue of agricultural producers, stimulating the participation of farmers in their organization activities.

In the state of São Paulo, since 2000 it was implanted the State Program of Hydrographic Micro Basins (PEMBH), inspired on the projects "Micro basins" (1991-1999) of the state of Santa Catarina, and "Rural Paraná" (1989-1996) of Parana state, through the Decree 41.990, of 1997. The management of the program was under the responsibility of the Coordinating Office of Integral Technical Assistance (CATI), subordinated body of the Agricultural Secretariat. The development of this program was due, mainly, to the historic of the agricultural development in Brazil, which throughout the years started to present an advanced degradation scenario. For NEVES NETO and HESPANHOL (2008), the usage of products from the technological package of the "Green Revolution" (insecticides, pesticides, inputs, genetically modified seeds, agricultural machinery) took place in Brazil mainly since the military governments (1964-1985). This fact, on one hand, increased farming productivity, but also caused huge damages to the environment, such as soil erosion, river siltation, deforestation of the main biomes, like the Cerrado, the Atlantic Forest and the Amazon Rainforest.

For the program implantation, we defined priority areas, where the life quality and the environment were found to be highly prejudiced, to actually benefit mainly the small farmers and their families (CATI, 1997). The choice of the priority areas verified areas with highly eroded soil or with high susceptibility to erosion, for they indicate the

areas with major issues of environmental nature; and areas with higher levels of indigence, which indicates the poorest areas. The estimated cost for the intervention of the PEMBH I in the state of São Paulo, according to HESPANHOL (2005) was of US$ 124.740.200.00 of a total of US$ 55.348.200.00 that was financed by the International Bank for Reconstruction and Development (BIRD) and the remainder, US$ 69.392.000.00, by the state of São Paulo. Approximately 102 million were invested in the adoption of conservationist practices that include the preservation of rural roads, individual and collective incentives (SÃO PAULO [ESTADO], 1997). The estimated cost by acre was of US$ 28.00 requiring, in average, US$ 83.000.00 per micro basin and US$ 1,400.00 per beneficiary (HESPANHOL, 2005).

The Córrego Fundo basin located on the rural zone of the city of Ourinhos was one of the selected basins for the application of PEMBH I actions for being an area of priority 1. The environmental degradation level in the basin is worrisome. Laminar erosions and in furrows occur mostly in grazing areas, where there's no terracing, and also by the bad pasture handling, the erosions occur near the stream's water source. The stream presents clear signs of intense siltation, caused by years of intense erosion in the surroundings that had no sort of control of pluvial water, apart from the bad usage of agricultural soil ("down the hill" plantations, lack of terracing, cultures that did not propitiate good soil protection, poorly planned roads and inadequate soil handling). The lack of riparian forest also influences in a gradually on the siltation (CATI, 2002).

According to the Report of the Water Resources Conjuncture, "the usage of the information and indicators about the water resources situation has as main objective to provide subsidies for the managers and decision makers" (ANA, 2011). Therefore, to study and monitor the water resources situation is a necessary practice for the environmental management and planning. Therefore, the aim of this study was to analyze the evolution of water quality parameters in a hydrographic basin contemplated by the PEMBH I in order to verify the effectiveness of the interventions made in the area and its effects on the superficial water resources.

Material and Methods

Study area

The Córrego Fundo micro basin (Figure 1) is located in the rural area of the city of Ourinhos (SP) and is part of the Hydrographic Basin of the

