SYSTEMS & MANAGEMENT
Electronic magazine

EVALUATION OF THE TROPHIC STATE INDEX AND WATER QUALITY PARAMETERS IN THE RESERVOIR OF THE SÁ CARVALHO HYDROELECTRIC POWER PLANT, MINAS GERAIS, BRAZIL

Marluce Teixeira Andrade Queiroz
marluce.queiroz@bol.com.br
University Center East of Minas Gerais - Unileste, Ipatinga, Minas Gerais, Brazil

Carolina Andrade Queiroz
carolanq@yahoo.com.br
National Institute of Social Security - INSS, Ipatinga, Minas Gerais, Brazil

Felipe Andrade Queiroz
felipeandradeq@yahoo.com.br
University Center East of Minas Gerais - Unileste, Ipatinga, Minas Gerais, Brazil

Gildayne Figueiredo Benigno
gildayne_benigno@yahoo.com.br
University Center East of Minas Gerais - Unileste, Ipatinga, Minas Gerais, Brazil

ABSTRACT

The aim of this study was to evaluate the influence of soil use on the water quality of the reservoir of the Sá Carvalho Hydroelectric Plant (UHE-Sá Carvalho, acronym in Portuguese), Antônio Dias municipality, Piracicaba River Basin (BHRP, acronym in Portuguese), Minas Gerais, Brazil. Secondary data were obtained from the reports of the Environmental Research Laboratory of Companhia Energética de Minas Gerais (CEMIG), in the dry season (August) and rainy (November). In this context, points were selected for collecting water samples from the reservoir, which represented different conditions in relation to depth. Physicochemical parameters were measured: temperature, dissolved oxygen, electrical conductivity, pH, total nitrogen, total phosphorus, turbidity and total dissolved solids. The results showed seasonal variation, and the relevance of the contribution basin was detected. In addition, they showed significant differences in collection points closer to the top of the reservoir compared to those located at the bottom of the reservoir. The environmental variables showed significant oscillations, with turbidity varying between 88.6 NTU and 3.6 NTU in the rainy and dry seasons, respectively. The reservoir showed good conditions for dissolved oxygen contents during the entire sampling period. The minimum value was 7.6 mg/LO2 in the dry season and 4.4 mg/LO2 in the rainy season. This approach is concluded by suggesting intensification of conservation programs in the reservoir and the contribution basin.

Keywords: Hydroelectric reservoir; Water quality; Use of the soil; Mitigation.

PROPPI / LATEC
DOI: 10.20985/1980-5160.2019.v14n1.1363

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

1. INTRODUCTION

The aquatic bodies present a great variety in their uses. From this perspective, it is possible to highlight the generation of energy from the bus that allows the transformation of potential hydraulic energy into electric. It is an enterprise with a lower production of greenhouse gases compared to the use of fossil fuels. In addition, it has a higher level of safety when compared to nuclear power plants (Fearnside, 2015).

Hydropower reservoirs have other positive aspects, such as the regulation of river hydrology, minimizing the risks of floods and very low flows, and favoring the implementation of waterway corridors and irrigation projects. In addition, it identifies the multiple uses of water resources, such as sports and tourism (Figueirêdo *et al*., 2007).

In contrast, unfavorable aspects are also observed. Els (2014) informs that the environmental distortions related to the bus reach ecological and social dimensions from the moment of its installation in the water body. The researcher points out the negative aspects derived from the flooding of areas of native flora, arable land and historical and cultural heritage, as well as the displacement of populations. Nogueira *et al.* (2015) report that the cumulative effects of deforestation rebound on other ecosystems related to the water body. Silva et al. (2015), on the other hand, highlight the changes in the physical-chemical parameters of water; the elevation of toxic metal contents; and the increase of nutrient concentrations, with reflexes in any catchment basin.

The conditions regarding soil use and occupation also affect nitrogen and phosphorus concentrations in the lake of the hydroelectric dams, and may culminate with the trophic water body (Barros et Fearnside, 2015). These elements are macronutrient essences for aquatic phottrophs; however, when in excess, they can increase exponentially the populations of algae, bryophytes, pteridophytes and macrophytes (Jorcin *et al.,* 2009).

Eilers *et al*. (2011) reinforce that the biological phenomenon has been widely studied, allowing a science about its causes and consequences, although little is known about the critical concentrations of the nutrients that trigger the process. Environmental distortion, in general, culminates with the prevalence of cyanobacteria species to the detriment of other species. These organisms are endowed with mobility in environments with high turbidity and, therefore, can use nutrients present in deeper layers and then return to the euphotic zone (Güntzel *et al.,* 2012).

Several genera of these algae are endowed with the capacity to produce neurotoxins and/or hepatotoxins that affect human health, thus constituting obstacles for water treatment companies, especially when there is an occurrence of environmental conditions conducive to their proliferation in the aquatic environment (Roche *et al*., 2010). Among these conditions, it is widely accepted by microbiologists and limnologists who study the proliferation of the algae community, that nutrient load, water retention time, stratification and temperature are the main factors influencing the formation and intensity of blooms (Belli *et al*., 2014). For Fuentes et Petrucio (2015), the consequences of these problems include the probability of rapid death of phytoplankton, which also presents as an obstacle because it leads to the depletion of dissolved oxygen in the water column, triggering the death of fish and other aerobic organisms.

Güntzel *et al*. (2010) reinforce that the elevation of the hydrogen ion concentration $[H^+]$ contributes to the predominance of the reducing conditions, increasing the toxicity of many chemical elements that thus become more soluble, such as the toxic metals and the reduction of the capacity to recycle the organic matter, leading to accumulation of debris and sediment. Mitigation of impacts, preservation of water quality and maintenance of multiple uses of the reservoir depend on its proper management and the use of appropriate environmental management techniques (Coelho *et al*., 2011).

For the above, diagnoses were made regarding the water quality in the lake of the Sá Carvalho Hydroelectric Plant (UHE-Sá Carvalho) located in the middle section of the Piracicaba River Basin (BHRP) in Antônio Dias, Minas Gerais. It is worth noting that BHRP is characterized by intense economic exploitation (iron and steel, forest extraction, etc.) and high population density (Queiroz *et al*., 2015). The results of the physico-chemical parameters came from the reports pertaining to the calendar year 2014, produced through the certified laboratories of Companhia Energétida de Minas Gerais (CEMIG), meeting the highest standards of precision regarding its precision and accuracy.

2. THEORETICAL REFERENCE

2.1. Water classes

In Brazil, the Resolution of the National Environmental Council (CONAMA) No. 357/2005 establishes that the fresh waters are those with salinity ≤ 0.5%, a condition in which the BHRP falls. In addition, that legislation establishes quality classes for inland water. These are the set of water quality conditions and standards required to meet prevailing current or future uses. In compliance with these guidelines, the following classes are presented in Chart 1.

