HIDROGEOCHEMICAL COMPARATIVE STUDY OF THE JAÚ AND JACARÉ-GUAÇU RIVER WATERSHEDS, SÃO PAULO, BRAZIL

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(With 5 figures)

ABSTRACT

The main subject of the present work was to carry out a hydrochemistry comparative study between two river basins in São Paulo State: the Jacaré-Guaçu Basin (21°37'-22°22'S and 47°43'-48°57'W) and the Jaú Basin (22°09'-22°28'S and 48°16'-48°47'W). Nine sampling points in the Jacaré-Guaçu River and eight in the Jaú River were established. The water sampling was performed once each two months from March/95 to September/95. The following variables were analyzed: temperature (°C), pH, conductivity (μScm^{-1}), dissolved oxygen (mg/L) and ionic water composition. Comparatively the Jaú River showed higher spatial variability, less oxygenated water and higher mineralization, due to high pedological and geological substrate richness, point sources existence and less riparian forests. The Jacaré-Guaçu River showed less spatial variability, more oxygenated water with lower ionic concentration due to the lower geological and pedological watershed richness, absence of pollution from point sources and higher riparian forest protection.

Key words: river basin, river chemistry, land uses.

RESUMO

Estudo comparado das bacias hidrográficas dos rios Jaú e Jacaré-Guaçu, SP, quanto a variáveis hidrogeoquímicas

Este trabalho teve por objetivo realizar uma comparação hidrogeoquímica entre duas bacias hidrográficas relativamente próximas no Estado de São Paulo: as bacias dos rios Jaú (22º09'-22º28' latitude sul e 48º16'-48º47' longitude oeste) e Jacaré-Guaçu (21º37'-22º22' latitude sul e 47º43'-48º57' longitude oeste). Esses sistemas se encontram sob diferentes influências antrópicas, substratos geológicos e tipos de solos. Foram estabelecidos nove pontos de amostragem no Rio Jacaré-Guaçu e oito no Rio Jaú. As coletas de água ocorreram em intervalos bimestrais entre março/95 a setembro/95. Foram analisadas as seguintes variáveis: temperatura (°C), pH, condutividade (μScm^{-1}), oxigênio dissolvido (mg/L) e composição iônica da água. Comparativamente, no rio Jaú observou-se maior variabilidade espacial; águas menos oxigenadas e mais ricas ionicamente, reflexo da maior riqueza do substrato geológico e pedológico; presença de impactos pontuais; e pouca quantidade de matas ciliares. No rio Jacaré-Guaçu observou-se menor variabilidade espacial; águas mais oxigenadas e com concentrações iônicas mais baixas, devido à menor riqueza geo-pedológica da bacia; ausência de fontes pontuais; e maior proteção por matas ciliares.

Palavras-chave: bacia hidrográfica, qualidade da água de rios, composição iônica da água.

INTRODUCTION

Streams and rivers serve as integrators of terrestrial landscape characteristics and as recipients of pollutants from both the atmosphere and the landscape (Hunsaker & Levine, 1995).

Everywhere in the world, the river is saw as a simple channel to remove the water excess in agricultural area, to receive effluents or to hydroelectricity generation (Santos, 1993). Historically, urban areas were located along stream channels due to the importance of the river network as a transportation route for trade and travel. Furthermore, streams provided, and still do provide, a convenient disposal for urban wastes (Osborne & Wiley, 1988). Thus, is preocupant the fact that occur, in many cities, of discharge sewage in streams with low assimilation capacity.

The chemical composition of rivers vary greatly and is controlled by a series of factors such as climate, vegetation, topographic and geological characteristics of the catchment area (Hynes, 1970; Alaez *et al.*, 1988).

The comparative study of river basin, no doubt, is an important approach which constitute a powerful tool of assessment and understanding of the processes occurring in whole environments.

The main subject of the present work was to carry out a comparative hydrochemistry study between two river basins in the São Paulo State, the Jacaré-Guaçu River and the Jaú River. These systems are under different human activities, geological substrate and soil type.

MATERIAL AND METHODS

The Jacaré-Guaçu River basin is located in central north region of São Paulo State (21°37'-22°22'S and 47°43'-48°57'W).

The river is formed by Lobo and Feijão tributaries at 680 meters of altitude and downstream of the Lobo reservoir (Broa). The mouth is in Tietê River in the Ibitinga reservoir (Fig. 1).

