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# QUANTIFICATION OF METALS IN MACROPHYTES IN AN AQUACULTURE AREA OF THE ITAIPU BINATIONAL RESERVOIR

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**ABSTRACT -** The macrophytes in natural conditions perform an important role in the maintenance and balance of aquatic environments with a capacity of absorbing the excess of nutrients and pollutants serving as bioindicators of water quality in aquatic ecosystems. The objective was to evaluate the levels of trace metals in three species of macrophytes (*Egeria densa* - submerged and *Eichhornia crassipes* and *Salvinia auriculata* - floating) collected around an aquaculture area of cages in the Itaipu Binational reservoir, during the four seasons of the year. The macrophyte samples were submitted of nitroperchloric digestion. Subsequently, the quantification of metals (Cu, Zn, Fe, Mn, Pb, Cd and Cr) was carried out by flame atomic absorption spectrometry analytical method. The concentration of Cu, Fe and Mn in E. *densa* and *S. auriculata* was higher (P<0.05) than in *E. crassipes*. The samples of *S. auriculata* and *E. crassipes* had the lowest concentrations (P<0.05) of Pb. The lowest metal pollution index (MPI) was determined in *E. crassipes*. There was greater bioaccumulation of metals in the root concerning the stem and leaves of *E. crassipes* (P<0.05). The results obtained in this study show the influence of seasonal variation in the levels of Fe and Zn and the species analyzed on the concentration of Fe, Zn and Mn accumulated in aquatic macrophytes. The macrophytes *E. crassipes* and *E. densa* can be considered efficient accumulators of metals, indicating the exposure of the concentration of trace metals around the aquaculture area intended for the fish production in cages.
**Keywords:** bioaccumulation, *Egeria densa* Planch., *Eichhornia crassipes* (Mart.) Soms, metal pollution index, *Salvinia auriculata* Aubl..

# *QUANTIFICAÇÃO DE METAIS EM MACRÓFITAS DE UMA ÁREA AQUÍCOLA DO RESERVATÓRIO DE ITAIPU BINACIONAL*

**RESUMO -** As macrófitas, em condições naturais, desempenham importante função na manutenção e equilíbrio dos ambientes aquáticos, com capacidade de absorverem o excesso de nutrientes e poluentes, podendo servir como bioindicadoras da qualidade de água em ecossistemas aquáticos. Objetivou-se avaliar os teores de metais-traço em três espécies de macrófitas (*Egeria densa* - submersa e *Eichhornia crassipes* e *Salvinia auriculata* – flutuantes) coletadas no entorno de uma área aquícola de tanques-rede no reservatório de Itaipu Binacional, durante as quatro estações do ano. As amostras de macrófitas foram submetidas à digestão nitroperclórica. Posteriormente, a quantificação dos metais (Cu, Zn, Fe, Mn, Pb, Cd e Cr) foi realizada pelo método analítico por espectrometria de absorção atômica com chama. A concentração de Cu, Fe e Mn em *E. densa* e *S. auriculata* foi maior (P<0,05) que em *E. crassipes*. As amostras de *S. auriculata* e *E. crassipes* apresentaram as menores concentrações (P<0,05) de Pb. O menor índice de poluição por metais (MPI) foi determinado em *E. crassipes*. Houve uma maior bioacumulação de metais na raiz em relação ao caule e folhas de *E. crassipes* (P<0,05). Os resultados obtidos neste estudo evidenciam a influência da variação sazonal nos teores de Fe e Zn e da espécie analisada sobre a concentração de Fe, Zn e Mn acumulados nas macrófitas aquáticas. As macrófitas *E. crassipes* e *E. densa* podem ser consideradas eficientes acumuladoras de metais, indicando a exposição da concentração de metais-traço no entorno da área aquícola destinada à produção de peixes em tanques-rede.
**Palavras-chave:** bioacumulação, *Egeria densa* Planch., *Eichhornia crassipes* (Mart.) Soms, índice de poluição por metais, *Salvinia auriculata* Aubl..

## INTRODUCTION

Aquatic plants play an important role in continental ecosystems, as in natural conditions, they maintain water oxygenation, protect the banks against erosion, serve as a shelter, food and breeding place for various animals, as well as acting as a substrate for the peripheral community. In the treatment of urban and aquaculture effluents, they act in the cycling of nutrients, using them for their development and growth, supplying organic matter to the detritivorous chain in the decomposition process (CHAMBO, 2011; ESTEVES, 2011). However, in artificial environments of neotropical reservoirs, macrophytes can be potentially harmful to aquaculture activities, due to their uncontrolled propagation, competition and invasion, interfering with sedimentation, the speed of water flow and the physical

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and chemical characteristics of the water (HEGEL; MELO, 2016).