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

Chart 1. Classes of river water and destination

Class	Destination
Special	a) Supply for human consumption, with disinfection; b) Preservation of the natural balance of aquatic communities; c) The preservation of aquatic environments in integral protection conservation units.
1	a) Supply for human consumption after simplified treatment; b) Protection of aquatic communities; c) Recreation of primary contact, such as swimming, water skiing and diving, according to CONAMA No. 274/2000; d) The irrigation of vegetables that are consumed raw and of fruits that develop close to the ground and that are ingested raw without film removal; e) Protection of aquatic communities in Indigenous Lands.
2	a) Supply for human consumption after conventional treatment; b) Protection of aquatic communities; c) Recreation of primary contact, such as swimming, water skiing and diving, according to CONAMA Resolution No. 274/2000; d) Irrigation of vegetables, fruit trees and parks, gardens, sports and leisure fields, with which the public may come into direct contact; (e) Aquaculture and fishing activity.
3	a) Supply for human consumption after conventional or advanced treatment; b) Irrigation of tree, cereal and forage crops; c) Amateur fishing; d) Recreation of secondary contact; e) The watering of animals.
4	a) Navigation; b) The landscape harmony

Source: CONAMA, 2005a

2.2. Trophic state

To know the trophic degree in a hydroelectric reservoir, it is possible to calculate the Trophic State Index (TSI), which indicates the external inputs of nutrients from the launch of domestic sewage, industrial effluents and agricultural residues. In addition, trophic conditions are also influenced by specific characteristics of the reservoir, such as retention time, flow rate and hydrological regime. The investigation of the environmental conditions is important, as it supports the environmental planning that aims at the control of eutrophication and use of the water body (Fernandes *et al.,* 2017).

The measurement of the TSI makes it possible to classify the reservoir in different degrees of trophic, that is, it evaluates the water quality for nutrient enrichment and its effects, among them the excessive growth of algae and macrophytes (CETESB, 2009).

Von Sperling (1996) reports that the TSI by Carlson (1977) allows the limnological evaluation, indicating with good approximation the level of nutritional enrichment of the water body by incorporating three indicators: water transparency, chlorophyll a and total phosphorus concentration. The evaluation of this indicator allows establishing connections with other criteria, such as dissolved oxygen, biomass and composition and concentration of phytoplankton and zooplankton.

Considering the four variables cited for the calculation of the TSI of Toledo et al. (1990) - chlorophyll a, total phosphorus, orthophosphate and water transparency - currently only two apply in the calculation of Lamparelli (2004), chlorophyll a and total phosphorus. This is because the values of transparency can often not be representative for the trophic state, since it can be affected by the high turbidity due to suspended mineral material and not only by the density of planktonic organisms (Jorcin *et al.*, 2009).

2.2.1. Trophic Status Index

In this study, the applied indices were: the one proposed by Carlson (1977), having been modified by Toledo et al. (1983) and Toledo (1990), which considers water transparency measurements by means of the Secchi disk (m), the total phosphorus concentration ($\mu g.L^{-1}$), the orthophosphate concentration ($\mu g.L^{-1}$) and the concentration of chlorophyll a ($\mu g.L^{-1}$); and the Lamparelli index (2004), which considers only chlorophyll a ($\mu g.L^{-1}$) and total phosphorus ($\mu g .L^{-1}$), as proposed by CETESB (2009). High values related to these variables contribute to the excessive growth of adhered aquatic macrophytes that can interfere in the navigation, aeration and transport capacity by the channel. Thus, these indicators allow the classification of aquatic bodies in different degrees of trophic, that is, they allow evaluating the quality of the water in terms of nutrient enrichment and its effect related to the excessive growth of algae, or the potential for the proliferation of these photosynthetic organisms (Cotovicz *et al.,* 2017).

The TSI was obtained from Equation 1 (Carlson, 1977; Lamparellli, 2004):

$$TSIP_{Total} = 10x[6-[(0,42-0,36. (lnP_{total}) /ln2)] \text{ (Equation 1)}$$

Thus being: P_{total} = concentration of total phosphorus on the water surface.

In addition, the Chlorophyll-a Trophic State Index (TSI--Cla) was measured, as presented in Equation 2 (Carlson, 1977, Lamparellli, 2004):

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

TSI (Cla) = 10x [6-((-0,7-0,6x(lnCla))/ln 2)]-20 (Equation 2)

Thus being: Cla = concentration of chlorophyll-a on the water surface.

It should be emphasized that the results relevant to phosphorus ($TSIP_{Total}$) should be understood as a measure of the eutrophication potential, considering that the nutrient presents itself as a trigger of the biochemical phenomenon. On the other hand, the measurement of the TSI--Cla, in turn, probabilistically measures the response of the water body to the proliferation of algae in the localities of this study belonging to the UHE-Sá Carvalho reservoir.

In addition, according to the guidelines of the environmental agencies, the simple averages corresponding to the weighting (TSI) were obtained, given the concentrations of total phosphorus and chlorophyll a used in the calculation of $TSIP_{Total}$ and TSI-Cla, for all samplings performed, as shown in Equation 3 (Carlson, 1977, Lamparellli, 2004):

TSI = [$TSIP_{Total}$ + TSI-Cla] ÷ 2 (Equation 3)

These indicators made possible the classification of the aquatic body into six different trophic categories (CETESB, 2011): ultra-oligotrophic, oligotrophic, mesotrophic, eutrophic, super-eutrophic and hypereutrophic (Table 1). Coelho *et al.* (2011) emphasize the importance of diagnosing the aquatic body indicating the potential extent of anthropogenic sources capable of unbalancing the environment in the long term, leading to adverse reactions to the biotic components belonging to that habitat.

Thus, when the information was available, with consistent data of total phosphorus and chlorophyll-a, the mean of the two indexes was adopted, satisfactorily encompassing the cause and effect of the process (Tundisi *et al.,* 2015).

In addition, the TSI of the UHE-Sá Carvalho reservoir was related to other physico-chemical parameters (pH, electrical conductivity, etc.), making possible the relevant diagnosis to the externalities with repercussions for the environmental safety of the BHRP.

3. METHODOLOGY

3.1. Study area

The selection of the UHE-Sá Carvalho reservoir for the development of this study is justified by its location, and is influenced by urban and agropastoral areas, making it possible to exemplify the anthropic contribution in the hydric pollution of hydroelectric reservoirs, which is related to the entry of nutrients into the aquatic bodies. This project integrates planning pertinent to the development of the regional energy system, affecting and carrying the hydrological cycle of the BHRP. Rodrigues *et al.* (2013) point out the various socioeconomic repercussions that affect the regions related to hydroelectric dams.

The length of the dam UHE-Sá Carvalho reaches, in Antônio Dias and Severo, 112m and 34m, in this order, while the maximum height is quite similar in the two locations: 15m and 14m. The reservoir volume corresponds to only 1,38hm³ (Antônio Dias), four generating units and installed capacity of 78MW, making UHE-Sá Carvalho one of the largest in the region of BHRD-MG (CEMIG, 2014).

The construction of the hydroelectric plant affected the forest formation of the region, the Atlantic Forest, vegetation cover that has been the target of megassiviculture, with deforestation rate of 457 Km2/year; the remaining vegetation corresponds to about 22.25% (Schäffer et Prochnow, 2002).

