River Monjolinho Watershed: water quality, sediment and Hemeroby Index

Bacia do rio Monjolinho: qualidade da água, sedimento e Índice de Hemerobia

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ABSTRACT

The present work aimed at discussing the water and sediment quality with the naturalness and anthropic interference associated with landscape cover in an urban hydrographic basin. Analyses of temperature, dissolved oxygen, pH, electrical conductivity, nitrate, nitrite, ammonia, total phosphorus, heavy metals (Cd, Cu, Zn, Pb and Cr), cyanide and phenols were realized during the dry and rainy season of 2011. In relation to sediment, the heavy metals Cd, Cu, Pb, Cr, Ni and Zn were quantified too. Anthropic interference related to landscape cover was analyzed with the Hemeroby degree, what showed the predominant polihemeroby class that is characterized for artificial landscapes, i.e. intentionally created and totally dependent of human management and control. Agriculture was the mainly activity verified in the watershed, it contributes to landscape changes as well to water pollution and contamination of Monjolinho River.

Keywords: Metals. Hemeroby. Use and occupation. Anthropic activity.

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RESUMO

O presente trabalho teve como objetivo relacionar a qualidade da água e dos sedimentos com a naturalidade e interferência antrópica relacionada ao uso da terra em uma bacia hidrográfica urbana. Análises das seguintes variáveis limnológicas foram realizadas na estação de seca e de cheia de 2011: temperatura, oxigênio dissolvido, pH, condutividade elétrica, nitrato, nitrito, amônia e fósforo total, os metais (Cd, Cu, Zn, Pb e Cr), cianeto e fenóis. Para a análise de sedimentos, os seguintes metais foram quantificados (Cd, Cu, Pb, Cr, Ni e Zn). A interferência antrópica relacionada ao uso da terra foi analisada com base no grau de hemerobia identificando predomínio da classe polihemeróbia, que é representada por paisagens artificiais, i.e. intencionalmente criadas e totalmente dependente do controle e manejo humano. Sendo que a atividade predominante foi a agricultura, que leva à mudanças na paisagem e contribuem tanto para a poluição e contaminação da água do rio Monjolinho.

Palavras-chaves: Metais. Hemerobia. Uso e ocupação. Atividades antrópicas.

INTRODUCTION

The aquatic ecosystems are recognized by play an important role for all humankind, given the ecosystems services provision (e.g. water, biomass, nutrients cycling), their importance for the economic activities development and society structuration. Considering the anthropic activities in a region, these environments are considered vulnerable systems due to the constant changes in the adjacent areas (i.e. landscape cover heterogeneity in the basin) and exposition to a variety of pollutants and contaminants (KULKARNI et al., 2018) inserted in the environmental compartments (i.e. air, soil and water).

Organic or inorganic substances input in aquatic systems alter its quality, affecting directly or indirectly many aquatic ecosystem functions (COATES et al., 2013), as photosynthesis and biogeochemical cycles. Nowadays this scenario is worse, especially for the superficial waters, which have their quality (i.e. adequate physical-chemical and biological properties for a specific use) strongly affected by the changes in the landscape cover that is favored by policies created for economic development (DELKASH et al., 2018; VÉLEZA, GARCÍA, TENORIO, 2018). Furthermore, the nutrients (e.g. nitrogen and phosphorous) and others compounds (e.g. pesticides, heavy metals) imply in water quality loss and directly affect the biota (SCHIESARI et al., 2017; LATERRA et al., 2018), situation that occurs because of the landscape conversion and ecological processes deregulation.

The land use interference on aquatic ecosystem (e.g. SILVA et al., 2016; OLIVEIRA, CUNHA-SANTINO, BIANCHINI JR, 2017) and landscape naturalness (e.g. FUSHITA & SANTOS, 2015; ROMANINI, FUSHITA, SANTOS, 2016) are topics constantly investigated in the literature, however, there is a lack of an approach that consider both factors to promote hydric resources management and asses the environment autoregulatory capacity.

Therefore, seeking understanding an aquatic ecosystem functioning, we assumed that an aquatic environment is a set of interacting abiotic and biotic factors undergo to anthropic influence, where the ecological process maintenance demands the interaction factors synchrony. Although, the management in landscapes to meet human needs results in disturbs on aquatic ecosystems, promoting alterations in the metabolism and structure. In this way, quality water index (i.e. limnological variables group that are organized to measure the ecosystem status) and landscape analysis can contribute to scenario comprehension and decision-making.

At first, we believe that the human disturbance in managed landscapes has direct implication on water and sediment, situation that can be verified according to the limnological variables alteration during the temporal (i.e. dry and rainy season) and longitudinal gradient.