The bioaccumulation capacity of trace metals in macrophytes differs between species and plant tissue parts of plants (KUMAR et al., 2012; HENARES; CAMARGO, 2014). The ability of metals to accumulate in plants is a consequence of several factors such as adsorption, absorption, interaction with metabolic sites, storage and elimination of the metal. The importance of each of these mechanisms in the macrophyte response depends not only on biological characteristics but also on environmental and seasonal conditions (CAMPANELI et al., 2010; SOUZA et al., 2018).

Aquatic macrophytes have been used as bioindicators of water quality in aquatic ecosystems (ROCHA et al., 2012; HEGEL; MELO, 2016; KASSAYE et al., 2016; COUTINHO, 2018; FREITAS et al., 2018) and used for biomonitoring in aquaculture areas installed in reservoirs as a complementary analysis to the physical, chemical and biological parameters of water and sediment quality.

The increase in pollution levels of aquatic resources results in negative effects on aquaculture productivity, quality and safety of fish and profitability. Pollution or environmental contamination may be related to the increase in the concentration of chemical elements from domestic sewage, garbage and the disposal of agricultural and livestock waste, leading to changes in the water quality index, eutrophication and, possibly, bioaccumulation and availability of metals, among others (MARENGONI et al., 2013; GONÇALVES et al., 2014).

The work aimed at determining the levels of trace metals (Cu, Fe, Mn and Zn, Cd, Pb and Cr) in three species of macrophytes (*E. densa, S. auriculata* and *E. crassipes*) and to evaluate the possible correlation between seasonality and the concentration of metals in the macrophyte samples surrounding an aquaculture area for the production of fish in cages in the reservoir of the Itaipu Binational hydroelectric plant in Santa Helena, Paraná, Brazil.

## MATERIAL AND METHODS

The work was carried out during the period from April 2009 to March 2010 in an aquaculture area for experimental cultivation of native fish in cages, installed in the Itaipu Binational reservoir, in the western region of the State of Paraná in the municipality of Santa Helena, Brazil. The reservoir area where the macrophyte collections were carried out was located at geographic coordinates (DMS): 24°51’10.5”S 54°21’08.3”W 24°51’12.2”S 54°21’10.9”W and 24°51’14.2”S 54°21’07.3”W.

During the evaluation period, the aquaculture area consisted of 80 cages (5 m³) and 20 small volume cages (0.7 m³), intended for the production of native species such as pacu (*Piaractus mesopotamicus*), piracanjuba (*Brycon orbignyanus*), piapara (*Leporinus obtusidens*) and curimba (*Prochilodus lineatus*). The cages were located in a region with an average depth of eight meters and received approximately 230 kg of commercial feed with different chemical compositions daily to meet the nutritional requirements of the species of cultivated fish (NEU et al., 2014).

The macrophyte samplings were carried out monthly for twelve consecutive months. Three replicates of the samples of the submerged aquatic macrophyte *E. densa* and floating macrophytes *E. crassipes and S. auriculata* were collected. The *S. auriculata* was found in the reservoir from October 2009 to March 2010 only. The macrophytes were obtained at the surrounding of the experimental aquaculture area for the production of fish in cages, according to its area of natural occurrence during the annual cycle. The sample collection and preservation methodology were adapted from the national sampling guide proposed by the Environmental Company of the State of São Paulo (CETESB, 2011).

The collected samples were previously washed with water from the reservoir to remove all particles adhered to its surface and then packed in thermal boxes containing ice for transport to the laboratory of the State University of Western Paraná (Unioeste). Only the macrophyte *E. crassipes* was divided into three subsamples, consisting of the entire plant, the underwater portion (root) and the aerial portion (stem and leaves). The other two macrophytes were analyzed as a whole plant. The samples of plant tissue of the species were cut into fragments of approximately two centimeters in length, to facilitate the accommodation in trays, for drying in an oven with forced air circulation at 55°C for 72 h, until constant mass, to obtain the dry biomass. Subsequently, the samples were ground and sent to determine the metals in the analytical aliquots.