The watershed drain a total of 4,108 km^2 and nine urban areas, include São Carlos, Araraquara and Ibitinga.

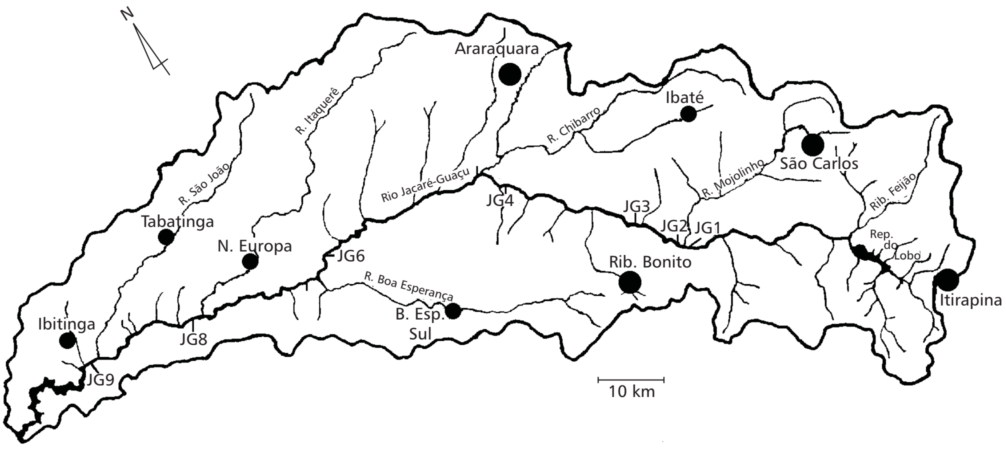

Fig. 1 — Location of sampling sites along the Jacaré-Guaçu River (JG1-JG9).

The climate is subtropical wet. Geologicaly, the catchment showed heterogeneity in forms, there are predominance of fluvial sandstone deposits, basalt and recent sediments. The soils type also showed great lithological variety in the drain area. Sand quartz and Podzol soils are common in the headwaters, and hydromorphics and organic soils, in the valleys.

The Jacaré-Guaçu River showed, in most course, meander conformation with relative riparian forest protection. There are point source pollution merely in tributaries and water quality is less impacted also due presence of wetlands in many localities in the catchment.

The Jaú River basin is located in central zone of São Paulo State (22º09’-22º28’S and 48º16’-48º47’W). Its source is situated in Dois Córregos City at an altitude of 640 m and its mouth river is the Bariri reservoir, Tietê River (Fig. 2).

The area of the basin is 745 km^2 and comprises the urban area of Dois Córregos, Mineiros do Tietê and Jaú. The climate is tropical with wet summer and dry winter. The geology is completely dominated by basalt rocks and soil type reflect this substrate which showed homogeneity in fertile soils regionally denominated of *terra roxa*.

Due soils fertility, the basin is intensively used by agriculture of sugar cane and contains few remnants of riparian forest along the river. The point source of pollution is represented by a factory mill located at 800 m downstream of headwaters and the discharge of untreated sewage and industrial effluents from Jaú City.