Machado et al. (2014) reinforce that deforestation is a preponderant coadjuvant factor in relation to the synergic and cumulative effects from the hydroelectric use. The depth of the UHE-Sá Carvalho reservoir was affected due to the mean flow rate and sediment volume retained. The

Table 1. Classification of trophic status for reservoirs according to Lamparelli (2004)

Trophic State	TSI	Weighting	Secchi-S (m)	TSI-PTotal (mg.m-3)	TSI-Cla (mg.m-3)
Ultraoligotrophic	IET£47	0,5	S ≥2,4	PTotal≤8	Cla ≤ 1,17
Oligotrophic	47<IET£52	1	2,4>S≥1,7	8<PTotal≤19	1,17<Cla≤ 3,24
Mesotrophic	52< IET ≤59	2	1,7>S≥1,1	19<PTotal≤52	3,24<Cla≤11,03
Eutrophic	59< IET ≤63	3	1,1>S≥0,8	52<PTotal≤120	11,03<Cla≤30,55
Supereutrophic	63< IET ≤67	4	0,8>S≥0,6	120<PTotal≤233	30,55<Cla≤69,05
Hypereutrophic	IET>67	5	0,6>S	233<PTotal	69,05<Cla

Source: CETESB, 2011.

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

increase in the sediment drag originates from the precariousness of the conservation practices pertinent to the soil. It is worth mentioning that the National Institute for Space Research (INPE, 2015, acronym in Portuguese) reports that the State of Minas Gerais presents itself as the federal unit with a high prevalence of accidental burnings. In addition, cultivation techniques still make use of fires, especially among producers with lower purchasing power. Coivara eliminates essential nutrients for plants, such as phosphorus, nitrogen and potassium, contributing to soil depletion and extermination of large native areas. It should be noted that agriculture currently has a share of the national economy of 26.5%, placing the country in a position evidenced as an exporter at the level of global reality (Catela et Gonçalves, 2013).

Table 2. Characteristics of the UHE-Sá Carvalho reservoir

Technical Parameters	Antônio Dias	Severo
Maximum level of the top of the gate	373,03m	370,5m
Normal maximum level	372,93m	369,50m
Minimum Operating Level	371,43m	366,00m
Quota threshold of the gate	375m	371,35m
Reservation volume at the maximum level	1,80hm3	0,098 hm³
Reservation volume at normal level	1,73hm3	0,0793 hm³
Minimum Operating Volume	0,77hm3	0,0326 hm³
Operating volume	0,96hm3	0,0467 hm³
Dead volume	0,7hm³	0,0326hm³

Source: CEMIG, 2014.

The energy efficiency of the UHE-Sá Carvalho is around 95%, and is dependent on the series of natural flows and the average long-term flow rate related to the pluviometric indexes in the region (CEMIG, 2014). The main characteristics of the reservoir are shown in Table 2.

3.2 Sampling and analytical procedures

For the physico-chemical parameters, the sampling techniques, the preservation, and the analyzes used in this study, it was taken into account the CEMIG Manual of Procedures for Collection and Methodologies for Water Analysis (2014) and the Standard Methods of the Examination of Water and Wastewater (Rice *et al.*, 2012). The marginal samplings were carried out on the surface of the water body, collected at 20cm from the water depth. Samples from the interior of the reservoir were obtained by a transversal profile of three distinct depths: surface (S), half of the trophic zone (ZF), and bottom (F) (CEMIG, 2014).

The monitoring carried out by CEMIG's specialized technicians took place in 13 distinct points, ten of them located in Rio Piracicaba, MG, in campaigns carried out in the dry season (August) and in the rainy season (November) of 2014, allowing the monitoring of physical and chemical indicators in different depths (Table 3).

The parameters ambient temperature, water temperature, dissolved oxygen, electrical conductivity, turbidity (T_{NTU}), and pH were measured in loco, by means of multiparameter probe, with ten replicates at each point. For the evaluation of the other indicators (total phosphorus, total nitrogen, etc.), there were also ten samplings in each

Table 3. Water quality monitoring stations in the UHE-Sá Carvalho reservoir

Station	Description	Water course*	Coordinates
SC-LI 01S	Start of the amount of Antônio Dias reservoir, located in an urban area, close to the central city bridge	Rio Piracicaba**	19º39'48.60"S 42º52'46.00"O
SC-LI 02S SC-LI 02ZF SC-LI 02F	Antônio Dias Reservoir about 500m from the bus located in urban area	Rio Piracicaba**	19º38'39.70"S 42º50'59.30"O
SC-LI 03S SC-LI 03ZF SC-LI03F	Severo Reservoir about 300m from the bus	Ribeirão Severo**	19º38'15.40"S 49º22'60"O
SC-LI 04S SC-LI 04ZF SC-LI 04F	Reduced flow rate upstream of the powerhouse	Rio Piracicaba**	19º38'11.30"S 48º18'60"O
SC-LI 05S SC-LI 05ZF SC-LI 05F	Downstream of the powerhouse	Rio Piracicaba**	19º38'2.20"S 42º48'19.80"O

Source: CEMIG, 2014.
* The Piracicaba River Basin (BHRP, acronym in Portuguese), Minas Gerais, Brazil
** Lotic watercourse

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

of the monitoring stations of the reservoir. The samples were stored in sterilized containers and Styrofoam boxes containing ice in order to guarantee their integrity during the conditioning period until the tests were carried out in the accredited laboratory, with the average temperature of 4°C being respected, according to technical parameters (CEMIG, 2014).

3.3 Parameters of interpretation of results

The interpretation of physicochemical and biological results pertinent to the water quality and trophic condition of the UHE-Sá Carvalho reservoir was carried out considering the current federal and state laws, CONAMA Resolution No. 357/2005 and COPAM/CERH Normative Resolution No. 01/2008 for Class 2 freshwater rivers. It is worth mentioning that BHRP received this framework according to the updates outlined in the framework report of the National Water Agency (ANA, acronym in Portuguese); In this way, the body of water can be used for the supply for human consumption, after conventional treatment, protection of aquatic communities, irrigation of vegetables, aquaculture and fishing activity (CEMIG, 2014).

4. RESULTS AND DISCUSSION

4.1. Rainfall precipitation and reservoir level

The monitoring of the physical-chemical conditions in the UHE-Sá Carvalho reservoir occurred during drought (August/2014) and rainy season (November/2014), showing different values for the lake level (Table 4) with repercussions on the TSI. Queiroz et al. (2016) report that the regulation of the lake in hydroelectric reservoirs occurs through the opening of the floodgates to contain the floods; therefore, no variations greater than 1% are identified and the conditions for normal operation of the hydroelectric project are preserved, guaranteeing the normal supply for system users. This condition was also identified in this study.

Table 4. Sampling period and lake level in the UHE-Sá Carvalho reservoir.

Period	Pluviometry (mm)	Lake level (m)1	Lake level (m)2
August/2014	175	372,15	366,87
November/2014	208	372,98	368,79

Source: CEMIG, 2015
[1]Dam on the Piracicaba River, in Antônio Dias
[2]Dam in Severo riverside, in Antônio Dias

4.2. Index of Trophic State and physical-chemical parameters of the water of the UHE-Sá Carvalho reservoir

The evaluation of the UHE-Sá Carvalho reservoir in the light of the Carlson TSI (1977), modified by Toledo et al. (1983), indicated an oligotrophic condition with a minimum value corresponding to 47.8 in SC-LI01-S and maximum of 65.7 in SC-LI05-S in the rainy season (Figure 1). In the dry season (August), the results were smaller, explaining the importance of the contribution basin with intensification as to the nutrient drag in periods with high rainfall (Bateni *et al.*, 2013).