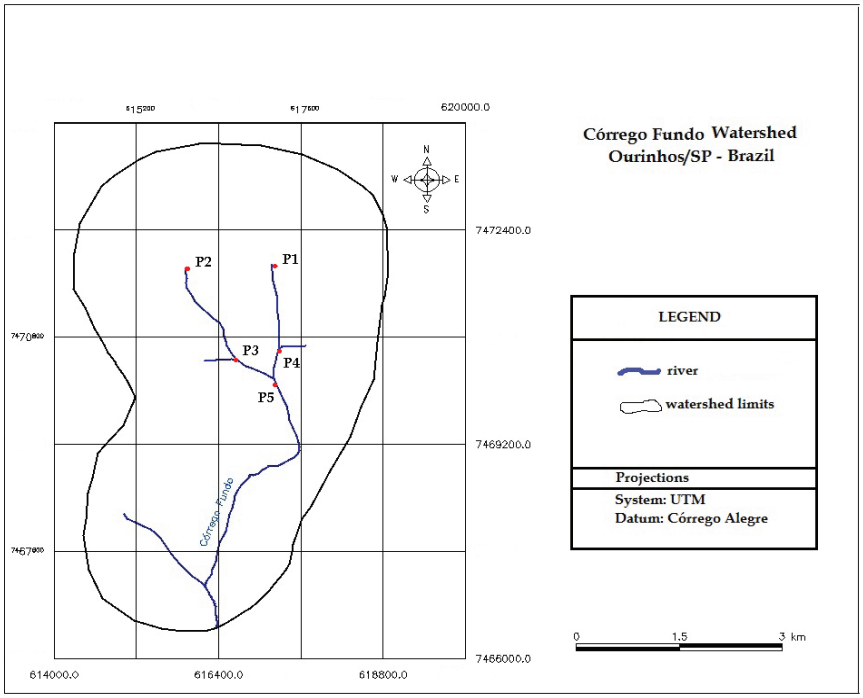

Figure 1. Schematic sketch of the Córrego Fundo Micro Basin, Ourinhos/SP.

Middle Paranapanema, inserted in the Water Resources Management Unit 17 (UGRH 17). Due to the environmental degradation level, the basin was chosen for the implantation of the PEMBH I, after a meeting held between the City Council of Rural Development in partnership with the CATIPEMBH I. The micro basin was chose according to the following criteria: environmental degradation level, concentration of small farmers, predominant explorations, sources of water supply, receptivity by the producers, area of the hydrographic micro basin within or near the Conservation Unit of Indirect use and higher percentage of permanent preservation area in the MBH.

According to BATISTA (2008) the basin presents an area of approximately 15 km², being composed by two channels that converge and form the stream until its outfall on the Turvo river. Along the course there are impoundments and several wetlands with the predominance of taboa (Typhadomingensis). Due to the soil usage for agriculture, about 95% of the area along the micro basin were deforested, remaining only fragments of the native vegetation in the Permanent Preservation Areas on the surroundings of the river sources and some reforested areas on the margins of Córrego Fundo.

The predominant soils on the region are Red Latosols, which are very leachate and susceptible to erosion, with predominant presence of cultures such as sugarcane and soy.

The plan for the Córrego Fundo Micro Basin elaborated by the CATI describes the problems of the basin in the year of the program implantation in 2002 (Frame 1).

Exactly ten years after the program implantation, it is still possible to observe the same issues in the micro basin, among them are the inadequate reforesting along the channels, the siltation and the predominance of sugarcane and maize cultivations too proximate of the channels. Due to the presence of a sugarcane factory on the region,

Frame 1. Priorities of the PEMBH I according to the Plan for the Córrego Fundo Micro Basin (2002).

Priorities	Causes	Activities and actions
Impassable roads in rainy seasons.	Water from the marginal properties invading the road. Inadequate tracing in part of the road.	- Qualification of the producers and machinery operators in road conservation. - Elaborated technical project of road adequacy. - Soil conservation in the adjacent areas of the roads. - Adequacy of 4 km of road. - Adequacy of the other roads through resources from the City Hall.
Erosion	Inexistent or inadequate soil conservation.	- Qualification of producers in soil conservation. - Elaboration of the PIP's (Integral Project of Property). - Lease of level lines. - Plating of species for green fertilization. - Elaboration of the PEC's (Community Enterprise Project). - Implantation of mechanical practices and incentive of direct planting utilization. - Machines and Equipments acquired (mowing, limestone distributor, spray, direct planting machine and knife roll) with incentive to soil handling and conservation and pollution control, with consequential benefit for the producers.
Streams siltation.	Riparian forest absence. Water from the roads and properties silting the stream by land transportation. Inadequate soil conservation.	- Qualification of producers in Environmental Preservation. - Planting of native species seedlings.