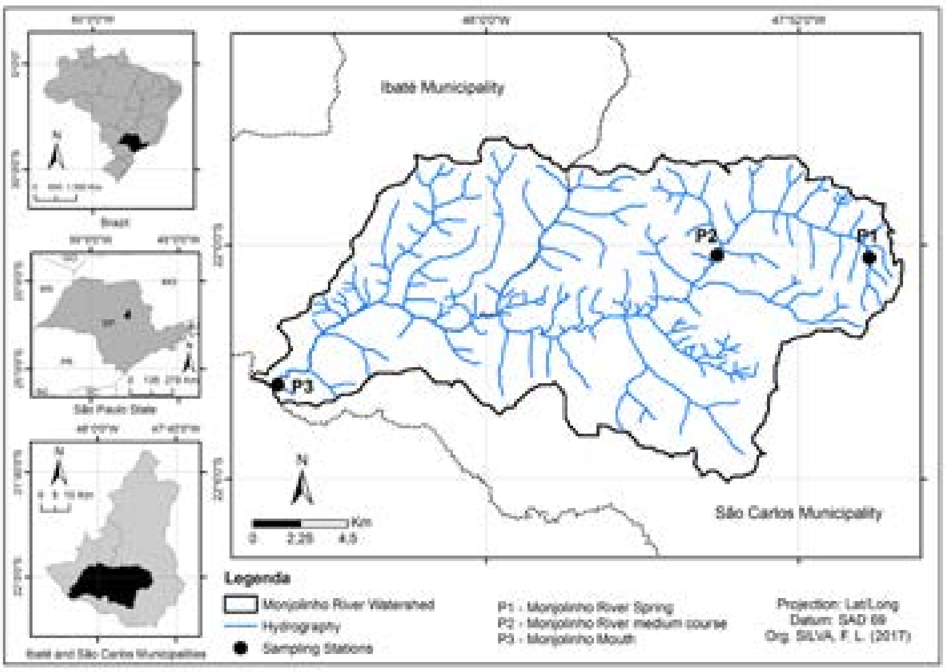
Aiming to verify this assumption, we employed an applied ecological approach based on limnological variables from sediment and water, as well as landscape ecology to assess the naturalness. Two water quality indexes (Toxic Contamination Index and Sediment Quality Assessment Criteria) were select to provide base for aquatic ecosystem characterization. In relation to the land cover, the Hemeroby Index was select, given its role as an integrative anthropic measure able to show the effects in relation to natural environment (SUKOPP & STARFINGER, 1999); and reflect autoregulatory capacity, energetic and technological dependence involved in the ecosystem maintenance (BARBARA et al., 2014).

Front of this, we aimed to verify the anthropic interference on the Monjolinho watershed (SP), looking for an association between water/sediment quality and human disturbance (i.e. hemeroby), providing base for the water management.

MATERIALS AND METHODS

Monjolinho river watershed (Ottobacia 846492) is localized in the center-north region of São Paulo State (Figure 1), between the parallels 21°57´- 22°06´ S e 47°50 - 48°05´ W, where its area is inserted in São Carlos city and Ibaté city. This watershed belongs to Paraná hydrographic region, specifically in the Tietê river (Ottobacia Level 3) and Jacaré-Guaçu river (Ottobacia Level 4). Agriculture represents the main landscape cover in this watershed, covering ca. 35.61% of total area, followed by the urban area.

Figure 1. Geographic localization of Monjolinho river watershed.



Water and sediment samples were sampled during the rainy and dry seasons between February and August of 2011. Water samples were collected in three sampling stations considering the longitudinal profile of the Monjolinho river (Table 1). Three water samples were collected manually in the subsurface (ca. 15 cm), keep at 4°C and carried to the laboratory analysis of the following limnological variables: nitrate, nitrite, ammonia, total phosphorus, metals (Cd, Cu, Zn, Pb and Cr), cyanide and phenols, determined according to Koroleff (1976), Strickland and Parsons (1960); Mackereth; Heron and Talling (1978), APHA; AWWA and WPCF (1998) and EPA (1996) methods, respectively. Temperature, dissolved oxygen (DO), pH, electrical conductivity (EC) and turbidity variables were measured in situ with the HORIBA U10 multiparameter probe.

In sequence, three bottom sediment samplings were collected in the central part of the river cross section of using an Ekman dredge in each station, the samples were conditioned in plastic bags and preserved at 4°C. Aiming the sediment characterization, the samples were dried (45°C) in a drying oven (Artlab, model 315 SE). The dry fraction was used to acid extraction in order to performed metals analysis. Cadmium (Cd), cooper (Cu), lead (Pb), nickel (Ni) and zinc (Zi) concentrations were determined for atomic absorption spectroscopy (APHA, AWWA &WPCF, 1998).

Table 1. Monjolinho sampling stations

Sampling Station	Description
P1 - Spring 23K 207.222 UTM 7.563.415	Station located at a rural area, is characterized for has partial riparian vegetation and sugar cane fields in the adjacent area
P2 - middle course 23K 207.236 UTM 7.563.910	Station located at an urban, is characterized for lack of riparian vegetation and consoled urban use in the adjacent area
P3 – river mouth 22K 800.250 UTM 7.557.815.	Station located at a rural area, is characterized for has a small riparian vegetation trip and sugar cane fields in the adjacent area

Toxic Contamination Index was employed to characterize the water quality in the different Monjolinho river courses (P1 to P3).That index considers the limnological variable limit value according to water body class defined by CONAMA Resolution n° 357/2007 (ANA, 2011). In order to compare limnological variables quality of the three Monjolinho river sampling stations (P1 to P3) considering the hydrologic period (dry and rainy season), all limnological variables mean from the sampling stations were tested using the principal component analysis (PCA). The data were organized in a set of points/hydrological period matrix (6 lines) and limnological variables (15 columns).