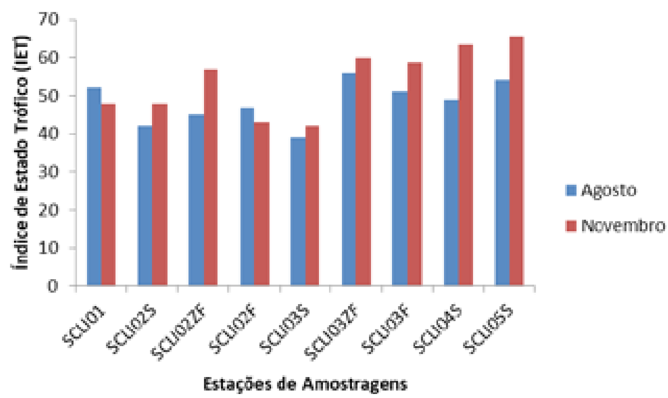

Figure 1. Index of Trophic State in the sampling stations of the UHE-Sá Carvalho reservoir

Vertical axis: Trophic State Index (TSI); Horizontal axis: Sampling Stations; Legend: August; November

The trophic condition of the UHE-Sá Carvalho reservoir, that is, the nutrient load detected was impaired through the decomposition of the vegetal material after the filling of the reservoir. From the stabilization of the system, this condition came to occupy a secondary position. For the consolidated system, the contribution of each taxpayer becomes even more outstanding. It is a body of water that receives uninterrupted influence from the formation basin and soil occupation (agriculture, industry, population density, margin conservation, and rainfall), adding values to its physical-chemical parameters and, thus, affecting the surface and groundwater quality (Els, 2014).

Sperling (2009) reports that eutrophication depends on the relationship between nitrogen and phosphorus acting as limiting. The researcher reports that if the N:P ratio is considerably higher than 16, there is an indication that phosphorus is the limiting nutrient. In the same way, it can be considered that if the N:P ratio is considerably lower than 16, the nitrogen will be the limiting nutrient. In this study, it was found that in the dry season, in all sampling stations, phosphorus behaved as the limiting nutrient; while in the rainy season, nitrogen behaved as

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

a limiting nutrient in SC-LI01, SC-LI02ZF, SC-LI04S and SC--LI05S (Table 5).

Table 5. Relationship between nitrogen and phosphorus (N: P) in the monitoring stations of the UHE-Sá Carvalho reservoir during dry and rainy periods

Sample station	Relation N:P (August/2014)	Relation N:P (November/2014)
SC-LI01	28,67	8,57
SC-LI02S	50,0	17,5
SC-LI02ZF	NA*	2,67
SC-LI02F	130	35
SC-LI03S	NA*	20
SC-LI03ZF	NA*	55
SC-LI03F	40	23,33
SC-LI04S	20	2,5
SC-LI05S	45	11,67

* NA - Not Applied

The detection of nitrogen as a limiting nutrient in the rainy season explained the relationship between the effect of surface runoff and sediment load from agricultural areas and inadequately disposed solid waste near the borders of the BHRP. It was also identified that hypsometry (Figure 2) and the discharge of untreated domestic sewage directly into the Piracicaba River by diffuse sources also allowed the elevation of total nitrogen contents in the reservoir waters. Sperling (2009) and Sperling et al. (2008) state that, in general, the contribution through sewage is much higher than that generated by urban drainage.

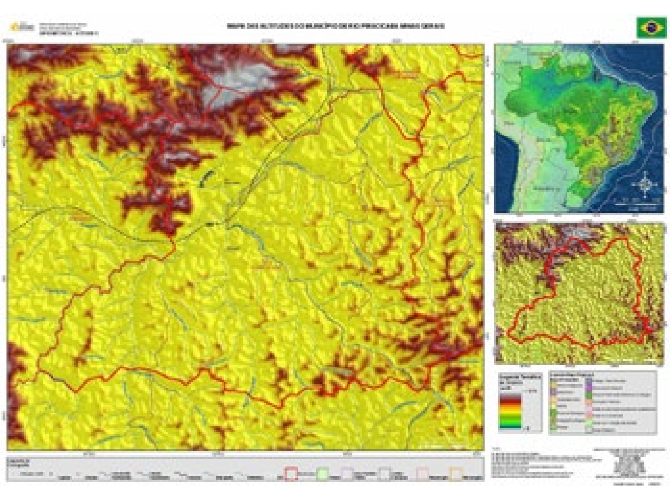

Figure 2. Hypsometry of BHRP

Source: IGAM, 2015.

The results showed that the total nitrogen load reached the peak value of 0.07mgN/L in SCLI01 in the rainy season, while in the dry season it was only 0.03mgN/L in SCLI01 and SCLI03F (Figure 3). Machado et al. (2015) reinforce the interference of rainfall in the increment of this nutrient in function of several mechanisms, such as the biofixation performed by bacteria and cyanobacteria present in the water bodies, which incorporate the atmospheric nitrogen in their tissues, contributing to the presence of organic nitrogen in the waters; the chemical fixation, a reaction that depends on the presence of light, also entails the presence of ammonia and nitrates in the waters, since the rain transports these substances, as well as the drag of the particles containing organic nitrogen to the water bodies.

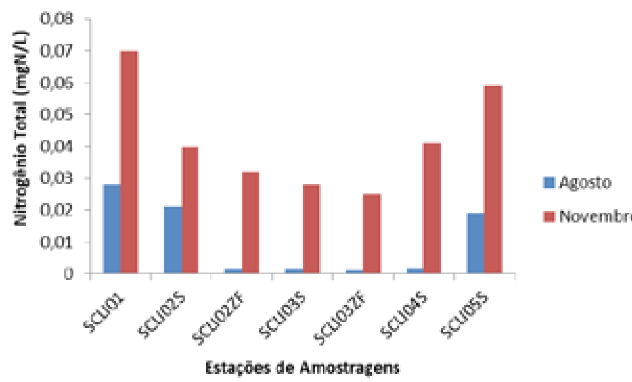

Figure 3. Total nitrogen content at collection points at UHE-Sá Carvalho reservoir

Vertical axis: Total Nitrogen; Horizontal axis: Sampling Stations; Legend: August; November

Sperling (2009) and Sperling *et al.* (2008) report that nitrogen and phosphorus are found in feces and urine, in food waste, detergents, and in other by-products of human activities. The detection of phosphorus as a limiting nutrient in the dry season has adverse repercussions that include the decrease of water transparency, episodes of algae outflows, increased turbidity during the dry season and the incidence of unpleasant odors. In accordance with CONAMA Resolution No. 357/2005, for Class 2 waters, the maximum permitted values (VMP) of total phosphorus (P_{total}) corresponds to 0.03 mg.L-1 in lentic environments and 0.05 mg.L- in intermediate environments with residence time between 2 and 40 days and direct tributaries of lentic environment. Therefore, analyzing this environmental parameter for the reservoir, the VMP corresponding to 0.05 mgP.L- was considered. In this sense, values were extrapolated to VMP in the rainy season in SC-LI01 and SC-LI05S (Figure 4).