Source: CATI, 2002. Organized by the authors.

some properties lease lands for its cultivation in large scale, and the predatory usage and inadequate soil handling may interfere in the quality of superficial and underground waters. The Córrego Fundo is one of the micro basins that are inserted in the acting area of the PEMBH I, not only due to environmental degradation level, but also to the concentration of small farmers and the predatory usage of soil.

There are 45 rural properties and 43 owners, whereas 37 (84.4%) are family farmers (CATI, 2002). The region also preserves the characteristic of having the majority of its farmers living in their rural properties, which obligate the neighborhood to have water supply for human consumption, enough to attend the demand. The majority of the properties have homemade wells, and some still use this water for supply and consumption, despite the presence of an artesian well to attend all properties, which highlights the necessity of monitoring and preservation of the source. One of the factors that motivated the study in this micro basin is that the Córrego Fundo Basin was the micro basin that reached the highest punctuation in the area of the city of Ourinhos regarding the degradation level according to the PEMBH I criteria.

Monitoring of the water quality patterns

The monitoring of the micro basin was conducted from the collect of samples in representative points throughout the year of 2012, being a point in each source (Point 1 and Point 2), one point in each of the two channels (Point 3 and Point 4) and one point after its confluence (Point 5). The places were beaconed by the work of BATISTA (2008) who monitored the water quality patterns of the basin in the year of 2008. The methodology of both studies was the same, respecting the collect conditions, sampling and packaging disposed in the Sampling Procedures Manual and physiochemical analyses of the water according to EMBRAPA (2011). For the monitoring, five sampling points were chosen (Frame 2).

The analyses were aimed to delimitate the water quality patterns in the micro basin, considering for that analysis the disposition of the soil use and occupation, since the demand increase of soil usage due to the presence of a sugarcane processing factory, and of small rural properties on the region, may alter the patterns of quality and availability of water in the micro basin. In view of the characteristics of soil usage and occupation of the basin, five physical and chemical parameters of water quality were chosen that were able to represent the current situation of the basin according to the resolution number 357/2005 of the CONAMA; were they: pH, electric conductivity, temperature, turbidity and dissolved oxygen as complementary analysis.

Results and Discussion

The obtained results on the analyses of Córrego Fundo refer to the period of April to July of 2008; and April to July of 2012. Altogether, we conducted nine field visits on the year of 2012, and the arithmetic averages of the data were grouped by month.

The pH (Figure 2) varied little in seasonality function. The values of all points varied close to neutrality, whereas the lowest values are on P1 (river source 1) that reached 5.82 and the highest value was found on P5 (downstream) reaching 7.16. Although the values were close to neutrality, the ideal for aquatic life and human consumption varies from 6 to 9.5. Thus, the tendency is that the points present a slightly acid nature. There was no significant variance between the years of 2008 and 2012.

For the electric conductivity (Figure 3) it was not established a parameter in the legislation, though in its highest concentration for being a indicative of salinity level or dissolved minerals in the water (EMBRAPA, 2011). The values increased gradually from 2008 to 2012 according to the observed (Figure 3). On P4 the electric conductivity presented a disparate value on April of 2008, but it was an isolated event, which may be associated with salt concentration in the water or even the dumping of some sort of substance on the river source. P2 (river source 2), P3 and P5 presented the highest levels in 2012. The hypothesis is that on those points there was a fertilizer entrainment into the stream, due to the planting of sugarcane and maize around the basin.