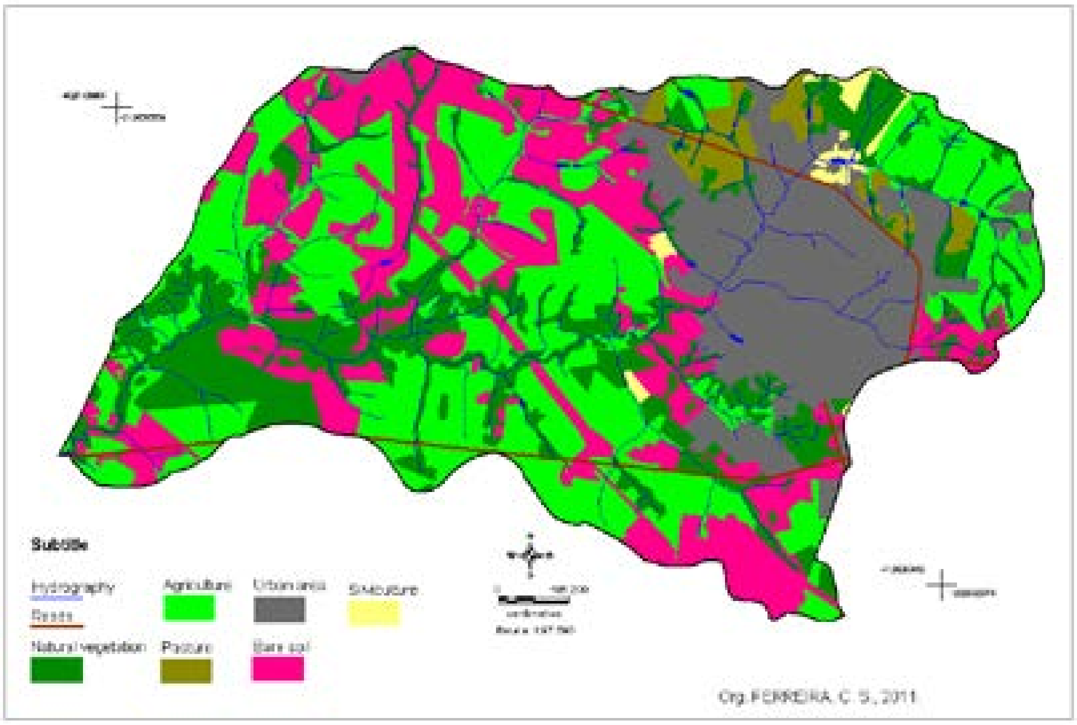
The sediment quality analysis was verified with the sediment quality assessment criteria (CETESB, 2016). Landscape cover and hemeroby degrees maps for the Monjolinho river basin were elaborated using the software ENVI (ITT Industries, 2005) to process the LANDSAT-5 satellite image sensor TM (orbit: 220, point: 75) with passage date of 2010, provided by National Institute of Spatial Research, with false color composition (5R4G3B) and, the software Mapinfo (Pitney Bowes Software INC., 2009).

RESULTS AND DISCUSSION

The average air temperature was 28.1°C (maximum) during the rainy season (May to October) and 16.2 °C (minimum) in the dry season (November to April) (INMET, 2015). Water temperature mean variation in both sampling periods was 18.4 °C to 24.4 °C (Table 1) being 1.2 times higher in rainy season compared to the dry season. Temperature fluctuations were due to regional seasonal climatic variations, which are characterized as a well-defined seasons with humid hot summers and cold dry winters (Table 2). Atmospheric precipitation during this study was 213 mm during the rainy season and 64 in the dry period, being the atmospheric precipitations in the rainy season 3.5 times higher than in dry season. The rainy and dry periods determine the water flow within a lotic system, in this way Monjolinho river mouth showed 33% less water flow in the dry season when compared with the rainy season (DORNFELD, 2006). This hydrologic pattern associated to the air and water temperatures is due to regional climatic seasonality.

Considering the landscape cover analysis (Figure 2), the middle course (P2) was the most influenced for the surrounding activities (consoled urban area), and the predominant land uses identified were: agricultural, bare soil being prepared for cultivation and natural vegetation.

Figure 2. Landscape occupancy of Monjolinho river watershed (Extract from FERREIRA & CUNHA-SANTINO, 2014).



In relation to the longitudinal Monjolinho river gradient, an increasing EC trend in spring-mouth direction was observed. The waters from P3 showed the highest ionic concentrations (dry period: 0.17 mS/cm and rainy period: 0.11 mS/cm, Table 2). This high ionic load in the Monjolinho river mouth (P3) was related to different chemical compounds inputs (i.e. fertilizers and animal residues) from non-point agricultural sources and the bare soil subject to erosion, upstream to this region (Figure 2), specially during the period corresponding to the sugar cane harvest (dry season). The ions input into continental waters is usually associated with chemical composition and rocks types that molded the drainage basin and the land cover categories, which in the P3 was essentially agricultural, with sugar cane and pasture (Figure 2).