In this study the access of cattle was detected around the reservoir, which explains the relevance of the evaluation of the contamination of water with microorganisms existing in excretions from these animals. Fregonesi et al. (2006) point out that, among these microorganisms, only Escherichia coli is exclusively fecal in origin, and is always present in high densities in the feces of humans, mammals and birds and rarely found in water or soil that has not re-

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

ceived this type of contamination. Thus, fecal coliforms are used as a standard for the microbiological quality of surface water intended for supply, recreation, irrigation and fish farming (CETESB, 2009). In addition, the authors reinforce the exacerbation of the risk associated with the possibility of the presence of pathogenic microorganisms.

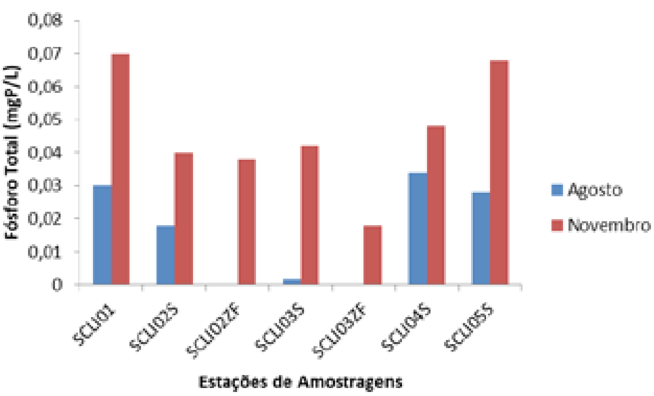

Figure 4. Total phosphorus at the collection points of the UHE-Sá Carvalho reservoir

Vertical axis: Total Phosphorus; Horizontal axis: Sampling Stations; Legend: August; November

The findings of this study showed the elevation of thermotolerant coliform content in the rainy season, showing a relation with the contribution of contamination from the BHRP (Figure 5). The results obtained for the points SCLI-04S (Piracicaba river) and SC-LI05S (Piracicaba river), which presented the highest values, showing the contributions of sanitary evictions and manure (livestock) from the basin of tributary contribution of the reservoir, should be highlighted.

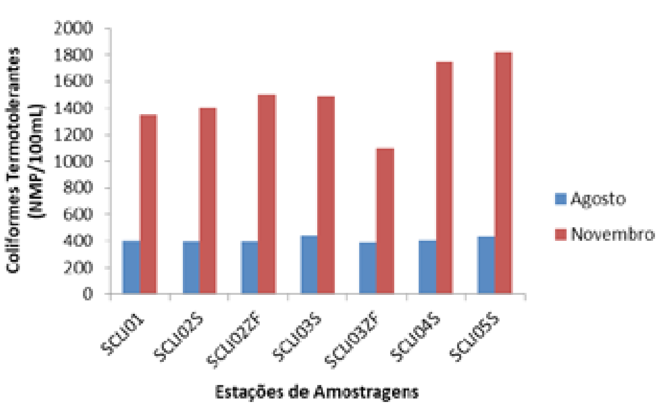

Figure 5. Thermotolerant coliforms at the collection points of UHE-Sá Carvalho reservoir

Vertical axis: Thermotolerant Coliform; Horizontal axis: Sampling Stations; Legend: August; November

It was verified, as a favorable point in the UHE-Sá Carvalho reservoir, that turbidity values were much lower than the limit of 100NTU (Figure 6), according to CONAMA 357/2005. However, the elevation detected in the rainy season in SC-LI04S, corresponding to 89.6NTU, probably associated to the bottom sediments that are revolved and/or carried from the banks (Amaral *et al.*, 2008).

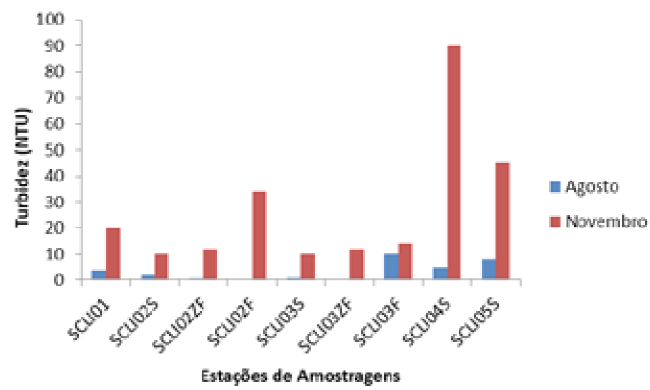

Figure 6. Turbidity at the collection points of the UHE-Sá Carvalho reservoir

Vertical axis: Turbidity (NTU); Horizontal axis: Sampling Stations; Legend: August; November

The BHRP is the main external source of material carried to the reservoir, playing a controlling role in both the rise and decrease of total dissolved solids (STD, acronym in Portuguese). Figure 7 shows that in the reservoir the highest result was detected in SC-LI03S in the dry season (67mg/L), all of which were well below the limit established by CONAMA Resolution 357/2005, which is 500mg/L. Said sampling point is located in one of the dendritic and protected arms of the bus, characterized by low hydrodynamic and high residence time (CEMIG, 2014).

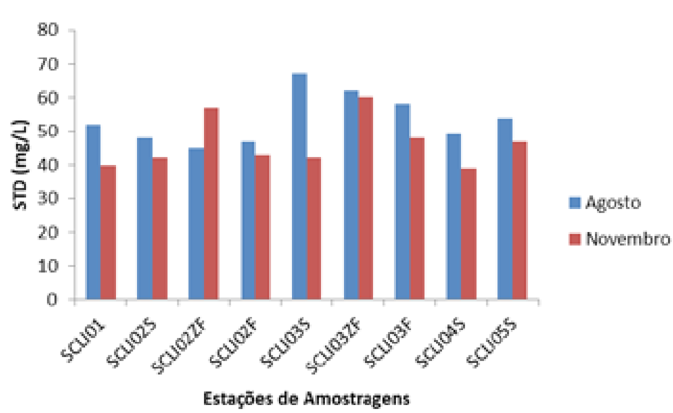

Figure 7. Total dissolved solids (TDS) at the collection points of the UHE-Sá Carvalho reservoir

Vertical axis: TDS; Horizontal axis: Sampling Stations; Legend: August; November

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

Another aspect analyzed was the charge of the anionic surfactants detected in wastewater containing saponacea. CONAMA Resolution 357/2005 establishes the VMP of 0.50 mg/L LAS for tensioactive substances that react with methylene blue. In this study, the maximum value of 0.29 mg/L LAS was identified in the dry season. Such a condition demands vigilance. The surfactants interfere in the aeration rates, by reducing the surface tension of the medium, decreasing the residence time of the air bubbles in the aquatic environment. In this sense, it is important to intensify the actions related to the control of dispersion of detergents in the aquatic environment. Thus, the control measures should be directed to reduce the phosphate concentration in the formulations of those products, with the main purpose of minimizing the trophic condition of rivers, lakes and waterways (Quevedo et Paganini, 2011).