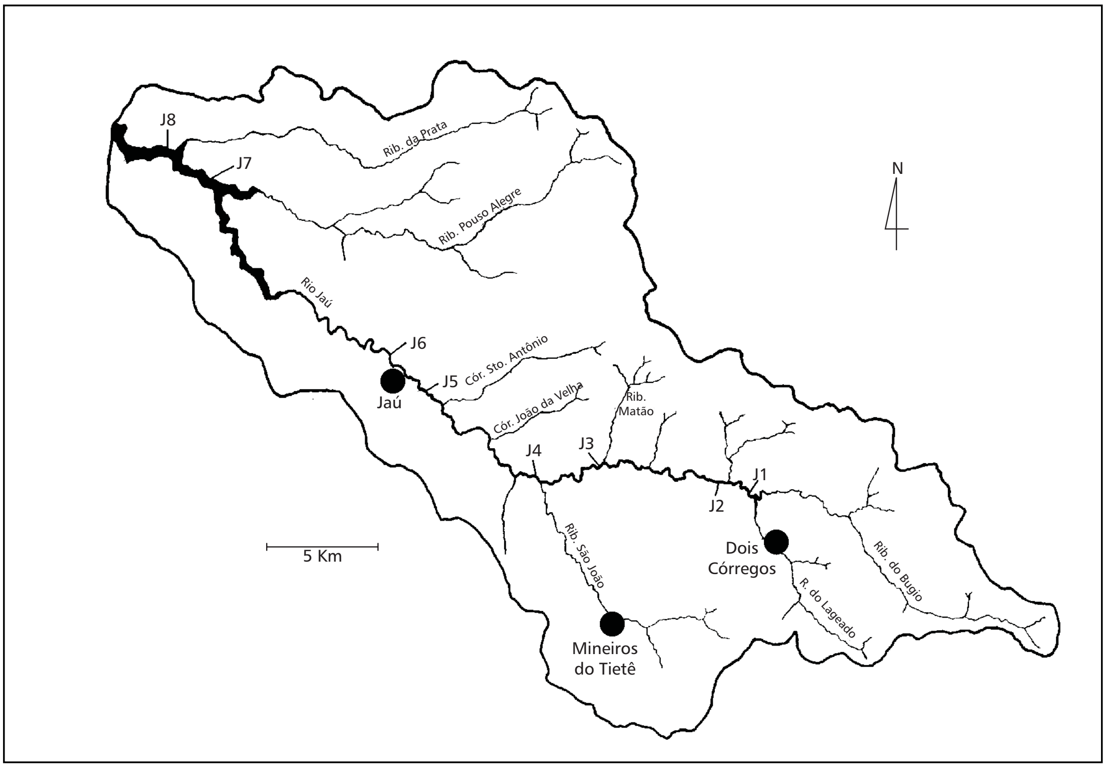

Fig. 2 — Location of sampling sites along the Jaú River (J1-J8).

Based on land use, main tributaries, point source pollution and access facilities, nine sampling points were established in the Jacaré-Guaçu River and eight in the Jaú River. The water sampling was carried out once each two months from March/95 to September/95. The following variables were analyzed: temperature (°C), pH, conductivity (μScm^{-1}) , dissolved oxygen (mg/L) and ionic water composition (mg/L): Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K) and Iron (Fe).

All statistic calculations were performed on mean values of variables measured. The primary multivariate description was obtained using cluster analysis and factor analysis. Subsequently it was carried out an analysis of variance (ANOVA). In the cluster analysis the Euclidean distance and the Unweighted Pair-Group Method Average (UPGMA) were utilized for group formation. In the factor analysis, the factors extraction was obtained by principal component analysis.

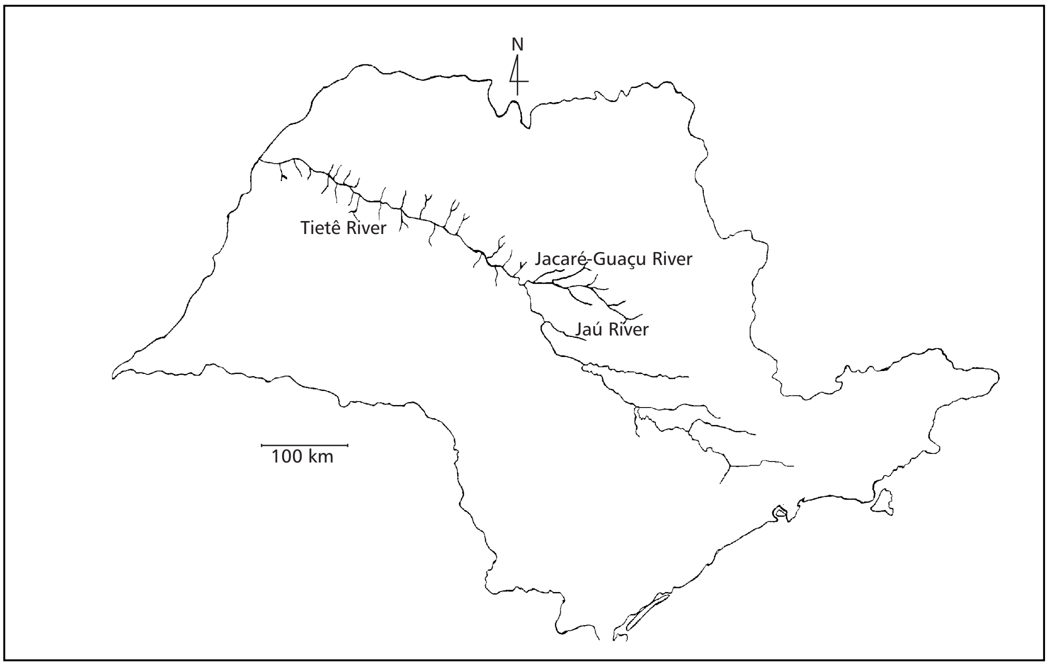

Fig. 3 — Location of Jacaré-Guaçu River and Jaú River in São Paulo State, Brazil.