Table 2. Limnological variables mean values: temperature, electrical conductivity, pH, dissolved oxygen concentration, turbidity, inorganic nitrogen (nitrate, nitrite and ammonia) and phosphorus at the sampling stations (P1: high course - spring, P2: middle course and P3: low course - mouth) according to the seasonality (dry and rainy).

Rainy season						
	P1		**P2**		**P3**	
	Mean	SD	Mean	SD	Mean	SD
T (°C)	21.4	0.3	24.4	0.3	24	0
EC (mS/cm)	0.01	0	0.12	0.002	0.11	0
pH	5.5	0.4	5.8	0.2	5.9	0.1
DO (mg/L)	7.3	0.2	6.5	0	7.6	0.2
Turbidity (NTU)	5.1	0.1	6.8	0.4	8.8	0.4
N-Nitrate (μg/L)	23.3	1.9	790.1	1.9	538.2	3.8
N-Nitrite (μg/L)	3.3	0.2	169.9	0	119.1	0.4
N-Ammonia (μg/L)	22.3	1.5	2408.5	3.0	2142.6	3.0
P-total (μg/L)	19.6	1.0	311.6	8.2	226.1	2.0
Cu (mg/L)	0.02	0.01	0.01	0.01	0.002	0.001
Cr (mg/L)	0	-	0	-	0	-
Zn (mg/L)	0.02	0.02	0.04	0.003	0.001	0.001
Pb (mg/L)	0	-	0	-	0	-
Cd (mg/L)	0	-	0	-	0	-
Phenols (mg/L)	0.001	0.001	0.002	0.003	0.002	0.001
Dry season						
T (°C)	18.6	0.1	19.0	0	18.4	0.1
EC (mS/cm)	0.01	0.001	0.50	0	0.17	0.001
pH	5.3	0.3	5.9	0.2	6.2	0
DO (mg/L)	7.1	0.2	5.8	0.2	7.3	0
Turbidity (NTU)	4.0	0	49.2	3.7	23.6	0.9
N-Nitrate (μg/L)	121.3	12.5	29993.9	20.8	2006.4	9.7
N-Nitrite (μg/L)	1.2	0.2	197.3	1.5	137.7	0.6
N-Ammonia (μg/L)	9.2	6.5	1400.0	533.0	1057.7	16.3
P-total (μg/L)	0.5	0.1	10.4	0.2	10.2	0.1
Cu (mg/L)	0.005	0.03	0.016	0.04	0.018	0.09
Cr (mg/L)	0.005	0.03	0.07	0.04	0.03	0.05
Zn (mg/L)	0.15	0.02	0.11	0.01	0.11	0.02
Pb (mg/L)	0.21	0.07	0.22	0.09	0.33	0.11
Cd (mg/L)	0.07	0.02	0.04	0.01	0.08	0.04
Phenols (mg/L)	0.001	0.002	0.006	0.004	0.006	0.003

The pH values were similar in both sampling periods, indicating that the aquatic environment of the Monjolinho river are slightly acidic, with a tendency to increase water pH in the spring - mouth longitudinal gradient. Monjolinho river waters are predominantly acid

(BIANCHI; ESPINDOLA E MARIN-MORALES, 2011) crossing the Brazilian Savanna region. A Monjolinho river basin pedology analysis indicates the Red Latosol and Red-Yellow Latosol predominance, factor that represents an acidic to slightly soils. In general, the Latosols attributes are dystrophic, eutrophic, with aluminum and iron oxides (JACOMINE, 2009) being characterized as highly weathered soils and with a thick subsurface oxic horizon (BRADY & WEIL, 2013). The aluminum hexahydrate presence in the soil is a H+ source after hydrolysis (SOUZA et al. 1995) thus, the Savanna soils for being rich in Al oxides are naturally acidic, contributing to the H+ input in the adjacent water bodies, especially during the high atmospheric precipitation period.

The DO concentrations were slightly higher in the greater precipitation period (Table 2), as consequence, an increase in the water flow was usually observed, reflecting current velocity elevation that provide the river water re-aeration in function of the turbulent water flow. Considering the Monjolinho river longitudinal profile, the P2 is located in the São Carlos urban perimeter (Figure 2), this sampling station presented, in both period (dry and rainy), the lowest DO concentrations, indicating a pressure on DO balance in the Monjolinho river middle course (P2). This sampling station is located after the sewage treatment plant and, even after primary and secondary treatment, an organic load partially oxidized may be discharged in this region. Low DO concentrations (1.7 a 5.9 mg/L) were measured in the Monjolinho river waters after the sewage treatment plant (CETESB, 2015). According to CONAMA 357/05, the DO concentrations should not be less than 6.00 mg/L considering the Class 1 and, 5.00 mg/L for Class 2. Worth to be mentioned that in urban areas, the marginal vegetation removal around the hydric bodies favor the ecosystem degradation (HAUSNER et al.; 2018) and the pollutants/contaminants input.