The transparency (Secchi disc) corresponded to 3.0m in SC-LI03S in the dry season. It is a point that makes explicit the need to improve conservation measures in the reservoir. The increase in the thickness of the algal layer may prevent the entry of light into the water and consequently prevent photosynthesis by the organisms present in the deeper layers, thus causing algae death, the proliferation of decomposing bacteria and the increase of oxygen consumption by these organisms. Such conditions may account for the reduction of the dissolved oxygen content, leading to the mortality of fish and other aerobic organisms. However, the analysis of the data showed that the reservoir presents good conditions related to this question.

In this study, it was verified that the UHE-Sá Carvalho reservoir presents dissolved oxygen contents higher than 5mg/L, both in the rainy season and in the dry season, except SC-LI05, which had a value of 4.4mg/L in November 2014 (Figure 8).

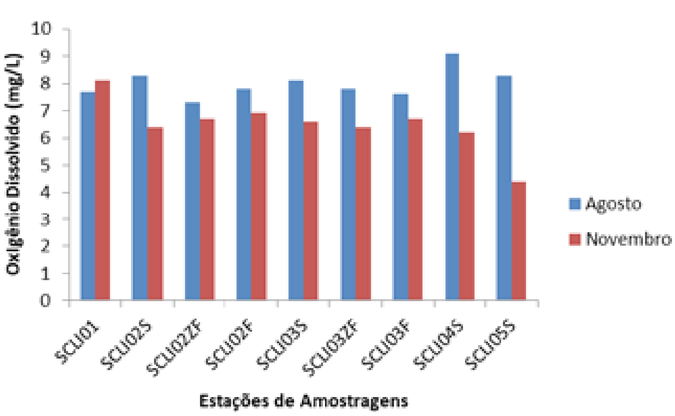

Figure 8. Dissolved Oxygen (DO) in the UHE-Sá Carvalho reservoir.

Vertical axis: Dissolved Oxygen (mg/L); Horizontal axis: Sampling Stations; Legend: August; November

Another physical characteristic of the water affected by the occurrence of blooms is the pH, as can be observed in Figure 9. Throughout the monitoring, higher pH values were observed when there were also occurrences of blooms in one or more sampling stations. These results are in agreement with those presented by studies carried out in hydroelectric reservoirs. Azevedo (2003), Chorus et Bartram (1999), Bouvy et al. (2000) and Molica et al. (2005) reported that pH, neutral or alkaline, at temperatures above 20º C are factors that benefit the occurrence of flowering in aquatic ecosystems.

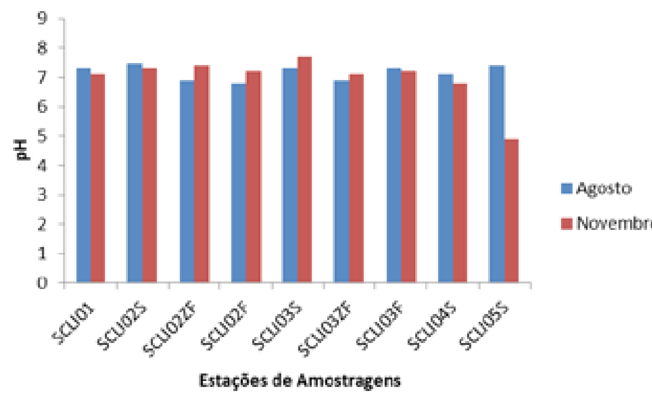

Figure 9. pH in the UHE-Sá Carvalho reservoir.

Vertical axis: pH; Horizontal axis: Sampling Stations; Legend: August; November

4.3. Management practices in the UHE-Sá Carvalho reservoir

The UHE-Sá Carvalho reservoir fulfills the objective of contributing to the energy demand in the Vale do Aço region, Minas Gerais, Brazil. However, it requires investments to improve environmental management in its area of comprehensiveness.

In the period of this study, algal blooms and oxygen depletion were observed in the central part of the water at the bottom of the lake, which requires the reduction of nutrient supply. Lima et al. (2017) report that mitigation actions include the use of mechanical, chemical, and/or biological processes. In addition, they point out the importance of practices capable of promoting aeration of hypolimnion, denitrification and removal of deep water and macrophytes and algae - mechanical processes capable of revitalizing the reservoir and improving water quality.

Fonseca et al. (2016) reinforce that the management of the reservoir with the use of chemical and biological processes can be effective and positively affect the entire catchment basin. As appropriate mitigating strategies, researchers indicate the use of algicides, precipitation of

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

nutrients and the use of herbivorous fish, cyanophages and biomanipulation (a combination of living organisms, commonly fish that can act directly in the food chain). Another important action is to carry out studies on the reproductive behavior and biology of migratory fish species in the dam, which support the design of reservoir repopulation strategies (Ritter *et al.*, 2017).

5. FINAL CONSIDERATIONS

The analysis of the collected data indicated that the waters of the UHE-Sá Carvalho reservoirs presented results according to the limits established by CONAMA Resolution 357/2005 and COPAM/CERH 01/2008 for Class 2 waters. The measurement of the TSI indicated the oligotrophic conditions: lakes with good transparency and productivity.

The sample stations had adequate concentrations of dissolved oxygen, the values being very close to the saturation concentrations of the aquatic environments. These conditions explain adequate balance, which favors the development of aquatic communities. Favorable conditions were also identified in relation to the oxygen dynamics, usually saturated, in the upper and lower layers, low presence of macrophytes, and low level of impact to multiple uses.

The results concerning the presence of solids and turbidity in the aquatic body showed low significance regarding the BHRP. The low concentrations related to STDs in all the sampling stations are highlighted, making explicit the good environmental conditions of the reservoir. In short, there was no greater risk of water use due to changes in quality, in view of the adequacy of compliance with CONAMA Resolution 357/2005 in the study period.

To conclude, the relevance of this diagnosis for environmental planning and the observation that it is necessary to increase the number of samples, including the periods of intermediate pluviometric precipitation (low rainfall), and the same collection frequencies and the same periods should be used for conducting new work. In addition, the importance of practices that aim at the conservation of the water quality of the UHE-Sá Carvalho reservoir and the preservation of the native vegetation are ratified.

REFERENCES

Amaral, A. L.; Ginoris, Y. P.; Nicolau, A.; Coelho, M. A. Z.; Ferreira, E. C. (2008), Stalked protozoa identification by image analysis and multivariable statistical techniques. Analytical and Bioanalytical Chemistry, Vol. 391, pp. 1321-1325.

Azevedo, M.F.O. (2003), Limnological features in tapacurá reservoir (northeast Brazil) during a severe drought. Hydrobiologia, Vol. 493, No 1-3, pp. 115-130.

Barros, H.S.; Fearnside, P. M. (2015), Pedo-transfer functions for estimating soil bulk density in central Amazonia. Revista Brasileira de Ciência do Solo, Vol. 39, No. 2, pp. 397-407, 2015.

