ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 10, Issue, 09, pp. 40789-40796, September, 2020
https://doi.org/10.37118/ijdr.20045.09.2020

RESEARCH ARTICLE OPEN ACCESS

AQUATIC MACROPHYTE AND BREWERY EFFLUENT: DYNAMIC AND PERSPECTIVES

*[1]Aline Costa Gonzalez, [2]Nyamien Yahaut Sébastien, [3]Pitágoras Augusto Piana and [4]Cleonice Lubian

[1]Graduate Program in Sustainable Rural Development, Western Paraná State University, Marechal Cândido Rondon, Paraná, Brazil; [2]Graduate Program in Environment Science, Western Paraná State University, Toledo, Paraná, Brazil; [3]Graduate Program in Fishery Recources and Fisheries Engineering, Western Paraná State University, Toledo, Paraná, Brazil; [4]Agronomist graduated from the Federal of Paraná University, Palotina, Paraná, Brazil

ARTICLE INFO

Article History:
Received 17th June 2020
Received in revised form
21st July 2020
Accepted 06th August 2020
Published online 30th September 2020

Key Words:
Phytoremediation, Contaminants, Phytoextraction.

Corresponding author:
Aline Costa Gonzalez

ABSTRACT

Biological treatment consists on using living organisms to remove pollutes from substrates. This research aimed at evaluating and comparing the efficiency of two macrophyte species in removing polluting substances of brewery effluent, as a sustainable technologic alternative, using natural resources. The design was a system experimental in mesocosmos (open top tanks of 100 L) composed by two treatments represented by each specie (*Salvinia molesta* and *Limnobiumlaevigatum*) with four repetitions each one. For each mesocosmo, 80 L of crude effluent diluted in water at 25% was added together with 40 g of macrophyte. The experiment was conducted for 28 days with weekly collections of effluent for measuring of limnologicalvariables in laboratory. Both species was capable of clearing the water, partially eliminated the scent and significantly reduced pollution load which parameters at some point got within permitted values by current Brazilian law, but phosphorus. These macrophyte present high potential as polluting removers, beyond forming great biomass production. Their utilization in biological technologies for effluent treatments may be recommended, enabling the reuse of treated water and biomass.

Citation: ***Aline Costa Gonzalez, Nyamien Yahaut Sébastien, Pitágoras Augusto Piana and Cleonice Lubian. 2020.*** "Aquatic macrophyte and brewery effluent: dynamic and perspectives*", International Journal of Development Research*, 10, (09), 40789-40796.

INTRODUCTION

In last decades, environmental problems had become even more criticized and frequent, mainly due to industrial activity expansion (Kunz, 2002) that occupy the second position on total water consumption (Mees *et al*, 2009) and generate changes on its quality by polluting liberation, impacting on hydric resources (Cotta *et al*, 2006). Besides freshwater being a scarce resource in many regions in the world (Boyd *et al*, 2007), releasing of both industrial and home effluents in hydric bodies turn it even more eutrophicand polluted (Macedo &Sipaúba-Tavares, 2010). This leads to lesser availability of this natural resource that needs previous treatment, complex and expensive, to be used later (Tundisi, 2008). Therefore, it is necessary choose sustainable technologies that promote environmental conservation and use of natural resources (Hasan *et al*, 2014), enabling efficient water appliance, reducing costs and saving water for other sectors to use (Boyd *et al*, 2007).

Related to hydric resources consumption, breweries require high amounts of excellent quality water. Further, many activities played in such industry, as filtration and fermentation stages and cleanness cause intense effluent outputcarrying moderate or high organic load and solid suspension (Santos, 2005). By this token, for preserving natural resources effluent treatment in breweries is essential, once water is employed as raw material and environmental impacts are worrying, such as degradation, pathogens proliferation, diseases-carrying dissemination and so on (Cancian, 2007). Nowadays, any facility producer of wastewater needs installing a treatment system to ensure environmental preserve, according to parameters established by 357/2005 and 430/2011 resolutions, of Environmental National Counseling– CONAMA (2005 and 2011). In activities such as fish farming, generating a high amount of effluent, rich in phosphate and azote compounds origined from feces and leftover food, with drastic consequences on the quality of rivers, one of the requirements of the public ministry is to perform the proper treatment of this wastewater before its release in river courses. According to Valenti (2002), modem aquaculture is based on three components: profitable production, environmental preservation and social development. Thus, the quality of wastewater generated in fish farms/farms is to he best possible, so that the impacts or changes caused in downstream water bodies are minimized (SILVA *et al*., 2013). Couple of studies had looked for alternatives on effluent treatment, some of them applying floating aquatic macrophyte showed their ability at removing and storing high quantity of nutrients further being great growers (Benítez et al, 2008; Martínez et al, 2010; Martelo& Borrero, 2012; Aponte&Pacherres, 2013). Such characteristics are common to species belonging to Salvinia genus (Henry-Silva & Camargo, 2006; Freitas et al, 2009; Pistori et al, 2010). On the other hand, there are few studies that investigated performance of *Limnobium laevigatum*, although Murillo-Castillo *et al*. (2012) propose its efficiency. By analyzing above-mentioned, the objective of this study was to test and compare the efficiency of the macrophyte Salvinia molesta and *Limnobium laevigatum* at removing of brewery effluent, as a biological technologic alternative, clean, efficient and low energetic costly.

METHODS

Area and Experimental Design: The experiment was conducted into a greenhouse at Environmental Aquaculture Research Institute (InPAA) and analyses at Limnology Laboratory of Universidade Estadual do Oeste do Paraná – UNIOESTE, *campus* Toledo. (Latitude: 24º 42'49'' S; Longitude: 53º 44'35''W; height: 560 m). Experimental design used was completely randomized whit treatments were composed by species *Salvinia molesta* and *Limnobium laevigatum,* conditioned in polyethy lenemesocosmo of 0.73 m diameter and 0.41 m height. Mesocosmos were filled with 80 L of brewery crude effluent, diluted in water at 25% with four repetitions for each specie, evaluated during 28 days, among June third and July first, 2014.

Material collection: Floating aquatic macrophyte were collected in natural systems (fishpond) in InPAA. The vegetal material was washed several times aiming to remove periphyton, organic debris and inorganic particle associated (Henry-Silva & Camargo, 2006). Industrial effluent came from a brewery located at Toledo city, Paraná State.