RESULTS

Mean values of physical and chemical variables in each sampling points are showed in the Tables 1 and 2.

In Jaú River, higher values for pH, conductivity, Ca, Mg, Na, K and Fe were found. At sites J6 and J8 showed low values of dissolved oxygen were registered.

The Fig. 4 illustrate the cluster diagram results of mean values registered for the monthly study. According to cluster analysis, three main groups were distinguished: the first group containing headwater sites of the two rivers (J1, J2, JG1 and JG2); the second group containing all sites of Jacaré-Guaçu River (JG3 to JG9); the third group showed the remaining sites of Jaú River (J3 to J7). The site J8 of Jaú River appeared isolated.

In the factor analysis, the two factors explain 83,47% of the variance (Table 3). Conductivity, Ca, Mg, Na and K were the variables with the highest positive correlation with regard to the Factor 1 contrary to dissolved oxygen which is associated with the negative part of this axis. The Factor 2 did not indicate variables correlating significantly. The Factor 1 can be identified as the degree of ionic richness of the river waters.

The Fig. 5 showed site distribution along the factors. Similarly to what was found cluster diagram similar groups were obtained. The sampling points J3, J4, J5, J6, J7 and J8 of Jaú River were highly correlated with Factor 1, and namely, are sites that showed highest values of ionic content and lowest dissolved oxygen. The headwater sites of two rivers and other sites of Jacaré-Guaçu showed a ionic gradient in this factor.

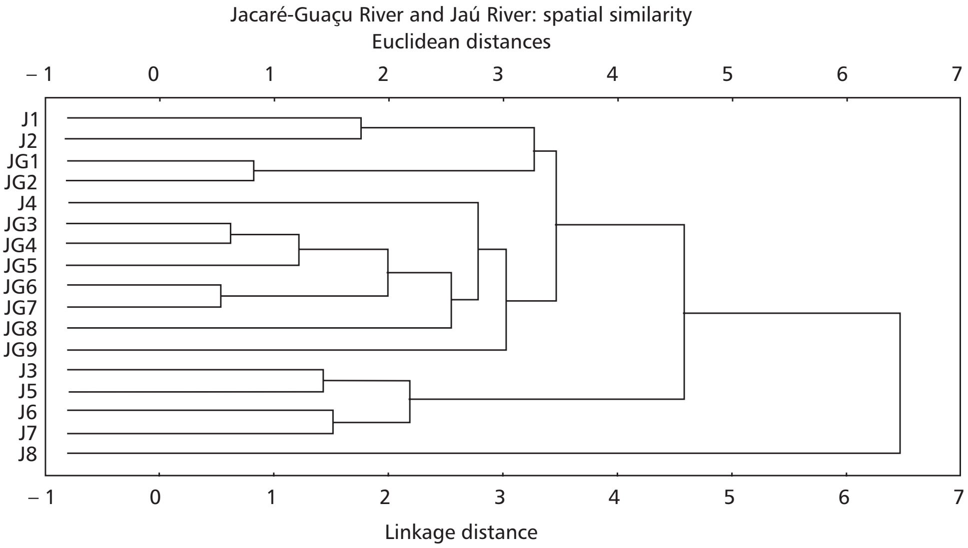

Fig. 4 — Cluster diagram of Jacaré-Guaçu River and Jaú River sites based on mean values of the variables measured.