During the macrophyte collections, dissolved oxygen, water temperature, electrical conductivity and pH were measured *in situ* using a portable multi-parameter potentiometer (Hanna Instruments®) and the transparency of the water obtained through the Secchi disk. Three replicates were performed at each sampling point for macrophytes and abiotic factors.

The monthly values referring to the rainfall were made available by the Technological Institute (Simepar), the base of Santa Helena, Paraná. The region is characterized by a subtropical temperate climate with rainfall concentrated in the summer between November and January, with an average annual rainfall of 1,600 mm. Spring was the season with the highest volume of rainfall, with a monthly average of 240.80 mm.

The chemical analyzes of the macrophyte samples were carried out at the Unioeste Environmental and Instrumental Chemistry Laboratory, *Campus* Marechal Cândido Rondon-PR. Concentrations of trace metals copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), lead (Pb), cadmium (Cd) and chromium (Cr) were determined through nitroperchloric digestion of the aliquots (AOAC, 2005) and quantification by atomic absorption spectrometry, in flame modality (WELZ; SPERLING, 1999) using GBC equipment, model 932AA. Aqueous inorganic standards were used for calibration and all analyzes were determined in triplicate. The detection limit used for trace metals was 0.01mg $kg^{-1}$.

The Metals Pollution Index (MPI) was applied to the trace elements (Cu, Zn, Fe, Mn, Cd, Pb and Cr) and determined in the samples of the three species of aquatic macrophytes. The MPI values were calculated using the Equation 1, proposed by Usero et al. (1996).

MPI = (CF1 x CF2 x CF3 ... CFn)1/n (Equation 1)

Where:
CFn = metal concentration in sample n.

The values of metal concentrations in the three macrophytes were tabulated, per month and in the four seasons during the collection period, and subjected to statistical analysis. The effects of the species, root portion, or the stem of *E. crassipes* and seasons were compared. The data that met the assumptions of normality and homogeneity at 5% of the residues, by the Shapiro-Wilk and Levene tests were submitted to analysis of variance (ANOVA), and when significant differences were observed ($P<0.05$), the Tukey test ($\alpha = 0.05$), using the SAS program (2004).

**RESULTS AND DISCUSSION**

The values of the physical and chemical variables of the water surrounding the aquaculture area showed seasonal variation ($P>0.05$), possibly due to the dynamics of the water volume of the Itaipu Binational hydroelectric plant reservoir, corroborating the values found by Diemer et al. (2010) and Neu et al. (2014). The average monthly ambient temperature in the evaluation period was 22.7ºC±3.9ºC, with a maximum (27.2ºC) observed in February and a minimum (16ºC) in June 2010, according to the data obtained from the Simepar base in Santa Helena, Paraná, Brazil.

The water in the study area fits, according to the predominant use, established in Resolution n. 357 of the National Environment Council (CONAMA, 2005) as class II freshwater, which can be considered as an oligotrophic area (BUENO et al., 2008) and suitable for aquaculture of tropical fish in cages and fishing activity. Besides, class II freshwater bodies are intended for supply to human consumption, after conventional treatment; the protection of aquatic communities; the recreation of primary contact; and irrigation with which the public may come into direct contact.

The conductivity can help to detect polluting sources in the system and grows linearly with the concentration of salts in the aquatic environment. Critical values can be linked to point charges in the reservoir, such as sediment transport, leaching of nutrients or waste disposal and the discharge of effluents discharged into the aquatic environment, through anthropic action (DIEMER et al., 2010; MARENGONI et al., 2013). The conductivity results (44.50 to 58.30 µS $cm^{-1}$) remained below the limit stipulated by Brazilian legislation (CONAMA, 2005) and corroborates those observed by Bueno et al. (2008) for the same area of the reservoir. However, conductivity can be affected by natural inputs; and mainly it is not influenced by organic contaminants such as various types of pesticides, making it impossible to infer in the absence of some type of water polluting source in the aquaculture area.

The incidence of light is among the main physical variables of the aquatic ecosystem (PÉREZ et al., 2010). This influences primary production and interferes with the movement of microscopic organisms, contributing to the amplitude of variation in the transparency of the water monitored during the evaluation (0.85 m to 2.80 m). In this context, the transparency of water was high in months characterized by low temperatures, when precipitation and nutrient input are lower, influencing the phytoplankton communities. However, in the wettest months, during the spring of 2009, an increase in suspended solids was observed, which may have contributed to reducing transparency and increasing water turbidity.