Laboratorial analyses: Firstly, crude effluent was characterized from which samples of each mesocosmo were collected weekly for parameter analysis in laboratory, to determine pollution load concentrations throughout treatment. Turbidity was measured using turbidimeter (Quimi, model Q-279PiR – TURB); pH values were taken by a set Digimed (model DM2P – V1.1) and conductivity by conductivity meter Digimed (model DM3P – V1.2). Chemical Oxygen Demand (COD), total phosphorus, orthophosphate, nitrate, nitrite, ammonia and total nitrogen were analyzed according to a method proposed by Apha (2005). There was five analisis during experiment, weekly distributed. Fourty grams os each macrophyte were placed at each mesocosmo at the beggining of experiment, beign weigthed weekly. At any measuring, water excess retained in roots was removed using a sieve thought which water scooted for five minutes (*sensu* Cancian, 2007). Foliar area was measured weekly for monitoring plants development. In this process, a square (25x25 cm) was used to group plants together to go along their biomass growing by measuring the occupied area inside square. At the end, nitrogen and total phosphorus were analyzed in macrophyte, according to Association of Official Analytical Chemists (AOAC, 1990) method, to infer the nutrient and biomass concentration.

Treatment Efficiency Analyses*:* Treatment efficiency proportionated by species was evaluated through remotion porcentage, according to the determination of parameters observed at the beggining and throughout experiment. The equation applied was: R = 100-[(100*Cetrat)/Ce], where: R = remotion porcentage; Cetrat = nutrient concentration in treated effluent; and Ce = nutrinet concentration in brewery effluent (Henry-Silva & Camargo, 2008).

Data Analyses: At the beginning, biomass from macrophyte collected from fishpond was evaluated to be compared to the last evaluation that considered macrophyte cultivated in open top tanks containing brewery extract, in order to identify whether plants grew by absorbing effluent nutrients (nitrogen and phosphorus). In sequence, the variable conjunct was summarized by Principal Components Analyses (PCA), applied at a matrix of bivariate correlations, adopting criteria of Kaizer-Guttmannfor retention and interpretation of axes (Gotelli& Ellison, 2011). In multivariate approach, all parameter above mentioned are now summarized in three main components (resulting from PCA) and tested by variance analyses of repeated measures.This procedure has advantage of reducing variable number submitted to hypothesis tests, since original variables are combined in new orthogonal composed variables that maintains high proportion of total data variability (Mccune& Grace, 2002). Retained axeswere then submitted to variance analyses of repeated measures (Scheiner&Gurevitch, 1993), considering species as factors (*L. laevigatum* and *S. molesta*) and as repeated measures, the four weekly measures. Variables presented quite normal distribution by Shapiro-Wilk test, not being necessary any transformation, homogeneous variance by Levene test and by sphericity test. Principal component test was run in the Pc_Ord 5.0 software (Mccune&Mefford, 2006), while variance analysis of repeated measures was run by software Statistic 7.1 (Stafsoft, 2005).

RESULTS

In comparison to nº 357/2005 resolution of Environmental National Counseling – CONAMA and nº 70/2009 resolution of Environmental State Counseling – CEMA of Environmental Institute of Paraná – IAP, that establish conditions and patterns for effluent releasing in hydric bodies,we noticed that parameter of turbidity, COD and total phosphorus were bigger than values stipulated by such legislations, for crude effluent. IAP resolution follows the same CONAMA indications, however it has one limit value more for COD (Table 1).

Table 1. Physical and chemical characteristics of crude brewery effluent compared to environmental legislation

Parameter	Crudeeffluent	CONAMA	IAP
pH	6.18	6 a 9	-
Condutivity ($\mu S.cm^{-1}$)	580	-	-
Turbidity (NTU)	228	100	-
COD ($mg.\ L^{-1}$)	3635	-	200
Phosphorus T ($mg.\ L^{-1}$)	5.65	0.05	-
Orthophosphate ($mg.L^{-1}$)	2.05	-	-
Nitrogen T ($mg.L^{-1}$)	21.98	3.07	-
Ammonia ($mg.L^{-1}$)	1.81	2	-
Nitrite ($mg.L^{-1}$)	0.14	1	-
Nitrate ($mg.\ L^{-1}$)	5.59	10	-

Characteristics of crude effluent varied throughout treatment, some of them decreased continually, other decreased until given time and then settled down, moreover, other decreased a little, established and return to increase until the end of test. Among them, pH was little acid becoming gradually alkaline by treatment with *L. laevigatum* and *S. molesta*, steadied at 8.3 and 8.4, respectively, between second and third week. Macrophyte played an important role at diminishing pollution load in which *L. laevigatum* and *S. molesta* removed 54% and 51% of ions, respectively. Conductivity to both presented high reduction until third week, with slight increase until the end of experiment. For turbidity, there was continuous reduction until the final period, reaching 96% for *L. laevigatum* and 95% for *S. molesta* (Table 2). reductions until the end, while nitrate reduced until second week and then kept quite constant. Total nitrogen reduced until second week, posteriorly showed light elevation (Table 2). Both *L. laevigatum* and *S. molesta* triplicated biomass where as foliar area increased 24% and 86% respectively (Table 2). It implied in phosphorus reduction of 10.7% for *L. laevigatum*, related to a loss of 0.70 g. Kg^{-} while *S. molesta* caused little increase 2.7% and 0. 12g.Kg^{-1}. For nitrogen level, there was a growing of 7.43 g.kg^{-1} to *L. laevigatum* biomass and 10.9 g.kg^{-1} to *S. molesta*, representing a gain on biomass production of 71% and 113%, respectively. Three main components represent 81.17% of total variability of effluent characteristics during treatment. According to graph 1, the first one, with 52.76% computed was positively associated to Chemical

Table 2. Average (x) and standard deviation (DP) for *L. laevigatum* (L) and *S. molesta* (S) related to treatment time, where time zero represents crude effluent and times from 1 to 4 are the weeks

