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STATISTICAL AND EXPERIMENTAL EVALUATION OF THE EFFICIENCY OF MACROPHYTE FLOTATION FILTERS FOR THE TREATMENT OF EUTROPHIC LAKE WATER

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Abstract
In the present study, the efficiency of Floating Macrophyte Filters FMF in the removal of Nitrogen and Phosphorus (eutrophying nutrients) was determined for the treatment of wastewater present in the Colta Lagoon, an ecosystem considered at risk because it is influenced both by agricultural and grazing activities of the communities located in the outskirts, as well as by surface runoff, causing the uncontrolled growth of aquatic plant species, a process known as eutrophication. To develop this research, three biofilters were built with three replicates each (B1, B2 and B3); in each biofilter, Totora (macrophyte) was used on a floating structure, to control its proliferation, thanks to its particularity of transporting the oxygen present in the atmosphere and introducing it through its roots into the water, the reproduction of aerobic microorganisms were allowed, which degraded the organic matter and nutrients. Biofilter 1 (B1), Biofilter 2 (B2) and Biofilter 3 (B3) were made up of water from the Colta Lagoon and Totora, with oxygenation and a solution of mineral salts and biologically active phytohormones (biostimulant for the growth of Totora) being the control variables used for comparison. Characterizations were carried out 15 and 30 days after starting the treatment, obtaining sufficient quantitative results that allowed determining that the three biofilters (B1, B2 and B3),

together with their respective replicates, reduced the total nitrogen and phosphates in a percentage higher than 90%. This allowed concluding that the Floating Macrophytes Filters FMF, correspond to green and innovative technology in the development process, compared to other conventional treatments and that, through a correct application, could generate a future solution to the contamination of aquatic ecosystems by wastewater. Therefore, it is recommended to carry out new tests to determine the efficiency of the FMF filters against other components with different pollutant loads that simultaneously represent an environmental problem.

Keywords: BIOTECHNOLOGY, FITORREMEDIACIÓN, WATER CHARACTERIZATION, SURFACE RUNOFF, NITRÓGENO, FÓSFORO, EUTROFIZACIÓN, FLOATING MACROPHYTE FILTERS, COLTA (CANTON).

1. Introduction

The eutrophication of the different bodies of surface water in Ecuador, such as rivers, streams, lakes and lagoons, is mostly influenced by natural and anthropogenic sources, as is the case of wastewater discharge, with large amounts of solid and liquid waste; from human settlement activities and soil runoff due to rainfall and agricultural runoff that accumulate different concentrations of pollutants. Among the pollutants present are: sediments with a large amount of organic matter remains from fertilizers, pesticides, detergents and soaps, increasing values of nitrogen and phosphorus, which are considered essential nutrients for plants, and in high concentrations, cause excessive growth of vegetation in the water, which is related to the reduction of dissolved oxygen and the biological capacity of the same.

Self-purification is a phenomenon that occurs in most surface waters and is of great importance because it allows them to regenerate themselves, thanks to physical, chemical and biological principles that occur naturally during their journey at different distances and speeds. As a result, the water comes into contact with the oxygen in the atmosphere, allowing pollutants to be diluted, reducing their danger and permanence, as long as the pollutant load does not exceed its regeneration capacity. However, when talking about lakes or lagoons, the situation becomes different since there is no internal circulation of water and since they are monomictic bodies, they are influenced by wind and surface runoff (Mazzeo et al., 2005, pp. 40-43).

Among the freshwater bodies most prone to eutrophication are lakes and lagoons, such as the Colta Lagoon, located in the Colta Canton, Province of Chimborazo, with a length of 2500 meters and a width of 1000 meters and a temperature that varies between 12°C and 15°C. This micro-watershed is surrounded by 15 communities whose main activities are agriculture and grazing (Moreta, 2008). This micro-watershed is surrounded by 15 communities whose main activities are agriculture and grazing (Moreta, 2008). Over the years, the lagoon has become the primary recipient of effluents from anthropogenic activities, causing the growth of a large amount of Totora in its waters, which causes eutrophication processes (Delgadillo et al., 2016, p. 21).

Totora is an invasive plant of high productivity, which over time has become complex to control

because it does not need favorable conditions such as optimum environmental temperature, high oxygenation, specific substrate and a certain pH for its development. On the contrary, it is resistant to lack of oxygen and requires nutrients such as nitrogen and phosphorus (causing eutrophication) for its reproduction, commonly found in wastewater of anthropogenic origin (Delgadillo et al., 2016, pp. 21-26), thus causing the deterioration of the lagoon, due to the decrease of dissolved oxygen by the decomposition of organic matter, an increase of sediments and turbidity, which determine the green-grayish coloration and reduction of the water mirror (Moreta, 2008, pp. 1-5).
Because of this reality, the present research aims to analyze previous studies that describe the initial processes of eutrophication in lakes and lagoons related to the different pollution sources.