The turbidity (Figure 4) presented a positive variation, from 2008 to 2012. Its values decreased gradually, presenting values very close to 0 UNT in the driest period. In rainy seasons the tendency of turbidity is to rise due to the leaching and particle transport from soil to the margins of water courses, though. According to what was found at field, the decrease of turbidity values may be associated with the recent reforesting conducted on Points 3 and 4 of the stream, where two artificial impoundments are formed. This may be an indicative that the

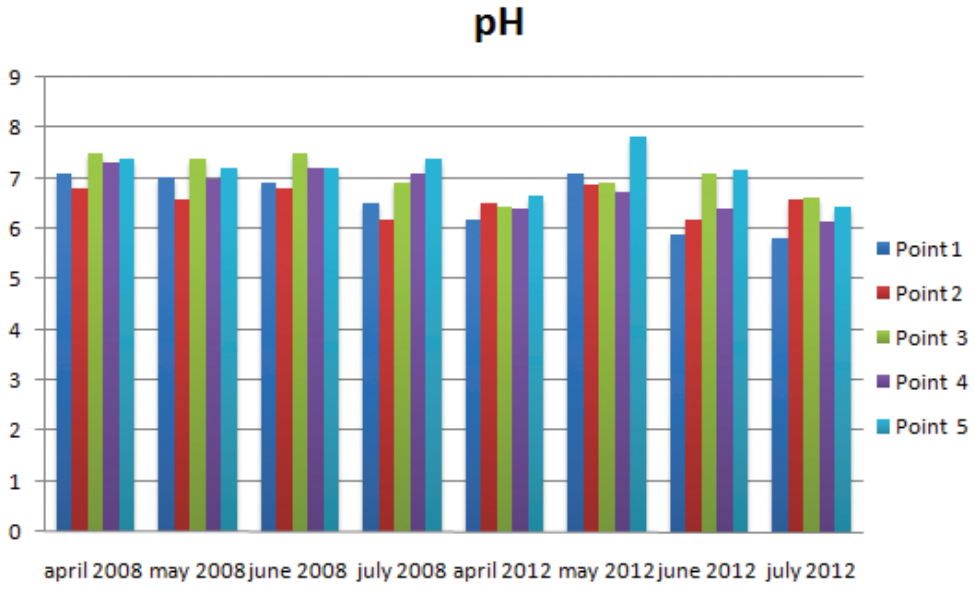

Figure 2. pH values of water in the Córrego Fundo micro basin in the period of April to July of 2008 and April to July of 2012.

Frame 2. Description of the sampling points in the Córrego Fundo Basin, Ourinhos/SP.

Point	Location	Geographic Coordinates	Current situation
P1	Córrego Fundo River source	22º 51′ 20.4″ S 49º 51′ 27.7″ W	- Partially preserved area, very steep land, which enables the entrainment of residues into the interior of the source.
P2	Ribeirão Fundo River source	22º 51′ 27.1″ S 49º 51′ 27.1″ W	- Partially preserved area with native vegetation, however there are sugarcane and maize plantations on the surroundings of the source.
P3	Bridge after the Ribeirão Fundo source	22º 51′ 47.4″ S 49º 51′ 57.4″ W	- Pasture areas and properties, there's no native vegetation in the local. The presence of vegetation in the interior of the stream indicates the advanced stage of siltation.
P4	Impoundment after the Córrego Fundo source	22º 51′ 22.5″ S 49º 52′ 16.1″ W	- There is practically no native vegetation on the surrounding of the impoundment. There are evidences of attempts of reforesting in the área, although the trees were planted far from each other, and there's still presence of vegetation in the interior of the impoundment, which hampers the water body observation.
P5	Confluence of the two channels of the stream	22º 51′ 23.50″ S 49º 51′ 28.40″ W	- It is predominant the presence of taboa (Typhadomingensis.), and the road that passe above the point propitiates the soil entrainment into the interior of the stream. The sugarcane plantation and the pasture area are too proximate from the stream.