Time (Week)		1		2		3		4	
Specie		L	S	L	S	L	S	L	S
Ammonia	X	1.09	0.97	0.94	0.78	0.51	0.60	0.35	0.38
(mg.L^{-1})	DP	0.07	0.10	0.04	0.06	0.10	0.10	0.06	0.06
COD	X	980	805	364	376	195	180	223	226
(mg.L^{-1})	DP	122.90	51.03	71.72	85.01	21.35	32.27	16.14	31.25
Total_P	X	0.74	0.75	0.49	0.59	0.49	0.59	0.33	0.59
(mg.L^{-1})	DP	0.21	0.08	0.12	0.04	0.09	0.04	0.08	0.15
Nitrite	X	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.01
(mg.L^{-1})	DP	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Nitrogen	X	3.74	3.19	2.14	1.47	1.26	1.26	3.61	3.64
(mg.L^{-1})	DP	0.31	0.31	0.21	0.35	0.16	0.16	0.37	0.46
Orto_P	X	0.31	0.34	0.18	0.23	0.21	0.28	0.16	0.38
(mg.L^{-1})	DP	0.10	0.09	0.06	0.03	0.04	0.03	0.03	0.07
Turb	X	38.40	39.10	23.40	22.93	15.95	17.90	8.84	10.86
(NTU)	DP	6.30	3.12	1.02	1.69	0.66	1.20	0.66	1.18
CE	X	313.00	330.25	297.00	307.00	212.75	228.00	267.75	282.50
(µS.cm^{-1})	DP	16.83	24.32	15.64	25.38	9.18	8.83	10.91	16.84
pH	X	6.80	6.79	7.56	7.71	8.57	8.53	8.29	8.43
	DP	0.07	0.05	0.17	0.13	0.04	0.11	0.03	0.14
Nitrate	X	1.23	1.08	0.25	0.22	0.26	0.26	0.35	0.37
(mg.L^{-1})	DP	0.54	0.42	0.02	0.12	0.03	0.09	0.04	0.03
Biomass	X	89.59	84.36	109.44	110.82	104.36	114.10	125.80	134.74
(g)	DP	11.98	8.81	16.17	22.30	17.13	15.76	24.35	6.16
Foliar area	X	239.37	231.25	282.50	273.75	251.87	308.12	296.87	429.87
(cm^2)	DP	46.48	16.14	22.27	34.25	56.03	59.46	83.15	47.63

Table 3. Correlation among characteristics measured during experiment with main components (CP). Characteristic associated to CP are in bold

Variable	CP1	CP2	CP3
COD	0.96	0.03	0.14
Turbidity	0.96	0.15	-0.07
Ammonia	0.85	0.24	-0.07
Nitrate	0.79	0.00	0.31
CE	0.71	-0.30	0.34
P_total	0.70	-0.43	-0.42
Nitrite	0.60	-0.21	-0.59
pH	-0.94	-0.10	-0.20
Biomass	-0.64	-0.48	0.18
P_Orto	0.40	-0.78	-0.31
Ar_Fol	-0.46	-0.73	0.06
Nitrogen	0.36	-0.44	0.71
Self-value	6.33	1.97	1.44
Explanation %	52.76	16.41	12

COD from effluent set 3635 mg. L^{-1} and drop between second and third treatment week to both species. After this period occurred a process called feedback that leaded to small variation on concentration, reaching 223.8 mg. L^{-1} for *L. laevigatum* (93,8%) and 226,9 mg. L^{-1} for *S. molesta* (93,6%) (Table 2). Therefore, this feedback type is a positive one. There was a reduction on concentrations of phosphorus and orthophosphate in the first week to both specie, without relevant alterations after the second week. Related to nitrogenous compounds, ammonia and nitrite displayed Oxygen Demand (COD), Turbidity (TUR), Ammonia (NH_4), Nitrite (NO_2), Conductivity (CE), Total phosphorus (PTO) and Nitrate (NO_3) (group 1) and negatively to Potential of Hydrogen (pH) and Biomass (BIO) (Group 2). This conjunct of characteristics declined as time passed, but presented a different behavior related to both species. The effluent containing *L. laevigatum* had values lightly superior to *S. molesta* for group 1, but inferior to group 2, until second and third experimental week, reversing demeanor from this time on until the end of experiment (Table 3).

Second component (Graph 2) had 16.41% of variability with negative associations only to orthophosphate and foliar area. In the first week both species presented similar values of orthophosphate and foliar area, however from second week on, *S. molesta* started presenting higher concentrations of orthophosphate in effluent and foliar area, intensifying such difference until the final of experimental period (Table 3). Third component explained 12% of variability and had been associated positively only to nitrogen. This way, nitrogen concentration was evaluated directly in samples. Its concentration declined until third week and then return to be high, however, in average, *S. molesta* was superior to *L. laevigatum* at removing nitrogen until 14 days, equaling the removals at 21st day and releasing again in water, similar concentration to that in first week. Such differences do not have statistical support, although principal effect to specie has been (Table 3).

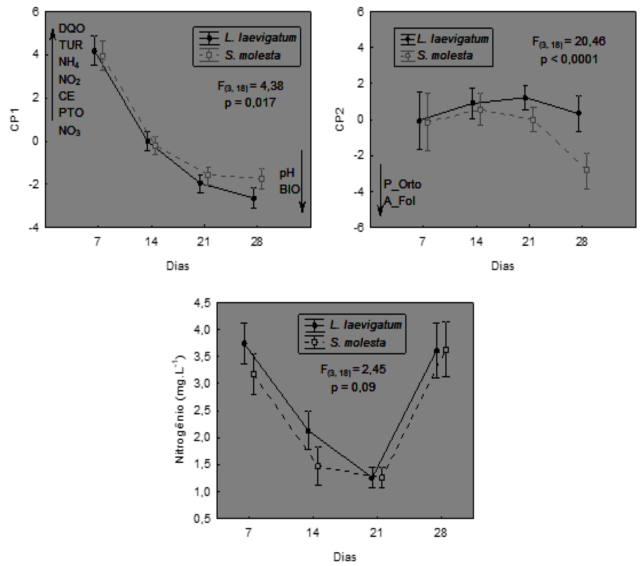

Figure 1. Media and confidence interval (95%) for principal components during experimental period, categorized by macrophyte species. Characteristics associated to the components were presented near axes, with an arrow indicating the correlation sense. A) First principal component (FPC). B) Second principal component (SPC). C) Nitrogen concentration (unique factor associated to third principal component (TPC). COD = Chemical Oxygen Demand, TUR = Turbidity, NH4 = Ammonia, NO_2 = Nitrite, CE = Conductivity, PTO = Total Phosphorus, NO_3 = Nitrate, pH = Potential of Hydrogen, BIO = Biomass, P_Orto = Orthophosphate and A_Fol = Foliar area