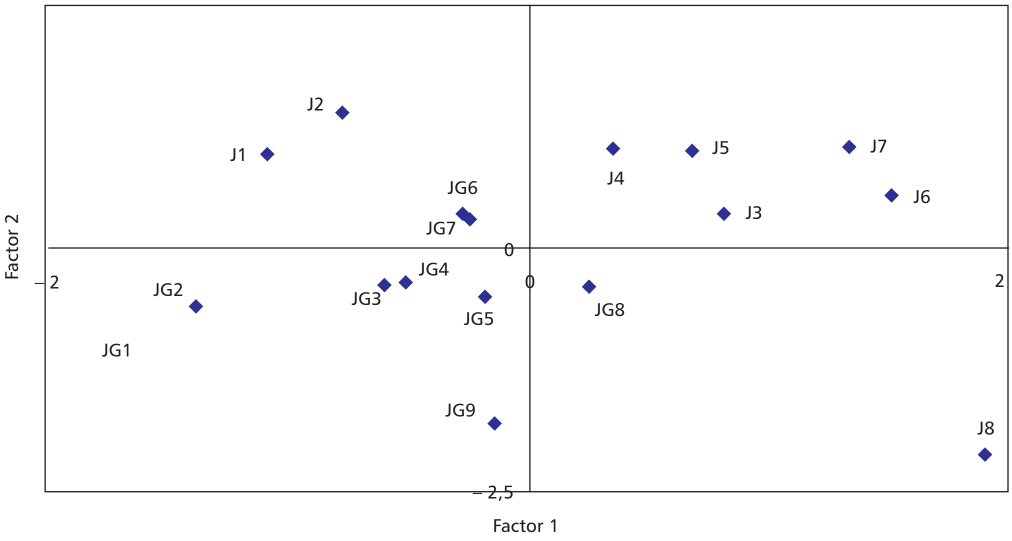

Fig. 5 — Ordination of sampling sites (factor scores) in the space according to the first two factors of the factor analysis carried out with mean values of the variables measured.

The analysis of variance (ANOVA) showed that the river basin was the main factor of difference, with the following variables Mg, Ca, conductivity, pH, K and Fe, being important was. When the time was the fixed factor, the number of variables decreased. In this case only temperature, Ca and pH were significant.

TABLE 1

Mean values of physical and chemical variables registrated in sampling sites of Jaú River.

	Temp. (°C)	**pH**	**Cond. (µS/cm)**	**OD (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**Na (mg/L)**	**K (mg/L)**	**Fe (mg/L)**
J1	18.50	6.55	34.00	8.28	3.73	1.55	1.38	1.08	2.70
J2	18.50	6.98	44.50	8.83	5.03	2.08	1.43	1.18	1.98
J3	21.43	6.60	75.50	5.48	7.93	3.38	2.05	2.20	3.75
J4	20.17	6.97	72.33	7.93	5.83	3.20	2.13	2.33	2.90
J5	20.10	6.65	72.25	6.12	6.85	3.48	2.48	2.30	4.30
J6	20.95	6.68	101.75	4.86	8.05	4.05	3.78	2.75	4.48
J7	20.60	6.88	93.25	6.15	8.00	4.13	4.83	2.30	4.58
J8	23.23	6.78	114.00	3.80	7.50	3.78	7.98	2.85	1.23

TABLE 2

Mean values of physical and chemical variables registrated in sampling sites of Jacaré-Guaçu River.

	Temp. (°C)	**pH**	**Cond. (µS/cm)**	**OD (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**Na (mg/L)**	**K (mg/L)**	**Fe (mg/L)**
JG1	20.28	5.80	21.00	8.45	1.85	1.10	1.03	1.10	1.90
JG2	20.18	6.05	25.50	8.29	2.20	1.15	1.45	1.18	1.90
JG3	19.88	6.23	51.00	7.47	3.90	1.65	3.03	1.60	2.28
JG4	22.40	6.70	50.00	5.47	4.50	2.10	2.10	1.60	2.80
JG5	20.23	6.35	54.25	5.64	4.40	1.88	3.00	1.83	2.63
JG6	20.80	6.63	52.50	8.81	4.63	1.95	2.85	1.88	3.08
JG7	20.88	6.73	52.75	8.37	4.65	1.98	2.60	1.88	2.78
JG8	22.60	6.60	55.00	6.15	5.13	2.23	2.63	1.97	3.60
JG9	22.33	5.95	49.25	5.37	4.50	2.03	2.38	2.10	1.93

TABLE 3

Factor analysis. Factor loadings of variables measured in Jacaré-Guaçu River and Jaú River.