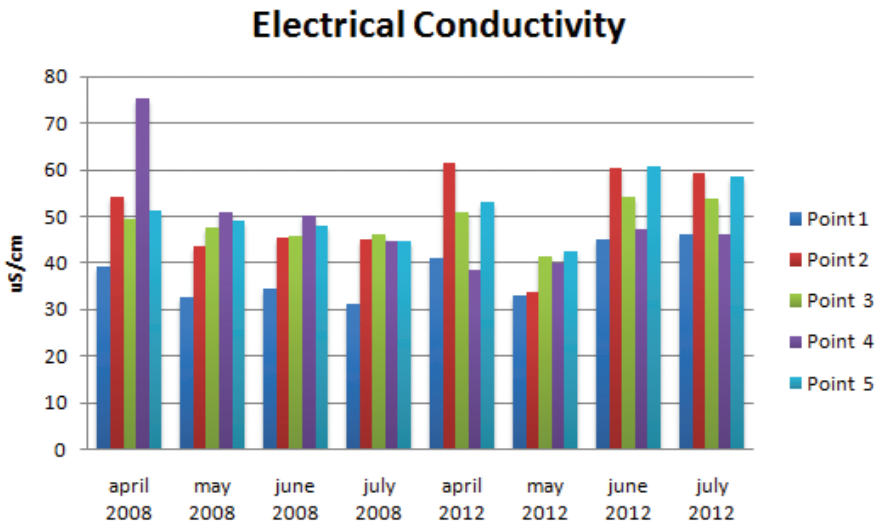

Figure 3. Electric conductivity of water in the Córrego Fundo micro basin in the period of April to July of 2008 and April to July of 2012.

proposed actions, though they were not followed and maintained throughout these four years, had some effect.

Since the acceptable values for human consumption, according to the actual legislation (CETESB, 2005), are up to 5 UNT and, for aquatic organisms, considering a river source of fresh water class 2, are up to 100 UNT, there are no major problems in the basin during the studied period. However, for a more reliablecharacterization regarding the turbidity in Córrego Fundo Basin, it is recommended that the monitoring should be done continuously in all periods of the year, so that critical events are possible to be measured. We understand as critical events intense rains that, possibly, would carry particulate matter into the drainage, since the vegetation coverage on PPA areas is small and does not comply with the law (BRAZIL, 2012).

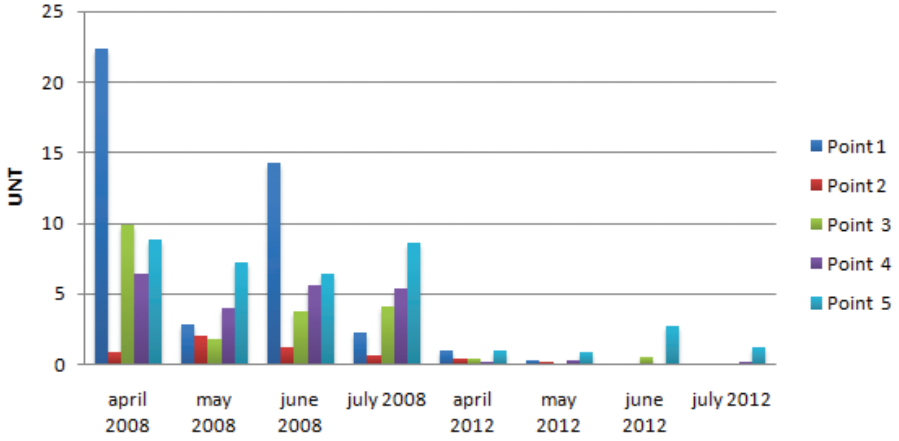

Figure 4. Water turbidity in the Córrego Fundo micro basin in the periods of April to July of 2008 and April to July of 2012.

The dissolved oxygen (DO) was conducted as complementary analysis (Figure 5), since the studies of BATISTA (2008) did not contemplate this parameter. As seen on Figure 4, Points 2 (river source) and 4 (impoundment after source) presented an atypical variation of dissolved oxygen level. In cases of river sources, it is expected lower levels of oxygen, since the water was not in contact with the atmosphere. However, the differences between the values of the two river sources (P1 and P2) demonstrate that the reasons may be other. Another proposed hypothesis is that fertilizers used on the soil after being converted in substances such as the nitrate (NO_3^-) and transported to ponds and impoundments, changed mostly the quantity of dissolved oxygen, by the excessive growth of plants that will consume this oxygen, leading to degradation processes such as the eutrophication.