DISCUSSION

Initial and final values of pH observed in brewery effluent treatment were similar to those checked by Limons (2008) related to *Salvinia* sp. use for treatment of starch effluent. This author and Henry-Silva (2005) say that such increase arises from biological degradation of organic matter and by medium oxygenation by photosynthesis. In crude effluent, high carbonate concentration promotes pH to establish next to 6.35. As CO_2 is consumed by photosynthesis it does not alter pH in medium anymore. Ammonia in medium form ammonium hydroxide that changes pH toward alkalinity around 9.26 (pka of ammonium hydroxide) (Campos *et al*., 2013). In effluent treatments, final values of pH around 8 favor dissociation of ammonium ion and, consequently, its diffusion to atmosphere, that is, it helps in nitrogen removal by ammonia volatilization and increment of insoluble phosphates precipitation Von Sperling (2005). There was drop of electrical conductivity. However, the light increase observed in last days, probably, derived from availability of soluble mineral salts in water (Esteves, 2011) coming from decomposition of plant parts, as noticed by Martins e Pitelli (2005). Turbidity dropped significantly, reaching 96%, similar to observations made by Ferreira *et al*. (2012) who studied the efficiency of debugging of *Lemna gibor* floating macrophyte in effluent treatments. This happening may be assigned by suspended solid adsorption through root system to both species, since roots form a dense web able to retain very tiny particles in suspension (Gentelini *et al.*, 2008). Such web creates an environment full of microbial activity what classifies a depollute-agent (Andrade *et al*., 2007) as well as precipitate particulate matter due to low depth of mesocosmos used (Henry-Silva e Camargo, 2008). Turbidity reduction was companied by COD reduction, once this measuring indicates oxygen demand to organic matter oxidation. COD dropped to both species reaching values allowed by IAP resolution nº 70/2009 (200 mg. L^{-1}) until 21 days, tough values were lightly superior to this limit at the end of experiment. This situation points to a removal deadline of macrophytes. Such results match with Hidalgo *et al.* (2005) study, showing a reduction of 67 to 97% using *Eleocharis* sp for sewage treatment, as well as, by Borrero (2012) finding on reduction ability of *E. crassipes* around 90% in wastewater.

Our results were superior to those observed by Murillo-Castillo *et al*. (2012) who evaluated sewage phytoremediation using *Limnobium laevigatum* that reduced COD at 80%. It suggests their potential for biological treatment of wastewater, considering organic matter removal.

Although phosphorus was not contained in patters established by environmental legislation (0,05 mg. L^{-1}), there was a reduction of 94% for effluent treated with *L. laevigatum* and 89.5% for *S. molesta.* (Biudes & Camargo, 2010) treated aquaculture effluent with *E. crassipes* and *P. stratiotes* that came up into phosphorus reduction higher than 80% for both species against little up more than 70% by *S. molesta*. Campos *et al*. (2006) tested *Salvinia sp.* on purifying starch effluent and registered removal of 93.5%.

In relation to orthophosphate reductions were 92.1 and 81.6% by *L. laevigatum* and *S. molesta*, respectively, with a significant decline for phosphorus and for orthophosphate until 14th day to both treatments. Macagnan (2011) also found higher phosphorus removal rates until 17 days from brewery effluent treatment using microalgae. After this period, phosphorus concentration treated with quite did not alter while orthophosphate arise, showing an evident reduction on removal efficiency after some time, process that occurs when support capacity of plant is affected (Biudes e Camargo, 2010). *Limnobium laevigatum* removed a bit better phosphate parameter in last seven days probably due to mucilaginous material presence found in long roots from 21 days on, forming a microbial biofilm capable of convert nutrients in cellular material (Diniz *et al*., 2005). As it was observed high reduction on effluent but almost no alteration on phosphorus concentration got by biomass it is clear that although macrophytes have had assimilated this nutrient it was practically not detected by analysis. It occurs due to analysis of total phosphorus in vegetal tissues for verifying phosphorus mainly in its mineral form (Malavolta, 2006). Thus, macrophyte would use phosphorus in organic form, because according to Jackson e Hagen (1960), the phosphate absorbed by plants evolve readily in metabolic process, being integrated in organic ompounds. This way, as plant needy increases, total phosphorus is converted to organic phosphorus, mainly from orthophosphate source (Foyer; Spencer, 1986) from what on start acting in phosphoric esters groups, phospholipids, nucleotides and phytic acid (Prado, 2008). This nutrient directly relates to energy supply (Marschnner, 1995), basically stored in adenosine triphosphate (ATP) form and used in several vital process, since solute transport by cell membranes, nutrient active absorption, cellular division and elongation (Prado, 2008), DNA and RNA synthesis, including intermediates of respiration and photosynthesis (Taiz; Zeiger, 2013). Other possibility includes pumping effect when macrophyte absorbs phosphates excretes a part in water and even before nutrients reach water, bacteria and periphytic algae use them (Esteves, 2011). Same authors reveal that phosphates are also decomposed by microorganisms before being assimilated by macrophyte and the part that is not readily released in water is deposited in sediments, so, phosphates in this study probably got linked to sediments presents in effluent or by not being released by plant absorption yet. Diniz *et al*. (2005) also affirms that part of phosphorus precipitateand Maurer and Boller (1999) comment about removal through bacterial activity. Nitrogen values also were in agreement to CONAMA 357 resolution among 14 and 21 days of treatment with both species. However, in last seven days, there was devolution of nutrient to effluent, presenting at the end a removal of 83.6% for *L. laevigatum* and 83.4% for *S. molesta*. Sales (2011) observed nitrogen removal in rates of 88.2 and 93.1% using *E. crassipes* and *P. stratiotes* in brewery effluent treatment whereas Li *et al*. (2015) found nitrogen removal levels ranging from 74% to 92% using the following macrophyte species: *Iris pseudacorus*, *Canna lily*, *Potamogeton crispus* and *Oenanthe javanica*.