Atypical rains occurred in the western region of Paraná, with an accumulation of approximately 730 mm, especially in the spring of 2009. This fact corroborates the hypothesis that the increase in water flow may contribute to the release, retention or receipt mineral elements for the water column. Also, intensive agriculture predominates in the region, which may also have contributed to surface leaching which seeps into the reservoir. However, Campaneli et al. (2010) associated the temporal dynamics of metal availability in *E. crassipes* to rainy and dry seasons in rivers in southeastern Brazil. The authors suggest that metals in bioassimilable form tend to be more available in the dry season, probably due to the lower concentration of suspended particulate matter.

The levels of trace metals Cu, Fe and Mn in *E. densa* and *S. auriculata* were higher ($P<0.05$) than those found in *E. crassipes* (Table 1). When compared with the values found in this study, Henry-Silva and Camargo (2006) found higher levels of manganese (1,233.33 mg $kg^{-1}$), iron (5,425.00 mg $kg^{-1}$) and copper (25.83 mg $kg^{-1}$) in *E. crassipes* collected in wastewater treatment systems. Likewise, Gonçalves Junior et al. (2009) observed higher concentrations of Cu (30.00 mg $kg^{-1}$) and Cr (10.00 mg $kg^{-1}$) in dry biomass of water hyacinth (*E. crassipes*) used for adsorption and removal of metals in contaminated water, in controlled laboratory conditions.

The average concentrations of trace metals Cd and Cr did not show significant differences ($P>0.05$) between the three species of macrophytes evaluated. However, the Pb content (17.25 mg $kg^{-1}$) in *E. densa* was significantly higher ($P<0.05$) than that quantified in *S. auriculata* or *E. crassipes*. The capacity of macrophytes to accumulate metals varies depending on the different species of vegetables as well as the portions (root, stem and leaves) analyzed (KUMAR et al., 2012; HENARES; CAMARGO, 2014).

The highest values ($P<0.05$) of the Metal Pollution Indices (MPI) were determined for the samples of *S. auriculata* and *E. densa* concerning relation to *E.*

*crassipes*. It is observed that the levels of Fe and Mn, regardless of the species of macrophyte analyzed, were high and with wide variation, compared to cultivable and forage species. The absorption of nutrients in aquatic plants occurs not only by fibrous roots but also by submerged leaf rhizomes, leading to greater absorption of nutrients such as *E. densa*, classified as a submerged and rooted aquatic plant. However, the impact of contamination and/or pollution by metals must be quantified not only by the total concentration of metals but, above all, by their "toxicological bioavailability", this being a property related to the mobility and absorption of metallic elements that can be bioaccumulated by macrophytes (ALHASHEMI et al., 2011).

**TABLE 1 -** Mean values (mg kg$^{-1}$) and standard deviation of trace metal levels and Metals Pollution Index (MPI) in macrophytes collected in the Itaipu Binational hydroelectric plant reservoir, from April 2009 to March 2010.

| Analyte | Macrophyte | | |
|---|---|---|---|
| | *Salvinia auriculata* | *Egeria densa* | *Eichhornia crassipes* |
| Cu | 45.67±3.32 a* | 43.25±3.07 a | 15.83±2.02 b |
| Fe | 1798.33±17.95 a | 1548.67±51.01 a | 833.79±72.39 b |
| Mn | 855.33±76.98 a | 792.42±75.18 a | 273.38±23.28 b |
| Zn | 31.33±2.59 a | 38.83±21.05 a | 14.63±1.43 b |
| Cd | 1.00±0.00 a | 0.67±0.18 a | 0.33±0.06 a |
| Pb | 6.67±2.94 b | 17.25±5.53 a | 7.83±1.56 b |
| Cr | 5.17±1.60 a | 12.58±3.05 a | 5.21±0.26 a |
| MPI | 64.13±8.32 a | 67.88±6.49 a | 29.85±5.27 b |

*Values followed by the same letter, on the line, do not differ by Tukey's test, at 5% probability.