As for the atypical change of the dissolved oxygen patterns on P4 in relation to P1 (course source) denotes that the water body suffers alterations throughout its course (SILVA et al., 2012). The sugarcane crops on the surroundings of the impoundment, along with the lack of adequate practices of soil conservation and absence of exuberant riparian forest, following minimally the patterns established by the Forest Code – Law number 4771/65 (BRAZIL, 2012) contribute to the entrainment of fertilizers and sediments into the dam, favoring the growth of aquatic plants that consume the oxygen, causing the loss of water quality. The presence of macrophytes on the pond formed by the impoundment was verified in field. According to RESENDE (2002), in more extreme cases, the nitrate (main form of oxygen associated with the water contamination by agricultural activities) may be harmful to animals and human health in high quantities on water bodies, raising the risk of environmental impacts due to these activities.

The temperature (Figure 6) did not exceed 25° C in all sampling points, the seasonality influenced in this point, since the studied period corresponded to autumn/winter, where the temperatures are milder. There is no maximum limit, in the legislation, for water temperature, but certain animal and vegetal species grow better in a specific range of temperature (between 25° to 30° C), other organisms such as bacteria, phytoplankton, as well as physical and chemical processes, may respond favorably to temperature increase. The rate of the majority of processes that affect water and soil quality doubles every 10° C on the temperature, the seasonality also may influence in this process (EMBRAPA, 2011).

On Table 1 are presented the averages of the analyzed parameters for each sampling point in the periods of April to July of 2012.

It was also possible to observe that there wasn't abrupt variation of the average temperature in all points, except the oxygen values where the difference is discrepant on Point 4 in relation to the other points, since it obtained the lowest average of DO.

In relation to the analyzed parameters, the variation of dissolved oxygen levels on P4 is the most significant and harmful to health and the aquatic life, mainly to the farmers that use water from the river sources for consumption, since the values are below recommended (>5 mg L^{-1}).

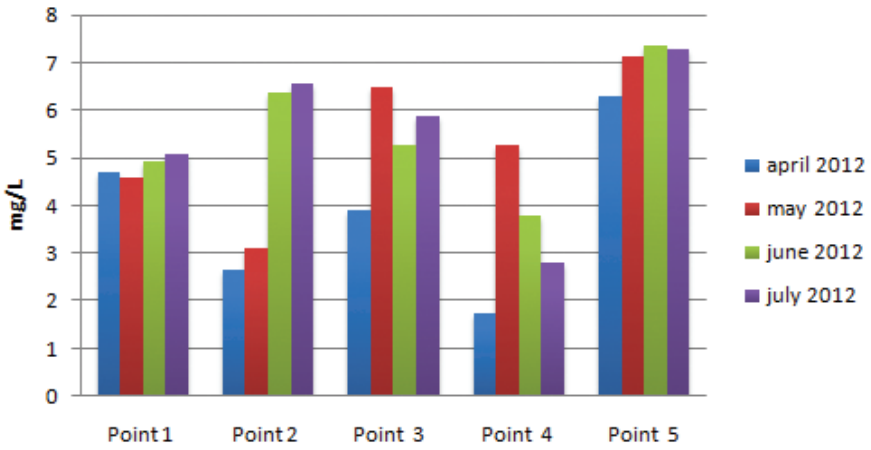

Figure 5. Dissolved oxygen in the water of Córrego Fundo micro basin in the period of April to July of 2012.