Bateni, F.; Fakheran, S.; Soffianian, A. (2013), Assessment of land cover changes & water quality changes in the Zayandehroud River Basin between 1997-2008. Environmental Monitoring Assessment, Vol. 185, No. 12, pp. 10511-10519.

Belli, T. J.; Coral, L. A.; Recio, M. A. L.; Vidal, C. M. S.; Lapolli, F. R. (2014), Total nitrogen removal in membrane sequencing batch bioreactor treating domestic wastewater. Acta Scientiarum Technology, Vol. 36, No. 2, pp. 221-227.

Bouvy, M.; Falcão, D.; Marinho, M.; Pagano M.; Moura, A. (2000), Occurrence of Cylindrospermopsis (Cyanobacteria) in 39 Brazilian tropical reservoirs during the 1998 drought. Aquatic Microbial Ecology, Vol. 23, pp. 13-27.

Braga, B.; Porto, M.; Tucci, C. E. M. (2006), Monitoramento de quantidade e qualidade das águas. In: Rebouças, A. C.; Braga, B.; Tundisi, J. G. Águas doces no Brasil: Capital ecológico, uso e conservação. 3. ed. São Paulo: Escrituras, pp. 145-160.

Branco, S. M. (1986), Hidrobiologia aplicada à engenharia sanitária. 3a ed. CETESB/ASCETESB, São Paulo.

Carlson, R. E. (1977), A trophic state index for lakes. Limnology Oceanography, Vol. 22, No. 2, pp. 361-369.

Catela, E. Y. S.; Gonçalves, F. (2013), Comércio Internacional e dinâmica da performance das firmas brasileiras. Revista Economia, Vol. 14, No. 1, pp. 429-452.

CEMIG - Companhia Energética de Minas Gerais (2014), Relatório Final de Monitoramento da Qualidade da Água – UHE Sá Carvalho, CEMIG, Minas Gerais.

CETESB - Companhia Ambiental do Estado de São Paulo (2009), Significado ambiental e sanitário das variáveis de qualidade das águas e dos sedimentos e metodologias analíticas e de amostragem. Apêndice A. Série Relatórios. Qualidade das águas interiores no estado de São Paulo, CETESB, São Paulo.

CETESB - Companhia Ambiental do Estado de São Paulo (2011), IAP – Índice de Qualidade das Águas Brutas para fins de Abastecimento Público. Relatório técnico, Companhia Ambiental do Estado de São Paulo, São Paulo.

Chorus, I.; Bartram, J. (1999), Toxic cyanobacteria in water: a guide to their public health consequences, monitoring and management, World Health Organization, Geneva.

Coelho, L.S.; Roche, K. F.; Paranhos Filho, A.C.; Lemos, V. B. (2011), Uso do sensor CBERS/CCD na avaliação do estado trófico do reservatório Lago do Amor (Campo Grande, MS). Revista Brasileira de Cartografia, Vol. 63, pp. 221-232.

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

Comitê da Bacia Hidrográfica do Rio Doce - CBH-DOCE (2015), Comitê da Bacia Hidrográfica do Rio Doce, Agência Nacional das Águas.

Conselho Nacional do Meio Ambiente (2005a), Resolução CONAMA n° 357, de 17 de março de 2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. Diário Oficial da República Federativa do Brasil, Brasília.

Conselho Nacional do Meio Ambiente (2005b), Resolução CONAMA n° 359, de 29 de abril de 2005. Dispõe sobre a regulamentação do teor de fósforo em detergentes em pó para uso em todo o território nacional e dá outras providências. Diário Oficial da República Federativa do Brasil, Brasília.

Cotovicz, L. C.; Knoppers, B. A.; Brandini, N.et al. (2017), Predominance of phytoplankton-derived dissolved and particulate organic carbon in a highly eutrophic tropical coastal embayment (Guanabara Bay, Rio de Janeiro, Brazil). Biogeochemistry, Vol. 137, No. 1-2, pp. 1-14.

Deliberação Normativa Conjunta COPAM/CERH-MG N.º 1, de 05 de maio de 2008. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. Diário Executivo, Belo Horizonte, 2008.

Eilers, V.; Oliveira, M. D.; Roche, K. F. (2011), Density and body size of the larval stages of the invasive golden mussel (Limnoperna fortunei) in two neotropical rivers. Acta Limnologica Brasiliensia, Vol. 23, pp. 1-10.

Els, R. H. V. (2014), Wetenschap over de grens. Academic Journal of Suriname, Vol. 5, pp. 461-463.

Fearnside, P. M. (2015), Emissions from tropical hydropower and the IPCC. Environmental Science & Policy, Vol. 50, pp. 225-239.

Fernandes, G. M. D.; Ramalho, A. A. D.; Araujo, E. A. et al. (2017), Economic analysis of oil production by applying steam-assisted gravity drainage (SAGD) to reservoirs from the Potiguar basin. Energy Sources Part B-Economics Planning and Policy, Vol. 1, pp. 1-6.

Figueirêdo, M. C. B. de; Teixeira, A. S.; Araújo, L. de F. P.; Rosa, M. F.; Paulino, W. D.; Mota, S.; Araújo, J. C. (2007). Avaliação da vulnerabilidade ambiental de reservatórios à eutrofização. Revista de Engenharia Sanitária e Ambiental, v.12, p. 399- 409.

Fonseca, A. L. S.; Bianchini, I.; Pimenta, C.M.M.; Soares, C.B.P.; Mangiavacchi, N. (2016), The effect of hydrostatic pressure on the decomposition of inundated terrestrial plant detritus of different quality in simulated reservoir formation. Lakes and Reservoirs, Vol. 21, pp. 216-223.

Fregonesi, B.; Nikaido-Suzuki, M.; Sampaio, C. F. et al. (2015), Emergent and re-emergent parasites in HIV-infected children: immunological and socio-environmental conditions that are involved in the transmission of Giardia spp. and Cryptosporidium spp. Revista da Sociedade Brasileira de Medicina Tropical, Vol. 48, pp. 753-758.

Fuentes, E. V.; Petrucio, M. M. (2015), Water level decrease and increased water stability promotes phytoplankton growth in a mesotrophic subtropical lake. Marine and Freshwater Research, Vol. 66, pp. 711-718.

Guerra, C. B. (2007), Atlas Escolar da Bacia do Rio Doce. Nosso Território, Nossa Gente- Vol. 1 Regiões Hidrográficas. Projeto Águas do Rio Doce.

Güntzel, A. M.; Panarelli, E. A.; Silva, W. M.; Roche, K. F. (2010), Influence of connectivity on Cladocera diversity in oxbow lakes in the Taquari River floodplain (MS, Brazil). Acta Limnologica Brasiliensia, Vol. 22, pp. 93-101.

Güntzel, A.M.; Melo, I. K. M.; Roche, K. F.; Silva, V. F. B.; Pompiani, P. G. (2012), Cladocerans from gut contents of fishes associated to macrophytes from Taquari River Basin, MS, Brazil. Acta Limnologica Brasiliensia, Vol. 24, pp. 97-102.

IGAM – Instituto Mineiro de Gestão das Águas (2015), Plano Integrado de Recursos Hídricos da Bacia do Rio Doce e dos Planos de Ações de Recursos Hídricos para as Unidades de Planejamento e Gestão de Recursos Hídricos no Âmbito da Bacia do Rio Doce. IGAM, Minas Gerais.