2. Objectives

2.1 General Objective

To compare the efficiency of Floating Macrophyte Filters in treating eutrophic lake water.

2.2 Specific objectives

- ✓ Conditioning of floating structures for the growth of Totora in experimental units.
- ✓ Establish the different control parameters to be applied in the experimental units.
- ✓ Determine the efficiency of the Floating Macrophyte Filters from the concentration of nitrogen and phosphorus obtained in the characterization of treated water.

Research methodology

3.1 Place of investigation

Colta Lagoon, Colta Canton, Province of Chimborazo, Chimborazo Province

3.2 Hypotheses

3.2.1 General assumptions

Macrophyte Flotation Filters based on Totora are efficient for treating eutrophic lake water.

3.3 Type and design of research

This is descriptive-experimental research because different control parameters were manipulated to obtain quantitative results and to characterize and evaluate the experimental units.

3.3 Unit of analysis

The design criteria for wetlands with aquatic plants in Table 1-5, according to EPA (2006), were used as a reference for the sizing and construction of the experimental units. The unit of analysis consisted of three biofilters, each with its respective replicates, as detailed below:

Biofilter 1 (B1): Totora was placed on floating structures, which allowed keeping the roots inside the water to be treated (Colta Lagoon) and the stems on the outside. These experimental units were considered the target of the research since no control variables were applied to them, allowing the comparison of their results with those obtained in Biofilters B2 and B3, which were identified as follows:

B1r1 (Biofilter 1 replica 1), B1r2 (Biofilter 1 replica 2), B1r3 (Biofilter 1 replica 3)

Biofilter2 (B2): Totora was placed on floating structures, allowing the roots inside the water to be treated (Colta Lagoon) and the stems outside. Oxygenation was added to these experimental units as the first control variable, 24 hours a day, 7 days a week, identified as follows:

B2r1 (Biofilter 2 replica 1), B2r2 (Biofilter 2 replica 2), B2r3 (Biofilter 2 replica 3)

Biofilter 3 (B3): Totora was placed on floating structures, which allowed keeping the roots inside the water to be treated (Colta Lagoon) and the stems on the outside. In addition to oxygenation, a solution of mineral salts and phytohormones was added to these experimental units to stimulate the growth of the plant species as a second control variable, identified as follows:

B3r1 (Biofilter 3 replica 1), B3r2 (Biofilter 3 replica 2), B3r3 (Biofilter 3 replica 3)

The three experimental units and their respective replicates were placed inside a greenhouse 5 meters long by 3 meters wide to prevent climate variations from affecting the plants' development and the results' veracity.

Figure 1. Floating Macrophyte Filter Greenhouse
Source: Diana Quintana, 2017

3.4 Data collection technique

Different methods and experimental techniques required for the characterization of the water were used for the development of the research, in addition to the control of the different field conditions.

3.4.1 Experimental technique

Water characterization data for each unit of analysis were collected in three stages at the beginning, middle and end:

- ✓ An initial characterization of parameters such as total nitrogen, phosphates, BOD5, COD, total coliforms, Total Dissolved Solids (TDS), temperature, pH, turbidity and conductivity was carried out to determine the current state of the Colta Lagoon.
- ✓ After 15 days of treatment and to evaluate the removal of contaminants, a second characterization of total nitrogen, phosphates, temperature, Total Dissolved Solids (TDS), turbidity, pH and conductivity was performed.
- ✓ After 30 days and to evaluate water quality at the end of treatment, a final characterization of total nitrogen, phosphates, BOD5, COD, total coliforms, Total Dissolved Solids (TDS), temperature, pH, turbidity and conductivity was performed.

3.4.2 Observation technique

The observation techniques used during the research phase are shown below:

- ✓ Growth and development of Totora - Determination of the size of the stems and roots of the plant species at the beginning and end of the treatment in each experimental unit.
- ✓ Temperature, pH, odor and color monitoring - Temperature and pH recording for 4 weeks; subjective water color and odor determination.
- ✓ Sludge formation - Verify the presence of sludge in each experimental unit.
- ✓ Stability of floating structures - Control of floating structures placed on the water to be treated.

4. Results and discussion

4.1 Conditioning of floating structures for the growth of Totora in experimental units

4.1.1 Sizing of experimental units

Tank sizing

For the sizing of the experimental units, the criteria for the construction of wetlands with aquatic plants described in Table 1 were taken into account, as well as the volume of water to be treated, obtaining the following results:

Parameters	**B1** (White)	**B2**	**B3**
Length	1m	1m	1m
Height	0,30 m	0,30 m	0,30 m
Width	0,56 m	0,56 m	0,56 m
Volume	88 L	88 L	88 L

Distance between floating structures	0,5 m	0,5 m	0,5 m
Plants / biofilter	8 floors	8 floors	8 floors
Plant spacing	0,10 m	0,10 m	0,10 m
Depth of implantation	0,05 m	0,05 m	0,05 m
Type of water	Lake water	Lake water	Lake water
Oxygenation	No	24/ d, 7 days a week	24h/d, 7 days a day week
Retention time	30 days	30 days	30 days
Substrate	No	No	Yes