Considering the EC, a similar water turbidity increase was observed in the spring-mouth direction due to rainy in relation to the dry period. In the course of the river, from its spring occur the incorporation of several materials (both in dissolved and particulate forms) originated from its tributaries and the basin drainage. Among various substances that alter the water clarity are: clay, dissolved inorganic/organic matter and living organisms (i.e. biogenic turbidity). The raise in the water runoff in the rainy seasons increases the water turbidity with dissolved and particulate materials from adjacent bare soils. Despite the increase in turbidity, only P2 in the dry season presented values above to that recommended by CONAMA 357/05 for Class 1 (40 UNT).

Independent of the hydrological cycle, the nutrient concentrations (N and P) presented an increase in P2 when compared to P1 and P3 (Table 2). Regardless the sampling stations, two patterns were observed in relation to the increase in the atmospheric precipitation (i.e. rainy season): (i) the increase in N-ammonium and P_{total} the concentrations and (ii) the decrease in the N-nitrate concentrations (Table 2). The P2 always presented the highest nitrate, nitrite and ammonium concentrations compared to P1 and P3. This increase is due to nutrient from diffuse sources (e.g. from agriculture and urban areas) during the rainy season, added to the landscape cover around the P2 (Figure 2), which is the São Carlos urban perimeter downstream. As potential nitrogen sources, there is different agroindustrial inputs, i.e. nitrogen fertilizers such as urea, ammonium sulfate, ammonium nitrate and ammonium phosphate (DIAS & FERNANDES, 2006) from agroforestry users (annual crops, bare soil, forestry and pasture) that was identified in the river basin (Figure 2). Due to high atmospheric precipitation, the plowed lands adjacent to Monjolinho river represent potential nitrogen sources reaching the aquatic environment by surface runoff, increasing the ammonium and phosphorus concentrations during the rainy season

(Table 2). The nitrate concentrations were higher during the dry season resulting from nitrification process that was intensified by higher DO concentrations in colder months. Regarding to the nitrite concentrations, there was no difference observed from sampling stations (P1 to P3) during the rainy and dry periods. However, a variation was observed when compared the different sampling stations. The P1 showed lower concentrations (3.3 μg/L - rainy e 1.2 μg/L - dry) when compared to P2 in the rainy (169.9 μg/L) and dry period (197.3μg/L).

Metals are non-biodegradable elements that accumulate in the different compartments (water, air and soil) and trophic levels (i.e. biota). These elements presented natural (i.e. weathering) or anthropic (e.g. industrial and agricultural) origin. Cu concentrations were higher in the dry period at P3 (0.018 mg/L), P2 (0.016 mg/L) and in P1 (0.02 mg/L) during the rainy season (Table 2). Cr concentrations were higher in dry period at P2 (0.07 mg/L) than the others sampling stations. The Zn concentrations were higher (0.15 mg/L) in dry period at P1 (Table 2). In relation to Pb, concentrations were higher during the dry season at P3 (0.33 mg/L). Considering the metals levels on the water, the Monjolinho river was characterized within Class 2, since it exceeded the limit allowed for Class 1 (0.001 mg/L Pb) at all sampling stations (P1 to P3) in the dry season. In the rainy season, no Pb concentrations were detected in the water (Table 2). The Cd concentrations were higher in dry period at P3 (0.08 mg/L). In other hand, during the rainy period no these metal concentrations were detected in the water. Phenols concentrations were higher in P2 and P3 (0.006 mg/L C6H5OH) during the lower precipitations period. Considering this limnological variable in rainy season and CONAMA 357/05 legislation, the Monjolinho river can be classified as Class 1, since no sampling stations exceed the value of 0.003 mg/L C6H5OH (Table 2), however in the dry period, a the phenol concentration was 0.006 mg/L C6H5OH. In relation to cyanide concentrations, this substance was always null in all sampling stations and periods.

Figure 3 shows the limnological variables dispersion as a function of sampling times and points as a main score components function. The Table 3 shows the main components scores (CP1 and CP2) indicating limnological variables variability (contribution) in the hydrological periods and sampling stations in the Monjolinho river. The principal components CP1 to CP4 (Figure 3) accounted 96.8% of data analyzed. A high correlation was observed among the following variables: Pb, Cu, Cr, temperature, P_{total}, electrical conductivity and N-Ammonia in rainy period for Monjolinho river middle course and the mouth (CP2 and CP3). During the dry season, a high correlation was observed for these points among phenol concentration, turbidity, N-nitrate, pH and N-nitrite (SP2 and SP3). The spring was different in the dry (SP1) and rainy (CP1) season from the other points.

Figure 3. PCA analysis diagram indicating the scores of the 15 limnological variables of the water sampled during the dry (S) and rainy (C) periods at the different Monjolinho river sampling stations: P1 to P3.