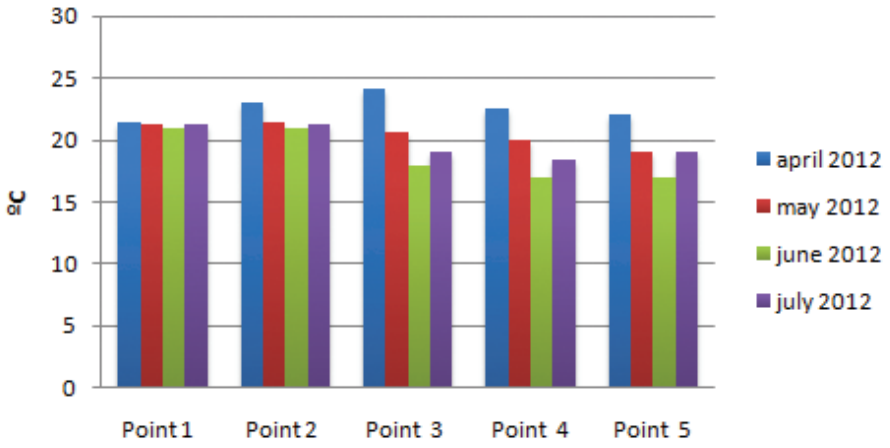

Figure 6. Water temperature in the Córrego Fundo micro basin in the period of April to July of 2012.

Table 1. Average values of the points for the analyzed parameters.

Parameters	Point 1	Point 2	Point 3	Point 4	Point 5
Temperature (ºC)	24.50	21.74	20.76	20	19.02
Dissolved oxygen (mg L^{-1})	4.83	5.04	5.3	3.26	7.02
Electric conductivity (µS cm^{-1})	40.54	52.49	50.34	41.85	53.87
pH	6.52	6.64	6.88	6.69	7.08
Turbidity (unt)	0.30	0.16	0.245	0.18	1.44

Organized by the authors.

The hypothesis points out that the fertilizers used on the soil, after being converted in substances such as the nitrate (NO_3^-), are transported to ponds and impoundments, and consequently change the oxygen quantity available in the water, since the water for supplying the sprays comes from the stream. The sprays washing are made in the own property without the necessary cares to avoid the contamination of the soil and aquifer (CATI, 2002).

The agricultural pesticides are eventually transported to the water through several mechanisms, and its residues remain on the environment due to its nonpolar character (EMBRAPA, 2011). The excessive quantity of nutrients on the natural reservoirs may lead to degradation processes such as the eutrophication (SILVA et al., 2012).

Córrego Fundo was one of the micro basins benefited by the PEMBH I, however, as described in PERUSI and AL ZAER (2012) the PEMBH I was terminated on the year of 2008 and since then no infrastructural measures or soil conservation were implanted in the city, only the fortification of the Córrego Fundo Association in an attempt to obtain resources from the PEMBH II. The PEMBH conducted interventions in this area due to the environmental degradation level, especially the lack of soil handling practices contributes to the stream's siltation. The main interventions of the program aimed to improve the soil handling techniques, though, in order not to damage productivity, that is, despite being in the objectives plan of the program the recovery of degraded areas, after the observations in field and the water quality analyses, it is possible to notice that the objective was not reached, for the stream still presents siltation characteristics. Although Córrego Fundo is still silted as described in the micro basin Plan, it presented lower turbidity levels in its waters to the ones found in 2008. Even without proper monitoring, the reforesting conducted may be contributing to the improvement of water quality in the basins.

It is a challenge of the micro basin's management to promote the responsible use of soil and of the water bodies, especially when the demand of this resource for agricultural reasons is big. In order to characterize the micro basin regarding the quality of its water resources, it is recommended the

continuous monitoring of its waters. The siltation is still a problem that must be solved and the proximity of cultures and inadequate reforesting contribute in speeding this process.

Conclusion

In comparison of the analyses of 2008 and 2012, the water quality kept the same tendencies in the analyzed periods regarding pH and conductivity;

The values of turbidity in the micro basin water in 2012 were lower to the ones found in 2008;

The analyses of DO and temperature did not indicate anomalies in the basin water characteristics and the implantation of the PEMBH also influenced the water quality in the analyzed period.

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