INPE - Instituto Nacional de Pesquisas Espaciais (2015), Sistema de Processamento de Informações Georeferenciadas, SPRING, disponível em: <http://www.dpi.inpe.br/spring/portugues/index.html> (Acesso: 10 jul. 2015).

Jorcin, A.; Nogueira, M. G.; Belmont, R. (2009), Spatial and temporal distribution of the zoobenthos community during the filling up period of Porto Primavera reservoir (River Paraná, Brazil). Brazilian Journal of Biology, Vol. 69, pp. 631-637.

Lamparelli, M. C. (2004), Grau de trofia em corpos d'água do Estado de São Paulo: avaliação dos métodos de monitoramento. Tese de doutorado, Universidade de São Paulo, São Paulo.

Lima, L.; Mangiavacchi, N.; Ferrari, L. (2017), Stability analysis of passive cooling systems for nuclear spent fuel pool. Journal of the Brazilian Society of Mechanical Sciences and Engineering, Vol. 39, pp. 1019-1031.

Machado, C. S.; Alves, R. I. S.; Fregonesi, B. M. et al. (2015), Integrating three tools for the environmental assessment of the Pardo River, Brazil. Environmental Monitoring and Assessment, Vol. 187, pp. 568.

Machado, F. H.; Dupas, F. A.; Vergara, F. E. (2014), Economic Assessment of Urban Watersheds Developing Mechanisms for Environmental Protection of Feijão River, São Carlos, SP - Brasil. Brazilian Journal of Biology, Vol. 74, pp. 677-684.

Molica, R. J. R.; Oliveira, E J A; Carvalho, P V. V. C. et al. (2005), Occurrence of saxitoxin sandanana toxin-a(s) - like anticholinesterase in a Brazilian drinking waters upply. Harmful Algae, Vol. 4, No. 4, pp. 743-753.

Electronic Journal of Management & System
Volume 11, Number 1, 2019, pp. 1-12
DOI: 10.20985/1980-5160.2019.v14n1.1363

Nogueira, E. M.; Yanai, A. M.; Fonseca, F. O. R.; Fearnside, P. M. (2015), Carbon stock loss from deforestation through 2013 in Brazilian Amazonia. Global Change Biology, Vol. 21.

Queiroz, M. T. A.; Queiroz, C. A.; Queiroz, F. A. et al. (2016), Estudo dos Parâmetros Físico-Químicos, Qualidade da água e Trofia no Reservatório da Usina Hidrelétrica Sá Carvalho, MG, Brasil. Revista Gestão Industrial, Vol. 12.

Queiroz, M. T. A.; Sabara, M. G.; Queiroz, C. A. et al. (2015), Estudo de Caso: Análise Espaço-Temporal do Ribeirão Caladinho, Bacia Hidrográfica do Rio Piracicaba, Minas Gerais, para Abastecimento Público. Ciência e Natura, Vol. 37, pp. 141-150.

Quevedo, C.M.G.; Paganini, W. S. (2011), Impactos das atividades humanas sobre a dinâmica do fósforo no meio ambiente e seus reflexos na saúde pública. Ciência e Saúde Coletiva, Vol. 16, No. 8, pp. 3539.

Rice, E. W.; Baird, R. B.; Eaton, A. D. (Editors) (2012), Standard methods for the examination of water and wastewater. 19ª ed., American Public Health Association, American Water Works Association, Water Environment Federation, New York.

Ritter, C. D.; Mccrate, G.; Nilsson, R. H. et al. (2017), Environmental impact assessment in Brazilian Amazonia: Challenges and prospects to assess biodiversity. Biological Conservation, Vol. 206, pp. 161-168.

Roche, K. F.; Queiroz, E. P.; Righi, K. O.; Souza, G. M. (2010), Use of the BMWP and ASPT indexes for monitoring environmental quality in a neotropical stream. Acta Limnologica Brasiliensia, Vol. 22, pp. 105-108.

Rodrigues, W.; Magalhães Filho, L. M. L.; Vergara, F. E. (2013), Valoração dos danos ambientais advindos da construção de hidrelétricas: o caso da UHE de Estreito. Informe GEPEC (Online), Vol. 17, pp. 23-39.

Schäffer, W., Prochnow, M. (orgs.) (2002), A Mata Atlântica e Você – Como preservar, recuperar e se beneficiar da mais ameaçada floresta brasileira, Apremavi, Brasília.

Silva, M. M.; Silva, S. R.; Carrano, E. G.; Uturbey, W.; Gonzalez, M. L. Y. (2015), Evaluating harmonic voltage distortion in load-variating unbalanced networks using Monte Carlo simulations. IET Generation, Transmission & Distribution, Vol. 9, pp. 855-865.

Sperling, E. V. (2009), Multiple water uses in Águas Claras pit lake, Brazil. Wissenschaftliche Mitteilungen-Institut für Geologie der Technischen Universität Bergakademie Freiberg, Vol. 41, pp. 66-70.

Sperling, E. V.; Ferreira, A. C. S.; Gomes, L. N. L. (2008), Comparative eutrophication development in two Brazilian water supply reservoirs with respect to nutrient concentrations and bacteria growth. Desalination (Amsterdam), Vol. 226, pp. 169-174.

Toledo, A. P. Jr. (1990), Informe preliminar sobre os estudos para a obtenção de um índice para avaliação do estado trófico de reservatórios de regiões quentes tropicais. CETESB, São Paulo.

Toledo, A.P.J.; Talarico, M.; Chinez, S.J.; Agudo, E.G. (1983) A aplicação de modelos simplificados para a avaliação do processo da eutrofização em lagos e reservatórios tropicais. In: CONGRESSO BRASILEIRO DE ENGENHARIA SANITÁRIA E AMBIENTAL, 12., Balneário Camboriú, Santa Catarina. ABES – Associação Brasileira de Engenharia Sanitária e Ambiental. p.1-34

Tundisi, J. G.; Matsumura-Tundisi, T.; Tundisi, J. et al. (2015), A bloom of cyanobacteria (Cylindrospermopsis raciborskii) in UHE Carlos Botelho (Lobo/Broa) reservoir: a consequence of global change?. Brazilian Journal of Biology, Vol. 75, pp. 507-508.

Von Sperling, M. (1996), Introdução à Qualidade das Águas e ao Tratamento de Esgotos. 2ª Ed. Belo Horizonte: Departamento de Engenharia Sanitária e Ambiental, Universidade Federal de Minas Gerais.

Received: Nov. 03, 2017

Approved: Feb. 11, 2019

DOI: 10.20985/1980-5160.2018.v14n1.1363

How to cite: Queiroz, M. T. A.; Queiroz, C. A.; Queiroz, F. A. et al. (2019), "Evaluation of the Trophic State Index and water quality parameters in the reservoir of the Sá Carvalho Hydroelectric Power Plant, Minas Gerais, Brazil", Sistemas & Gestão, Vol. 14, N. 1, pp. 1-12, available from: http://www.revistasg.uff.br/index.php/sg/article/view/1363 (access day abbreviated month. year).