The macrophyte *E. densa* has been used as a bioindicator of metal accumulation. This is also due to its efficient capacity to accumulate and remove nutrients and metals from contaminated solutions and water (LIU et al., 2010; CHAMBO, 2011; GONÇALVES Jr et al., 2011). The values of the concentrations of the metals Cu, Fe, Mn, Zn, Pb and Cr were higher ($P<0.05$) in the root compared to those found in the stem of *E. crassipes*. The analyte that showed the greatest variation among the macrophyte parts was Cr, with a concentration 96.73 times higher ($P<0.05$) in the root (10.08 mg kg$^{-1}$) when compared to the stem (0.33 mg kg$^{-1}$) (Table 2).

**TABLE 2 -** Mean values (mg kg$^{-1}$) and standard deviation of trace metal content and Metal Pollution Index (MPI) of the stem and root portions of the macrophyte *Eichhornia crassipes*, collected in the reservoir of the Itaipu Binational hydroelectric plant, from April 2009 to March 2010.

| Analyte | *Eichhornia crassipes* | | $F_{cal}$ | P |
|---|---|---|---|---|
| | Stem | Root | | |
| Cu | 7.00±2.22 | 24.26±5.08 | 9.10 | 0.006 |
| Fe | 418.00±36.31 | 1249.58±62.63 | 54.95 | <0.0001 |
| Mn | 151.25±54.77 | 395.50±25.53 | 41.86 | <0.0001 |
| Zn | 9.74±3.81 | 19.50±3.23 | 19.65 | 0.0002 |
| Cd | 0.16±0.08 | 0.50±0.17 | 2.20 | 0.152 |
| Pb | 5.33±4.35 | 10.33±4.52 | 10.43 | 0.004 |
| Cr | 0.33±0.07 | 10.08±1.60 | 18.22 | 0.0003 |
| MPI | 22.17±11.34 | 37.51±15.20 | 15.30 | 0.0007 |

Fcal = calculated F, P = critical value.

Table 2 shows that the Metal Pollution Index (MPI) at the root (37.51 mg kg$^{-1}$) was 40.90% higher ($P<0.05$) than observed in the stem and leaves (22.17 mg kg$^{-1}$). This result was expected for the floating macrophyte species, as it attributes to the root greater capacity to bioaccumulate trace elements concerning the stem and leaves, due to its contact directly with the reservoir water. In this context, the absorption of metal ions in floating aquatic plants is influenced by the area and the length of the root (BARROS; HENARES, 2015).

Considering the effect of seasonality and macrophyte species, it appears that the average concentrations of the metals Cu, Cd, Pb and Cr did not differ ($P>0.05$) between the plant species analyzed in the four seasons (Table 3). In winter and autumn, no Cd concentrations were detected in the total biomass (root or stem and leaves) of *E. crassipes* and *E. densa*, and Cr in the portion of the stem and leaves of *E. crassipes*. There was a significant difference in the concentration of Zn between macrophytes, with the lowest values quantified in the stem of *E. crassipes* in autumn (3.33 mg kg$^{-1}$) and winter (3.67 mg kg$^{-1}$) about the levels of this trace metal in the root of *E. crassipes* and *E. densa* ($P<0.05$). The concentration of Zn in *E. densa* in spring (62.00 mg kg$^{-1}$) and summer (51.67 mg kg$^{-1}$) exceeded ($P<0.05$) the values found in the plant in autumn and winter, and root and stem of *E. crassipes* and *S. auriculata*.

The period or season of the year in which sampling was performed is one of the factors that influence the variation in Zn concentrations in aquatic plants. Henry-Silva and Camargo (2006) and Gonçalves Junior et al. (2009) found a higher amount of Zn than the present study, reaching 81.82 and 51.00 mg $kg^{-1}$, respectively, in *E. crassipes*. In autumn and winter, the average values of Fe, Mn and Zn in the stem of *E. crassipes* were lower ($P<0.05$) than those quantified in the root of the same macrophyte and *E. densa*. In spring and summer, the highest concentrations of Mn ($P<0.05$) were observed in *E. densa* and *S. auriculata* when compared to the values of the metal in the root or stem of *E. crassipes*.

The *E. crassipes* has also been considered an important macrophyte that can be used as a plant that assists in adsorption, absorption, interaction with metabolic sites, storage and elimination of metals from the water column. Due to the ability of *E. crassipes* to bioaccumulate and reflect the levels of metals compared to the concentrations found in the environment, some researchers have also suggested as a bioindicator of the pollution of aquatic ecosystems by metals (KASSAYE et al., 2016; COUTINHO, 2018).