Results suggest a possible direct absorption of nitrogen by macrophyte (*sensu* Sooknah; Wilkie, 2004), in a positive relation between primary production and its high concentration (Biudes; Camargo, 2008). This conclusion is supported by an increase on biomass of *L. laevigatum* and *S. molesta* of 7.43 $g.kg^{-}$ and 10.9 $g.kg^{-1}$, respectively. Although ammonia, nitrate and nitrite were in accordance to patterns stipulated by CONAMA 357 resolution, ammonia that was quite in limit got removed by *L. laevigatum* at 80.8% and at 79% by *S. molesta*. These results are similar to those found by Greco (2010) who observed ammonia removal from an effluent at 78.8% using *Salvinia herzogii.* For nitrite, the removals were 98.4% and 93.2% while for nitrate, 93.7% and 93.4% using *L. laevigatum* e *S. molesta,* respectively. Reidel *et al*. (2005) tested aquatic macrophyte to treat fridge effluent and checked removal of 90% and 100% for nitrite and nitrate, respectively. Hussar & Bastos (2008) performed treatments composed by water hyacinthand pisciculture effluent, noticing nitrate removal at 79.5%. Results of nitrogenous compounds present compatible distribution to the nitrification processes during first week which nitrate concentrations are the highest than nitrate and ammonia. Passed this period, ammonia sets higher concentration than nitrate, revealing ammonification from nitrate (*sensu* Esteves, 2011). It means that probably there were anaerobic regions through plant roots, where oxygen diminution leaded anaerobic bacterial to do such process that, in turn, is significant once nitrogen is released, being eliminated from system (Andrade e*t al*., 1998; Esteves, 2011). For fresh biomass, although *L. laevigatum* had presented great increase on weight there was quite no increase on foliar area. This situation is related to the natural condition of this specie in growing vertically, with double increase on roots size from the beginning to the end of research time. Differently, *S. molesta* had a horizontal growth occupying larger room in water surface. Although *L. laevigatum* got slight better efficiency on nutrients and organic load removal, *S. molesta* resulted in higher biomass gain, in opposition to Biudes& Camargo (2010) who suggested that the system efficiency is higher on nutrients removal when biomass formation is higher too. In this experiment the Biomass ranged from 84.36 to 134.74g for e *S. molesta* and 89.59 to 125.80g for *L. laevigatum*. Plants productivity could have been affected by temperature that ranged from 10 and 26 ºC. This variation is considered good to these species that derived from regional region, presenting wide thermal tolerance (Whiteman&Room, 1991; Biudes & Camargo, 2008). *L. laevigatum* grows the best around 25 ºC (Biudes&Camargo, 2008) whereas *S. molesta*may die in temperature lower than 3 ºC and higher than 43 ºC (Whiteman & Room, 1991). Cancian (2007) analyzed *P. estratiote s*growth identifying better performance at 25 ºC and decrease on biomass production at temperatures higher than 30 ºC and lower than 15ºC.

Beyond that, nutrients availability in effluent favors macrophyte development (Seshavatharam, 1990; Henry-Silva; Camargo, 2005). Once Pistori (2005) verified higher primary production of *S. molesta* in a dam damaged by aquiculture effluent releasing compared to growing indexes in a not damaged dam. Finlayson (1984) registered double size on *S. molesta* in 2.7 days, relatingfast growth to the high concentration of nitrogen and phosphorus, 24 mg L and 9 mg L, respectively. Amounts close to those found on crude brewery effluent 21.98 mg L for nitrogen and 5.65 mg L of phosphorus. In a study of bromatological analysis conducted by Rosario et al (2 018) *Limnobium laevigatum*, *Salvinia molesta* produced in hydroponics system showed the following chemical composition: in organic matter (81.74 and 81.59 mg.m-2), cellulose (18.35 and 9.03), crude protein (28.96 and 21.72) amino acid (18.27 and 18.47) and ligin (8.53 and 18.25 g.m-2) respectively. Both species used in biological treatment lightened the water, practically eliminated stink and reduced significantly pollute loads. All parameters, but phosphorus, were, at some point in this study, in accordance to values allowed by current Brazilian legislation. In agreement with 20/1986 CONAMA resolution, water derived from these treatments can be reused for irrigation purposes in landscape areas, navy and less exigent uses. It is also possible its use in crops irrigation, park cleaning, paving and fabrics (Hespanhol, 2002). According to Hespanhol (2002) and the Law nº 9.433/97 of National Policy of Hydric Resources, the stimuli for the water reuse for less noble finality reduces costs to the public agenciesoffering environmental, social and economical advantages.

In addition, these results show an excellent perspective in raw material production for the pulp, feed and feed industries for cattle by protein, amino acid and organic matter content in earthworm production. The experiment then presents itself as a viable and sustainable alternative for fish far mers. This phytotechnology, installed downstream of fish farming tanks before the point of release of the effluent in the river will carry out in purification box being the collection of biomasses for the different purposes carried out every 21 days residence time of this purification box. Silva (2004) declares necessary the integration among public policies (housing, sanitation, transportation and environmental policy) besides partnership between private and public sectors for a sustainable management in urban regions. For that to happen, choices must groundactions and governmental programs. Giovanini (2015) attests that public policies need to prioritize the modernization of technological resources, diminishing the pressure on natural resources. Considered as a sustainable perspective, macrophyte biomass development may be used for fish and bird feeding, fertilizer for pisciculture tanks, soil fertilizer (Esteves, 1998), paper fabric, proteins extraction for ration use (Dinardi *et al*., 2003). Results obtained in this study suggests for future investigation on trials to reduce even more the concentration of all parameter analyzed, specially phosphorus, by changing plants between second and third weeks, since after this period the concentrations kept high stable or started increasing. Therefore, macrophytes have a tolerance limit and start returning nutrients to environment.

CONCLUSIONS

It is recommended to use the macrophytes *Salvinia molesta* and *Limnobium laevigatum* as biological alternative on brewery treatment, as far as they had presented efficiency on polluttion and organic load removal. Besides we checked treated water may be reused for other purposes, minimizing its scarcity. Both macrophyte species presented high nutrient removal potential so choose any of them depends upon biomass use finality, it is to say, whether there is interest in biomass reuse the best would choose *S. molesta* that displayed higher biomass weight. On the other hand, *L. laevigatum* showed lower biomass increment, very important in cases where it is preferable avoid accumulation of organic load in environment.

REFERENCES

Almeida, R.A.; Posch, S.; Pereira, L.S.; Godinho, C.A.; Oliveira, L.F.C. E Kliemann, H.J. (2005). Tratamento de esgoto com plantas: sistema zona de raízes. p. 115-134. In: *Prêmio CREA-Goiás de MeioAmbiente 2004: compêndio dos trabalhospremiados.* Conselho Regional de Engenharia Arquitetura e Agronomia do Estado de Goiás, Goiânia. p. 244.

Andrade, J.C.M.; Tavares, S.R.L.; Mahler, C.F. (2007). *Fitorremediação: o uso de plantas na melhoria e qualidade ambiental*. 1 ed., São Paulo, Oficina de Textos, p. 176.