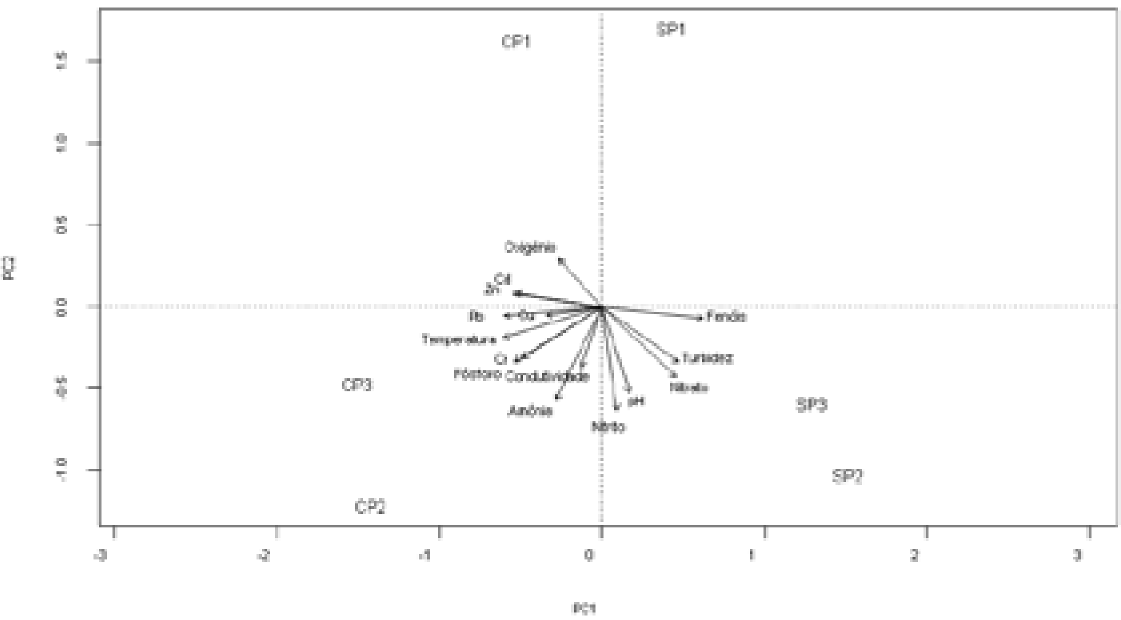


Table 3. Main components scores (CP1 and CP2) indicating the limnological variabilities in the hydrological periods and sampling stations.

	Axis 1 (CP1)	Axis 2 (CP2)
N-Ammonia (mg/L)	-0.3297	-0.67657
N-Nitrate (mg/L)	0.5353	-0.51575
N-Nitrite (mg/L)	0.1061	-0.74714
P-Total (mg/L)	-0.6284	-0.39959
T (°C)	-0.7166	-0.22831
EC (mS/cm)	-0.1478	-0.43917
Turbidity (NTU)	0.5528	-0.40721
DO (mg/L)	-0.3126	0.34339
pH	0.1932	-0.62543
Zn (mg/L)	-0.6131	0.09579
Pb (mg/L)	-0.7084	-0.06717
Cd (mg/L)	-0.6394	0.09658
Cu (mg/L)	-0.4029	-0.06265
Cr (mg/L)	-0.5813	-0.37287
Phenols (mg/L)	0.7281	-0.08673
Autovalue	7.0920	4.3908
Proportion	0.4728	0.2927
Accumulated ratio	0.4728	0.7655

The variables analyzed in Monjolinho river waters (Table 4) allowed evaluating the Toxic Contamination Index (TCI) according to the seasonality and longitudinal river profile. TCI showed that, only the Pb and Cd concentrations were characterized as high contaminated in the dry period. In the P2 (middle course) only the Cr concentration was classified as moderately contaminated. The other variables presented low values in relation to the classification limit, being categorized as low contamination. During the rainy period, the analyzed variables values in the present study classified the Monjolinho river with low contamination (Table 4); this fact can be explained by these compounds dilution effect, with the increase in the water flow rate during this period.

Table 4. Variables classification according to Toxic Contamination Index (adapted from ANA, 2011), where: H = high, M = middle and L = Low.

Variable	Dry season P1	Dry season P2	Dry season P3	Rainy season P1	Rainy season P2	Rainy season P3
Zn (mg/L)	L	L	L	L	L	L
Pb (mg/L)	H	H	H	L	L	L
Cd (mg/L)	H	H	H	L	L	L
Cu (mg/L)	L	L	L	L	L	L
Cr (mg/L)	L	M	L	L	L	L
PF (mg/L)	L	L	L	L	L	L
CN (mg/L)	L	L	L	L	L	L
NO_3 (µg/L)	L	L	L	L	L	L
NO_2 (µg/L)	L	L	L	L	L	L
NH_4^+ (µg/L)	L	L	L	L	L	L

The Table 5 shows metals concentrations in the sediment samples and also the criteria for sediment quality classification. Among the analyzed metals, only Cd and Mn contents presented classifications in the poor category. The other metals analyzed were categorized within excellent or good category, regardless dry or rainy period.