Variables	**Factor 1**	**Factor 2**
Temperature	0.58	–0.68
pH	0.58	0.62
Conductivity	**0.98**	0.02
Dissolved Oxygen	**–0.79**	0.44
Calcium	**0.95**	0.26
Magnesium	**0.95**	0.23
Sodium	**0.78**	–0.38
Potassium	**0.95**	–0.12
Iron	0.50	0.62
Eigenvalues	5.82	1.69
% Total Variance	64.67	18.80

TABLE 4

Results of two-way ANOVA for variables measured in the Jacaré-Guaçu River and Jaú River.

Variables	**Fixed Effects**		
	River Basin	**Time**	**R. Basin/Time**
pH	31.23	6.13	2.25*
Temperature	0.41*	29.10	2.60*
Dissolved oxygen	3.98*	0.11*	3.05
Conductivity	32.93	0.84*	0.18*
Ca	44.74	6.40	3.24
Mg	70.61	1.62*	0.41*
Na	3.65*	1.16*	0.67*
K	9.04	1.98*	0.95*
Fe	6.21	0.71*	0.69*

* F values not significant at p-level < 5%.

DISCUSSION

The seasonal rain variation, as well as, the nature of soil surface and the river basin geochemistry influences strongly the water of streams. Thus there is considerable individuality even between rivers that are located in restrict regions. The variability became key word in all efforts to characterize streams, and is influenced by edafic factors, human activities and bed morphology (Maier, 1978).

The results of Tables 1 and 2 showed an ionic difference between the rivers. The Jaú River showed a high water ionic richness which reflects geological and lithological formation in the drainage basin. The Jacaré-Guacu River pass geological substrate very poor, and therefore its water had low pH, conductivity, and ionic concentration. This river showed less spatial variability and the ionic contents was relatively constant along its course, compared to the Jaú River, which spatial variability was more expressive.

Sabater *et al.* (1990) reported that the lithology of the basin, the soil type and the various categories of land use, seem to play a major role in the increase of salinity downstream, together with topographical characteristics. However, there is a tendency towards a stabilization of the chemical composition of the water from the source to the river mouth. This can be interpreted as an acquisition of chemical inertia by the water, which rises when the drained surface increases. That is, the water develops a growing resistance to experimenting sudden changes downstream.

This seems to be the case of Jacaré-Guaçu River, which relative constancy in ionic values perhaps reflects this resistance developed along its course.

Neto *et al.* (1993), found mineralogical differences in water of tributaries of the Manso-Cuiabá River, due geological and type soil differences in the watershed.

Whitfield (1983) reported that geological factors together with land use are most important as determinants of water quality.

The factors related with separation between water of Jacaré-Guaçu River and Jaú River also suggest the influence of impact degree on both rivers.

Nakane *et al.* (1981) registered a clear separation between concentration of Ca, Mg, K, and phosphorus in watersheds on different geological characteristics and human activities.

The Jaú River have point source pollution and showed few protection in its banks, thus the human activities existing (agriculture, urban pluvial water etc.) influence fast in its water composition.

In the principal course of Jacaré-Guaçu River there is not point source pollution and the geological aspects of its banks, which showed meanders, wetlands and high riparian forest protection, provides a less external influence and highest spatial stability in the elements of water.

Meybeck *et al.* (1989) reported that the concentration of elements in streams is highly variable in small catchments, contrary to great catchments which water quality showed great changes in smaller scales.

The cluster analysis and the factor analysis, indicated almost the same sampling sites ordination. The analysis registered the formation of groups related with land use characteristics and antropic impacts. The first group indicated similarity of sites located in headwaters, where pristine conditions predominates and there is few perturbation. The second group which showed all sampling sites of Jacaré-Guaçu River, represented a high stability with regard to variables measured. The last group with sites of Jaú River showed points influenced by point source pollution which caused an increase in ionic concentration and a decrease in dissolved oxygen of the water. The sampling point J8 was isolated due its localization near river mouth, in the Bariri Reservoir, thus strongly influenced by the effects of damming.

The ANOVA results confirmed that the river basin peculiarity had great influence in the separation of them. The characteristics of each system (geology, land use, impacts etc.) are preponderant its separation regarding the water quality of the rivers studied.

Therefore, this comparative study possibilited to observe that the two river basins showed differences in the water with regard to chemical composition. This separation was related with differences in geological formation, soils type, land use and impacts existing in river basins.

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