Andrade, R.C.B.; Souza, M.F.L.; Couto, E.C.G. (1998). Influência de efluentes têxteis e alimentícios sobre o metabolismo e propriedades físicas e químicas do rio Piauitinga (Sergipe). *Química Nova*, *21*(4), 424-427.

AOAC. (1990). *Association of official analytical chemistis. Official methods of analysis*. v.1, 15 ed., 11-22.

APHA. (2005). *Standard Methods for the Examination of Water and Wastewater*. Washington, USA: American Public Health Association, 1134p.

Aponte, H.; Pacherres, C.O. (2013). Growth and propagation of *limnobium laevigatum* (hydrocharitaceae) under different nutrient concentrations. *The Biologist (Lima*), 11(1), 69-78.

Benítez, S.V.B.; Zapata, J.C.C.; Ramírez, N.J.A. (2008). Análisis comparativo de la remoción de um sustrato orgânico por las macrófitas *Pistiaestratiotes* y *Egeria densa* en un sistema Batch. *Gestión y Ambiente*, 11(2), 39-48.

Biudes, J.F.V.; Camargo, A.F.M. (2008). Estudos dos fatores limitantes à produção primária por macrófitas aquáticas no Brasil. *Oecologiabrasiliensis.*, 12(1), 7-19.

Biudes, J.F.V.; Camargo, A.F.M. (2010). Uso de macrófitas aquáticas no tratamento de efluentes de aquicultura. *Boletim ABLimno*, *38*(2), Availeble in: http://www.ablimno.org.br/boletins/pdf/bol_38(2-1).pdf. Access in: 20/03/2015.

Boyd, C.E.; Tucker, C.; Mcnevin, A.; Bostick, K.; Clay, J. (2007) Indicators of Resource Use Efficiency and Environmental Performance in Fish and Crustacean Aquaculture. *Reviews in Fisheries Science*, *15*, 327-360.

Campos, A.T.; Daga, J.; Rodrigues, E.E.; Franzener, G.I; Suguiy, M.M.T.; Syperreck, V.L.G. (2006). Residuary water treatment of fecularia by means of stabilization lagoons. *Engenharia Agrícola*, Jaboticabal, *26*(1).

Campos, J.C.; Moura, D.; Costa, A.P.; Yokoyama, L.; Araujo, F.V. Da F.; Cammarota, M.C.; Cardillo, L. (2013). Evaluation of pH, alkalinity and temperature during air stripping process for ammonia removal from landfill leachate. *Journal of Environmental Science and Health, Part A*: Toxic/Hazardous Substances and Environmental Engineering. 48, 1105- 1113.

Cancian, L. F. (2007). Crescimento das macrófitasa quáticas flutuantes *Pistia stratiotes* e *Salvinia molesta* em diferentes condições de temperatura e fotoperíodo. Dissertação de mestrado em Aquicultura. Universidade Estadual Paulista, Jaboticabal, SP. p. 66.

CEMA – Conselho Estadual do Meio Ambiente. Instituto Ambiental do Paraná – IAP. Resolução n.° 70, de 11 de agosto de 2009. Available in: http://www.iap.pr.gov.br/arquivos/File/Legislacao_ambiental/Legislacao_estadual/RESOLUCOES/resolucao_cema_70_2009.pdf. Access in: 15/04/2015.

CERVBRASIL – Associação Brasileira da Indústria da Cerveja. *A Indústria de cerveja na américa latina é muito focada na redução do consumo de água e energia.* Available in: http://www.cervbrasil.org.br/novo_site/a-industria-de-cerveja-na-america-latina-e-muito-focada-na-reducao-do-consumo-de-agua-e-energia/. Access in: 04/04/2020.

CONAMA – Conselho Nacional do MeioAmbiente. Resolução n.° 20, de 18 de junho de 1986. Brasília: DOU de 30/07/1986.

CONAMA – Conselho Nacional do MeioAmbiente. Resolução n.° 357, de 17 de março de 2005. Brasília: DOU de 18/03/2005.

CONAMA – Conselho Nacional do MeioAmbiente. Resolução n.° 430, de 13 de maio de 2011. Brasília: DOU de 16/05/2011.

Cotta, J. A.; Rezende, M. O. O.; Piovani, M. R. (2006). Avaliação do teor de metais em sedimento do Rio Betari no Parque Estadual Turístico do Alto Ribeira – PETAR. *Química Nova*, *29*(1), 40-45.

CUI, W.; CHENG, J. J. Growing duckweed for biofuel production: a review. *PlantBiology*, v. 17, p. 16–23, jan. 2015.

Dinardi A. L.; Formagi V. M.; Coneglian C. M. R.; De Brito N.N.; Sobrinho, G. D.; Tonso, S.; Pelegrini R. (2003). Fitorremediação. In: *III Fórum de Estudos Contábeis*. Faculdades Integradas Claretianas – Rio Claro, SP.

Diniz, C.R.; Ceballos, B.S.O.; Barbosa, J.E. De.L.; Konig, A. (2005). Uso de macrófitas aquáticas como solução ecológica para melhoria da qualidade de água. *R. Bras. Eng. Agríc.* Ambiental, Campina Grande, *9* (Suplemento), 226-230.

Epstein, E.; Bloom, A. Mineral Nutrition of Plants: Principles and Perspectives. Sinauer Associates, Sunderland, USA, 2005.

Esteves, F.A. (2011). *Fundamentos de limnologia*. 3ed., Rio de Janeiro, Interciência, p. 790.

Ferreira, C.J.; Pereira, M.S.S.; Luís, P.F.M. (2012). Análise da aplicação do tratamento de efluentes de águas residuais por leito de macrófitas. *Ecologia III*. Available in: https://cvcarlosjorgeferreira.files.wordpress.com/2012/04/fito-etar-final2.pdf. Access in: 29/03/2015.

Finlayson, C. M. (1984). Growth of *Salvinia molesta* in lake Moondarra, Mount Isa, Australia. *Aquatic Botany*, Amsterdam, 18, 257-262.

Foyer, C.; Spencer, C. (1986). The relationship between phosphate status and photosynthesis in leaves and assimilate partitionig. *Planta*, 167, 369-375.