**TABLE 3 -** Mean values (mg $kg^{-1}$) and standard deviation of trace metals quantified in macrophytes collected in the four seasons of the year in the Itaipu Binational reservoir, from April 2009 to March 2010.

| Season | *S. auriculata* | | *E. crassipes* (Root) | | *E. crassipes* (Stem) | | *E. densa* | |
|---|---|---|---|---|---|---|---|---|
| Cu | | | | | | | | |
| Autumn | - | | 8.33±5.03 | Aa* | 0.67±0.18 | Aa | 24.33±2.52 | Aa |
| Winter | - | | 15.00±2.89 | Aa | 2.00±1.73 | Aa | 12.33±0.58 | Aa |
| Spring | 47.33±3.21 | Aa | 35.00±1.19 | Aa | 14.33±0.58 | Aa | 76.00±15.13 | Aa |
| Summer | 44.00±3.00 | Aa | 40.33±10.33 | Aa | 11.00±2.65 | Aa | 60.33±12.52 | Aa |
| Fe | | | | | | | | |
| Autumn | - | | 1162.33±58.94 | Aa | 162.67±20.62 | Bb | 1274.33±17.79 | Aa |
| Winter | - | | 901.66±58.82 | Aa | 119.33±17.61 | Bb | 1160.00±36.17 | Aa |
| Spring | 1794.00±4.36 | Aa | 1369.23±66.74 | Aa | 777.33±50.18 | Aa | 1895.33±40.62 | Aa |
| Summer | 1802.67±27.02 | Aa | 1564.47±24.35 | Aa | 612.77±39.79 | Aa | 1865.00±67.18 | Aa |
| Mn | | | | | | | | |
| Autumn | - | | 288.67±46.32 | Aa | 95.00±27.64 | Ab | 647.00±77.60 | Aa |
| Winter | - | | 353.33±90.04 | Aa | 118.33±38.76 | Ab | 613.33±56.08 | Aa |
| Spring | 903.67±31.56 | Aa | 454.00±94.38 | Ab | 207.00±17.96 | Ab | 961.33±16.86 | Aa |
| Summer | 807.00±82.53 | Aa | 486.00±71.35 | Ab | 184.67±23.63 | Ab | 948.00±20.30 | Aa |
| Zn | | | | | | | | |
| Autumn | - | | 7.68±1.53 | Aa | 3.33±1.53 | Ab | 21.00±0.00 | Ba |
| Winter | - | | 12.33±1.53 | Aa | 3.67±1.53 | Ab | 20.60±4.16 | Ba |
| Spring | 32.67±2.08 | Ab | 36.33±3.58 | Ab | 17.00±2.00 | Ab | 62.00±7.00 | Aa |
| Summer | 30.00±2.65 | Ab | 21.27±7.36 | Ab | 15.00±3.00 | Ab | 51.67±8.61 | Aa |
| Cd | | | | | | | | |
| Autumn | - | | < LD | | < LD | | < LD | |
| Winter | - | | < LD | | < LD | | < LD | |
| Spring | 1.00±0.00 | Aa | 1.00±1.00 | Aa | 0.33±0.18 | Aa | 1.33±0.08 | Aa |
| Summer | 1.00±0.00 | Aa | 1.00±0.00 | Aa | 0.33±0.09 | Aa | 1.33±0.10 | Aa |
| Pb | | | | | | | | |
| Autumn | - | | 13.00±3.00 | Aa | 9.33±3.51 | Aa | 24.00±1.00 | Aa |
| Winter | - | | 11.67±0.58 | Aa | 6.69±6.11 | Aa | 13.60±1.67 | Aa |
| Spring | 7.00±2.00 | Aa | 9.33±1.39 | Aa | 2.67±2.08 | Aa | 16.33±7.02 | Aa |
| Summer | 6.33±4.16 | Aa | 7.33±2.08 | Aa | 2.35±1.53 | Aa | 15.00±4.36 | Aa |
| Cr | | | | | | | | |
| Autumn | - | | 14.33±1.53 | Aa | < LD | | 23.33±3.06 | Aa |
| Winter | - | | 11.33±4.57 | Aa | < LD | | 11.00±3.86 | Aa |
| Spring | 4.33±0.58 | Aa | 10.00±4.36 | Aa | 1.33±0.15 | Aa | 6.77±1.53 | Aa |
| Summer | 6.00±2.00 | Aa | 4.67±3.21 | Aa | 1.00±0.08 | Aa | 9.33±1.15 | Aa |

*Values followed by the same lowercase letter, on the line, and values followed by the same uppercase letter, in the column, do not differ by Tukey's test at 5% probability; LD = Limit of detection by the atomic absorption spectrometry method (FAAS/flame), LD 0.01 mg $kg^{-1}$.