Table 5. Metal concentrations (mg/kg) in Monjolinho river sediment: P1 (spring); P2 (middle course) and P3 (river mouth) and quality categorization according to the sediment quality criteria.

Metals (Station/Period)	P1 Rainy	P1 Dry	P2 Rainy	P2 Dry	P3 Rainy	P3 Dry
Zinc (Zn)	13.0	12.8	46.4	37.2	64.6	191.5
	Excellent	Excellent	Excellent	Excellent	Excellent	Good
Lead (Pb)	<1	19.3	5.7	15.7	25.3	32.3
	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Cadmium (Cd)	6.2	5.9	7.1	6.2	8.3	6.7
	Poor	Poor	Poor	Poor	Poor	Poor
Nickel (Ni)	9.8	15.7	15.9	20.1	22.5	26.2
	Excellent	Excellent	Excellent	Good	Good	Good
Copper (Cu)	0.7	3.3	14.7	13.0	19.7	33.8
	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Chrome (Cr)	7.3	13.3	6.0	12.3	3.9	15.5
	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent

The Cd and Mn contents indicated contamination and consequent sediment quality loss. The Cu, Fe, Cd and Cr and Zn were registered in aquatic environment sediments in areas adjacent to sugar cane plantation (CORBI et al., 2006). The agriculture practices were also identified in Monjolinho river basin, with annual crops predominance, mainly sugar cane monoculture.

The Figure 4 indicates the sediment metals dispersion in function of sampling periods and the sampling stations in function of principal components scores. The Table 6 shows the principal components scores (CP1 and CP2) indicating the metallic elements variability in the hydrologic periods and Monjolinho river sampling stations. The principal components CP1 and CP4 explained 92.42% of analyzed data. An elevated correlation between the fallowing variables was observed: Pb, Cu, Ni and Pb for Monjolinho river mouth (SP3 and CP3). Cr and Cd contents showed a weak correlation in relation to other points.

Figure 4. PCA diagram indicating the scores of the six sediment metals sampled in the dry (S) and rainy (C) seasons in the distinct sampling stations in the Monjolinho river.

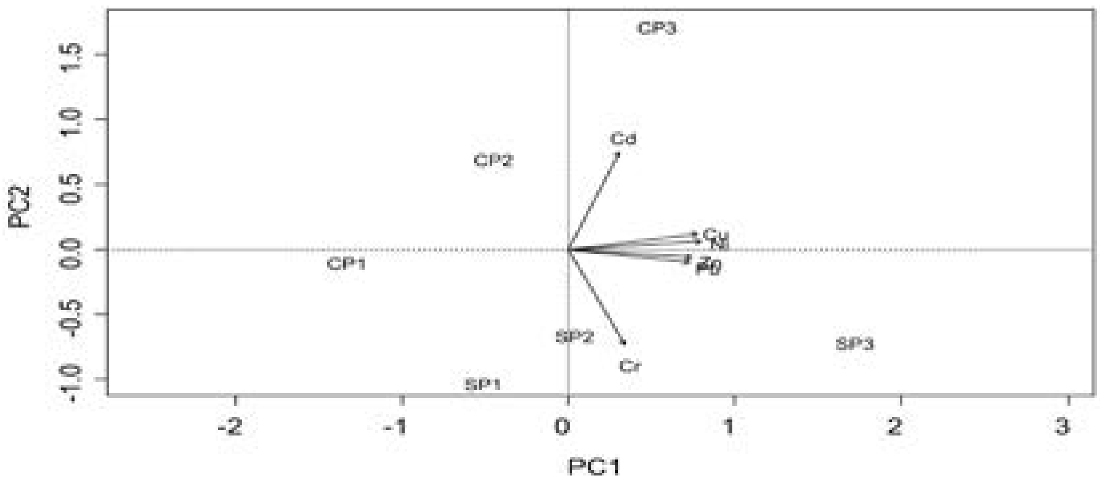


Table 6. Principal components scores (PC1 and PC2) indicating metals concentrations variability in the sediment during the hydrologic periods and sampling stations.

	Axis 1 (PC1)	Axis 2 (PC2)
Zn	0.8728	-0.07399
Pb	0.8582	-0.12085
Cd	0.3548	0.88245
Ni	0.9322	0.07328
Cu	0.9127	0.14152
Cr	0.3935	-0.86982
Autovalue	3.8133	1.7316
Proportion	0.6356	0.2886
Accumulated proportion	0.6356	0.9242

The predominant activities in the Monjolinho river longitudinal profile were agricultural practices that contaminated the sediments with pesticides application (Cd, Cu, Hg, Pb, Zn, e Cr; YONG et al., 2015), fertilizers (Cd: ROBERTS, 2014; Cd, Pb e As: ATAFAR et al., 2010) and sewage sludge (mainly from P2). Inadequate effluents discharges from urbanization (i.e. industrial and domestic sewage), soil waterproofing, deforestation, water contamination by metals interfere in the quality and quantity water available for population.