Freitas, J.M.A.; Weirich, C.E.; Bueno, G.W.; Feiden, A.; Boscolo, W.R. (2009). Produção de biomassa de macrófitas aquáticas no tratamento de efluente da suinocultura. *Anais do I Seminário Internacional de Ciência, Tecnologia e Ambiente*, 28 a 30 de abril de 2009. UNIOESTE, Cascavel – Paraná – Brasil. Available in: http://cac-php.unioeste.br/eventos/ctsa/tr_completo/104.pdf. Access in: 22/12/2014.

Gentelini A. L.; Gomes, S. D.; Feiden A.; Zenatti, D.; Sampaio, S.C.; Coldebella, A. (2008). Produção de biomassa das macrófitas aquáticas *Eichhornia crassipes* (aguapé) e *Egeria densa* (egeria) em sistema de tratamento de efluente de pisciculture orgânica. *Semina: CiênciasAgrárias*, Londrina, 29(2), 441-448.

Giovanini, D. 2015. Um colapso irreversível: a crítica falta de água. In: *Memorian*. n.47. v.8. p13-15.

Gonçalves, I. Z., Barbosa, E. A. A., Santos, L. N. S., Nazário, A. A., Feitosa, D. R. C., Tuta, N. F., Matsura, E. E. Water relations and productivity of sugarcane irrigated with domestic wastewater by subsurface drip. AgriculturalWater Management, 185, 2017, 105–115.

Gotelli, N.J.; Ellison, A.M. (2011). *Princípios de estatística em ecologia*; tradução: Fabrício Beggiato Baccaro; Rev. Técnica: Vitor Lemes Landeiro. Porto Alegre: Artmed, 528p.

Greco, M.F.P.S. 2010. Estudo exploratório de macrófitas aquáticas: potencial de fitorremediação (N-NH3) e de aproveitamento de biomassa. Dissertação de mestrado emTecnologia Ambiental da Universidade de Santa Cruz do Sul - UNISC, Santa Cruz do Sul, RS. 101p.

Hasan, S.D.M.; Limons, R.S.; Silva, F.M.; Klen, M.R.F. (2014). Nonliving *Macrophyte* sp. application for nutrient removal in starchy wastewater treatment of cassava industry. *Desalination and Water Treatment* (Print), *52*, 1-8.

Henry-Silva, G.G. (2005). Tratamento de efluentes de carcinicultura por macrófitas aquáticas (*Eichhornia crassipes* e *Pistia stratiotes*) e aproveitamento da biomassa vegetal em rações para tilápia do Nilo (*Oreochromis niloticus*). Tese de Doutorado em Aqüicultura da Universidade Estadual Paulista, Jaboticabal, SP. p.132.

Henry-Silva, G.G.; Camargo, A.F.M. (2005). Interações ecológicas entre as macrófitas aquáticas flutuantes *Eichhornia crassipe s*e *Pistia stratiotes*. *Hoehnea*, 32(3), 445-452.

Henry-Silva, G.G.; Camargo, A.F.M. (2006). Efficiency of aquatic macrophytes to treat Nile tilapia pond effluents. *Scientia Agricola*, 63(5), 417-513.

Henry-Silva, G.G.; Camargo, A.F.M. (2008). Tratamento de efluentes de carcinicultura por macrófitas aquáticas flutuantes. *Revista Brasileira de Zootecnia*, 37(2), 181-188.

Hespanhol, I. (2002). Potencial de reuso de água no Brasil: agricultura, indústria, municípios, recarga de aqüíferos. São Paulo. *RBRH – Revista Brasileira de Recursos Hídricos,* 7(4), 75-95.

Hidalgo, J.C.; Montano, J.J.; Estrada, M.S. (2005). Recientes aplicaciones de la depuración de aguas residuales con plantas acuáticas. *Theoria*, 14(1), 17-25.

Hussar, G. J.; Bastos, M.C. (2008). Tratamento de efluente de piscicultura com macrófitas aquáticas flutuantes. *Engenharia Ambiental*, 5(3), 274-285.

Jackson, P.C; Hagen, C. E. (1960). Products of orthophosphate absorption by barley roots. *Plant Physiolgy*, *35*, 326-332.

Kunz, A.; Peralta-Zamora, P.; Moraes, S.G. E Durán, N. (2002). Novas tendências no tratamento de efluentestêxteis. *Química Nova*, 25(1), 78-82.

Li, J.; Yang, X.; Wang, Z.; Shan, Y.; Zheng, Z. (2015). Comparison of four aquatic plant treatment systems for nutrient. *Bioresource Technology*, 179, 1-7.

Limons, R.S. (2008). Avaliação do potencial de utilização da macrófita aquática seca *Salvinia sp*. no tratamento de efluentes de fecularia. Dissertação de mestrado em da Universidade Estadual do Oeste do Paraná – UNIOESTE. Toledo-PR, 101p.

LINS, L. P. Produção de biogás a partir de resíduos de bovinocultura leiteira por meio da codigestão com macrófitas da espécie *salvinia*. Dissertação de mestrado em Tecnologias Ambientais da Universidade Tecnológica Federal do Paraná, 2017.

Macagnan, D.C. (2011). Tecnologia no tratamento de águas residuais. Dissertação de mestrado em Recursos Pesqueiros e Engenharia de Pesca. Universidade Estadual do Oeste do Paraná – UNIOESTE, Toledo, PR, 28p.

Macedo, C.F.; Sipaúba-Tavares, L.H. (2010). Eutrofização e qualidade da água na piscicultura: consequências e recomendações. *Boletim do Instituto de Pesca*, 36(2), 149-163.

Malavolta, E. (2006). *Manual de Nutrição Mineral de Plantas*.1ed., São Paulo, EditoraAgronômica Ceres, 638 p.

Marschner, H. (1995). *Mineral nutrition of higher plants*. 2ed. London, Academic Press, 889p.

Martelo, J.; Borrero, J.A.L. (2012). Macrófitas flotantes en el tratamiento de aguas residuales; una revisión del estado del arte. *Ingeniería y Ciencia*, 8(15), 221-243.

Martínez, S.A.A.; Toro, F.M.B.; Rojas, G.G.; Giraldo, J.P.S.; Ángel, M.L.H. (2010). Fitorremediación con humedales artificiales para el tratamiento de aguas residuales porcinas. Informador Técnico*,* 74*, 12-22.*

Martínez-Yáñez et al. Production and composition of aquaponic hydrophytes Ecosist. Recur. Agropec. 5(14):247-257, 2018.