The accumulation of trace metals is a complex process that affects almost all aspects of an organism, including growth, development and survival. However, plants have several defense systems, such as the exudation of organic compounds and the immobilization of trace elements by the roots, developed by tolerant species (GONÇALVES JUNIOR et al., 2009; GONÇALVES et al., 2014; SOUZA et al., 2015). In this context, the results indicate the different capacities to accumulate metals between the three species of macrophytes evaluated and the possible effects of seasonality and the aquatic environment.

Trace metals are chemically reactive and bioaccumulative and may pose a threat to organisms, since the toxicity of metals depends on their concentrations and specifications, on the physical and chemical conditions of the ecosystem and above all on the bioavailability of chemical elements (ALHASHEMI et al., 2011; WOOD et al., 2012; SOUZA et al., 2018). The high concentration of iron, manganese, zinc and copper in the plant tissues of the analyzed macrophytes may indicate that these nutrients are also available in the water or sediment of the aquaculture area of the reservoir (HEGEL; MELO, 2016).

The surface of the sediment is the most important reservoir of pollutants in aquatic environments. Therefore, rooted aquatic macrophytes and other aquatic organisms can play an important role in the sequestration of metals from the environment, storing them in the roots, stem or leaves. The tendency of absorption of trace elements in plants decreases as root>stem>leaf (LIU et al., 2010). Some species of macrophytes have different capabilities in removing and accumulating heavy metals. Reports are indicating that some species can accumulate specific heavy metals, such as *Typha angustifolia*, which belongs to the Typhaceae family. Liu et al. (2010) highlighted specific variations in the accumulation or removal of Cu, Cr and Ni from wastewater through phytoextraction between 19 species of aquatic plants. The MPI values infer from the E. crassipes root the ability to bioaccumulate trace metals, regardless of the season, corroborating with Campaneli et al. (2010) when relating that the preferred sites of Fe, Mn, Cu, Zn, Ni, Cr and Pb accumulation were the roots of *E. crassipes*.

The results obtained in this study show the influence of seasonal variation and the analyzed species on the concentration of trace metals by the submerged aquatic macrophyte *E. densa* and by the floating macrophytes E. crassipes and *S. auriculata*. However, the evaluation of the solubility and availability of metals that can be bioaccumulated in aquatic plants could assist in the monitoring of metals and substances found, whose concentrations indicate the degree of pollution or contamination, and may cause cumulative effects on the existing fauna. Thus, new studies with aquatic plants should be carried out as a measure to monitor environmental conditions. Furthermore, to encourage the use of water quality monitoring practices, especially in aquaculture areas intended for the production of fish in cages in the reservoirs in a sustainable and environmentally correct, contributing to the use of water resources for multiple purposes (BRABO et al., 2014; SAMPAIO et al., 2019). Bianchini Junior and Cunha-Santino (2018) reported the possible academic experiences as strategic contributions, developed in environmental studies, to assist the management of reservoirs.

The results of this study infer the need for care regarding the risks of contamination of the water quality of an aquaculture area due to the toxicity potential of the metallic elements whose levels were shown to be high in the analyzed macrophyte samples. It is believed that the origin of the metals is related to residues from intensive agricultural activity or natural geological processes. Therefore, researches are suggested that can quantify the possible sources of these metals, as well as monitoring in the environmental compartments (water and sediment) of the local watershed.

## CONCLUSIONS

The *E. crassipes* shows a greater ability to accumulate concentrations of trace metals in the root concerning the plant tissue of the aerial part of the stem and leaves.

There is an effect of seasonality on Fe and Zn levels, respectively for samples of *E. crassipes* and *E. densa* with lower levels of Fe and Zn in autumn and winter in relation to spring and summer.

The macrophytes *Eichhornia crassipes* and *Egeria densa* have an annual occurrence and metal accumulation capacity. Therefore, these macrophytes to demonstrate potential to be used in complementary analyzes to the physical, chemical and biological parameters of water and sediment quality, thus being able to indicate the exposure of trace metal concentration in the aquaculture area assessed.

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