Agricultural activities represent the larger water multiple uses, this activity in addicting to alter soil chemical characteristics (i.e. soil nitrate concentration influencing groundwater quality, pH changes, metals presence), can limit directly the human water consumption (MENEZES, 2012). Additionally, the water use in agriculture represents a consumptive use of the water (GIAMPÁ & GONÇALES, 2005).

Considering this scenario (Figure 2), the hemeroby considers the human actions effects within the landscape, according to the naturalness (i.e. ruderality) level that according to the human-nature interaction followed in the categories: (i) ahemerobiotic, (ii) oligohemerobiotic, (iii) mesohemerobiotic, (iv) euhemerobiotic, (v) polihemerobiotic and (vi) metahemerobiotic (Fushita, 2011). According all the hemeroby degrees in Monjolinho river watershed, the polihemerobiotic was the mainly class once the agriculture areas predominated, mostly by sugar cane monoculture (Figure 5), that represents an area of 95.58 km² and occupied 35.61% of watershed total area (Table 6).

Polihemerobiotic areas present landscape elements intentionally created and dependent of human management/control or the natural elements that are strongly altered (REIF & WALENTOWSKI, 2008). The uncontrolled pesticides use (e.g. herbicides, insecticides) and fertilizers damaged the soils in São Carlos municipality region, and consequently water quality, being important to plan the those areas use, considering economic, social and environmental factors.

Forestry areas, pasture and bare soil were classified in euhemerobiotic that represents an area of 61.74 km² covering 23.00% of total hydrographic basin area (Table 6), this hemeroby class is characterize by elements dependence of anthropic intervention, energetic and technological dependence (mainly fossil fuels and pesticide) for the ecological process maintenance (FUSHITA, 2011) and low self-regulation. The forestry supplied the wood demand for industrial production avoiding native vegetation deforestation, however, the species introduction and the monoculture practice on natural ecosystem is an issue to concern (GUIMARÃES et al., 2010). Pasture is an activity that generates environmental negative impacts as: (i) erosion, (ii) loss and soil compaction, (iii) silting, (v) water contamination by fecal coliforms from the animal feces, (vi) deforestation and (vii) impediment of sub-forest regeneration by trampling. Bare soil can generate damages to soil quality, once the rain act directly on the soil and displacing the soil particles to water bodies causing silting and influencing directly on quantity and availability of this resource.

Urban areas and roads were classified as metahemerobiotic, this class represent an area of 60.69 km² and cover 22.62% of the hydrographic basin, that present a total area of 268.4 km². This class displays high energetic and technological dependence for its process maintenance and depend totally of human management and control, having low or none self-regulation control.

Vegetative areas were classified as oligohemerobiotic, it represents an area of 50.39 km² and cover 18.77% of total watershed area (Table 7). Oligohemerobiotic areas area recognized for the reduced human alteration and anthropic regulation, but presented has a high self-regulation capacity (REIF & WALENTOWSKI, 2008), being fundamental to the maintenance and regulation of ecosystem services provision capacity; however, this class is the less predominant in the Monjolinho river basin. This fact difficult the genic flow between the vegetation fragments in function of connection lack, increasing the population extinction risk by inbreeding (O'GREDY et al., 2006). The vegetation play an important role in the soil and water conservation, by prevent the direct incidence of rain water on soil providing gradually the infiltration, superficial runoff and, percolation (AB'SABER, 2001), besides to prevents the nutrient input (i.e. nitrate, nitrite, ammonia, phosphorus and others) directly in water bodies.

Figure 5. Landscape cover around the sampling stations and hemerobiotic map of Monjolinho river basin.

Table 7. Hemeroby degree percentage in the Monjolinho river basin.

Hemeroby degree	Area (Km^2)	Percentage (%)
Polihemerobiotic	95.58	35.61
Euhemerobiotic	61.74	23.00
Metahemerobiotic	60.69	22.62
Oligohemerobiotic	50.39	18.77
Basin total area	268.4	100

CONCLUSION

The hemeroby analyses associated to sediment and water quality indexes are tools for environmental diagnosis, allowing to identify for the Monjolinho river basin, activities (as agriculture and urbanization) that induce changes on landscape compromising the self-regulation capacity of ecosystems and contributing to water pollution and contamination of Monjolinho river.

Considering the seasonality and the longitudinal gradient, is possible to observe that an increase in the limnological variables concentrations (CE, turbidity, phenols) and a metals moderate/high contamination (Pb, Cd, Cr). Stands out the during the dry season the limnological variables showed higher values than the rainy season (nutrients, phenol), probably in function of the water volume able to dilute these compounds.

The worse situation was observed in the urban area, factor that can be related with the strong human influence in the area and the sewage. In other hand, the urban area showed less variation in the data, situation that can be associated with the low rain influence, different from what happens in the agricultural areas.

It was possible to see the managed landscape exercises a strong implication on water and sediment, given the limnological variables alterations. The naturalness loss deeply alter the limnological variables, it was observed in the second sampling station, an urban area (metahemerobiotic).

Front of this is possible to conclude that landscape naturalness and water/sediment quality are closely related, a large influence can occurs in the areas that the ecological functions are strongly altered and the areas lost their self-regulation.

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