Martins, A. T; Pitelli, R. A. (2005). Efeitos do manejo de *Eichhornia crassipes* sobre a qualidade da água em condições de mesocosmos. *Planta Daninha*, *23*(2), 233-242.

Martins, D.; Velini, E.D.; Negrisoli, E.; Tofoli, G.R. (2002). Controle químico de *Pistia stratiotes*, *Eichhornia crassipes* e *Salvinia molesta* em caixas d'água. *Planta daninha*, 20, 83-88.

Maurer, M.; Boller, M. (1999). Modelling of Phosphorus precipitation in wastewater treatment plants with enhanced biological phosphorus removal. In: *Water Science Technology*, *9*(1), 147-163.

Mccune, B.; Grace, J.B. (2002). *Analysis of Ecological Communities*. MJM, Software, Oregon. 304 p.

Mccune, B.; Mefford, M.J. Pc-Ord. (2006). *Multivariate Analysis of Ecological Data*. Version 5.31 MjM Software, Gleneden Beach, Oregon, U.S.A.

Mees, J.B.R.; Damasceno, S.; Boas, M.A.V.; Fazolo, A.; Sampaio, S.C. (2009). Estabilização da biomassa de aguapé através da compostagem com águas residuárias de suínos e resíduos de frigorífico. *Semina: Ciências Agrárias*, 30(3), 709-716.

Murillo-Castillo, P.A.; Novoa-Acuna, L.G.; Rodríguez-Miranda, J.P. (2012). Evaluación de un humedal artificial de flujo superficial con *Limnobium laevigatum* para el tratamiento de aguas residuales combinadas (domésticas y pecuarias) en Bogotá D.C., Colombia, *TechnoAmbiente*, v.22, n. 232, p. 9–15.

Pistori, R. E. T. 2005. Crescimento da macrófita aquática flutuante *Salvinia molesta* em viveiros de aquicultura com distintos estados tróficos. Dissertação mestrado em Aquicultura da Unesp (CAUNESP), Jaboticabal, SP. 32 p.

Pistori, R.E.T.; Henry-Silva, G.G.; Biudes, J.F.V.; Camargo, A.F.M. (2010). Influence of aquaculture effluents on the growth of *Salvinia molesta*. *Acta LimnologicaBrasiliensia*, 22(2), 179-186.

Política Nacional de Recursos Hídricos. Lei 9433 de 8 de janeiro de 1997. Available in: http://www.planalto.gov.br/ccivil_03/Leis/L9433.htm. Access in: 20/04/2015.

Power, S.D.; Jones, C.L.W. Anaerobically digested brewery effluent as a medium for hydroponic crop production – The influence of algal ponds and pH. Clean. Prod. 139, 2016, 167–174.

Prado, R.M. (2008). Manual de nutrição de plantasforrageiras. 1. ed. Jaboticabal: FUNEP, v.1. 500p.

Reidel, A.; Damasceno, S.; Zenatti, D.C.; Sampaio, S. C.; Feiden, A.; Queiroz, M. M. F. (2005). Utilização de efluentes de frigorífico, tratado com macrófita aquática, no cultivo de tilápia do Nilo. *Revista Brasileira de Engenharia Agrícola Ambiental*, *9*, (Suplemento), 181-185.

Sales, C.V. (2011). Uso de duas espécies de macrófitas aquáticas, *Eichhornia crassipes* e *Pistia stratiotes* em tratamento de resíduos de cervejaria na cidade de Toledo/PR. Dissertação de mestradoem Recursos Pesqueiros e Engenharia de Pesca da Universidade Estadual do Oeste do Paraná – UNIOESTE. Toledo-Pr. 43p.

Santos, M.S. dos. (2005). *Cervejas e refrigerantes*. São Paulo: CETESB, 58 p. (1 CD): il.; 30 cm. (Série P + L) Available in: http://www.cetesb.sp.gov.br. Access in: 28/07/2013.

Scheiner, S. M.; Gurevitch, J. (1993). *Design and analysis of ecological experiments*. New York: Chapman & Hall Press, 445 p.

Seshavatharam, V. (1990). Traditional uses and problem of noxious growth. In: Gopal, B. (Ed.). *Ecology and management of aquatic vegetation in the Indian subcontinent*. Dordrecht: Kluwer Academic, cap. 9, p. 201-218. (Geobotany, 16).

Silva, F. P. da; Carvalho, C. V. de A.; Cardoso, A. M. Gestão da Água: A importância de Políticas Públicas para a implementação do reuso de água no Brasil. *Episteme Transversalis*, [S.l.], v. 10, n. 2, ago. 2019. ISSN 2236-2649.

Silva, M S G. M.; Losekann, M. E.; Hisano, H (2013) Aquicultura: manejo e aproveitamento de efluentes - Jaguariúna, SP: Embrapa Meio Ambiente, 2013. 39 p. — (Documentos / Embrapa Meio Ambiente; 95).

Silva, S.T. (2004). Políticas públicas e estratégias de sustentabilidade. In: *Série Grandes Eventos – MeioAmbiente*. Escola Superior do MinistérioPúblico da União. Brasília, v.1.

Sooknah, R.D.; Wilkie, A.C. (2004). Nutrient removal by floating aquatic macrophytes cultured in anaerobically disgested flushed dairy manure wastewater. *Ecological Engineering*, *22*(1), 27-42.

STATSOFT, INC. (2005). STATISTICA (data analysis software system), version 7.1. www.statsoft.com.

Taiz, L., Zeiger, E. (2013). Fisiologia vegetal. 5ª ed., Porto Alegre, Artmed, 918p.

Tundisi, J.G. 2008. Recursos hídricos no futuro: problemas e soluções. *Estudos Avançados,* 22(63), 7-16.

Valenti, W. C. Agricultura sustentável. In: Congresso de zootecnia, 12., 2002, Vila Real, Portugal. Anais... Vila Real: Associação Portuguesa dos Engenheiros Zootécnicos, 2002. p. 111-118.

Von Sperling, M. (2005). *Princípios do Tratamento Biológico de Águas Residuárias: Introdução à qualidade das águas e ao tratamento de esgoto.* 3Ed. Belo Horizonte: Departamento de Engenharia Sanitária e Ambiental; Universidade Federal de Minas Gerais, v.1, 452p.

Whiteman, J.B.; Room, P.M. (1991). Temperatures lethal to *Salvinia molesta* Mitchell. *Aquatic Botany,* 40(1), 27-35.

****