Table 1. Experimental unit sizing results
Source: Diana Quintana, 2017

4.2 Selection of the different control parameters to be applied to the experimental units

4.2.1 Initial characterization of the water of the Colta Lagoon

A physical, chemical and biological characterization of the water of the Colta Lagoon was carried out to determine its natural state before starting treatment in the biofilters; the following results were obtained:

Parameters	Unit	Value
Total Nitrogen	(mg/l N)	60
Phosphates	(mg/l $PO4^{3-}$)	20
pH		10
Temperature	(°C)	20
TDS	(mg/l)	1000
Conductivity	(mS/cm)	2,07
Turbidity	(NTU)	11,1
BOD	(mg/l)	40
COD	(mg/l)	60
Total coliforms	(UFC)	192

Table 2. Initial characterization of Colta Lagoon water
Source: Diana Quintana, 2017

Table 2 shows representative levels of total nitrogen (60mg/l) and phosphates (20mg/l), which are closely related to the accumulation of sediments that contribute nutrients and organic matter due to the lack of environmental sanitation of wastewater generated by anthropogenic activities in the study area such as agriculture, livestock, grazing and urbanization (Martelo & Lara, 2012). Another important parameter of the quality and effectiveness of the water treatment is total coliforms; their characterization showed high levels (192 CFU), a clear indication of water contamination, a product of animal and human excreta, due to the presence of nutrients and organic matter, which generate an optimal environment for their reproduction (Anon., 2008).

4.2.2 Definition of control parameters

Once oxygenation and mineral salts solution were defined as control variables in Biofilters B2, B3 and their corresponding replicates, the following parameters were characterized 15 and 30 days after starting treatment:

- ✓ Total nitrogen
- ✓ Phosphates
- ✓ Conductivity
- ✓ Turbidity
- ✓ Temperature
- ✓ pH
- ✓ Total dissolved solids
- ✓ BOD5
- ✓ COD.
- ✓ Total coliforms

Temperature was monitored for 4 weeks after the treatment systems were in operation, and the following results were obtained:

	T min. °C	T max. °C	T min. °C	T max. °C
	9:00 - 13:00		14: 00 - 22:00	
Week 1	17	25	25	22
Week 2	17	25	25	21
Week 3	17	24	24	20
Week 4	17	26	26	21

Table 3. Average temperatures recorded inside the greenhouse
Source: Diana Quintana, 2017

Table 3 shows the temperature values (°C) taken with an environmental thermometer, which were recorded in the morning (9:00-13:00) and afternoon (14:00-22:00). Due to the increase in solar radiation in the afternoon hours, the average greenhouse temperature was 25°C, which favored the increase of the microbial population responsible for the oxidation of the organic matter present in the water and the growth and development of the plants; ranges determined between 20°C and 30°C accelerate the chemical reactions responsible for the photosynthetic process (CANNA Research, 2015).

4.2.3 Intermediate characterization of the water of the Colta Lagoon

After 15 days of operation of the biofilters, the physical-chemical characterization of the established parameters was carried out, and the percentage of removal for each replicate was determined, obtaining the following results:

Intermediate characterization of Biofilter B1					
Parameter	**Unit**	**Replica 1**	**Replica 2**	**Replica 3**	**Average removal %**
Total Nitrogen	(mg/l N)	2	5	2,4	94, 78
Phosphates	(mg/l $PO4^{3-}$)	0,11	0,18	0,09	99,37
pH		9,48	9,22	9,33	6,57
Temperature	(°C)	22,3	22,3	22,3	
TDS	(mg/l)	860	670	940	17,67
Conductivity	(mS/cm)	1,61	1,25	1,76	25,61
Turbidity	(NTU)	2,32	1,44	2,25	81,95
Intermediate characterization of Biofilter B2					
Total Nitrogen	(mg/l N)	4	3,5	3,8	93,71
Phosphates	(mg/l $PO4^{3-}$)	0,27	0,05	0,18	99,17
pH		9,24	9,22	9,30	7,47
Temperature	(°C)	22,6	22,6	22,6	
TDS	(mg/l)	670	690	700	31,33
Conductivity	(mS/cm)	1,25	1,35	1,45	34,787
Turbidity	(NTU)	1,54	1,38	1,02	88,17
Intermediate characterization of Biofilter B3					

Total Nitrogen	(mg/l N)	15	14,5	12	76,94
Phosphates	(mg/l $PO4^{3-}$)	0,78	7	10	70,37
pH		8,58	9,33	8,05	13,47
Temperature	(°C)	22,5	22,5	22,5	
TDS	(mg/l)	820	720	650	27
Conductivity	(mS/cm)	1,54	1,35	1,80	24,47
Turbidity	(NTU)	18,5	17,0	19,0	0

Table 4. Intermediate characterization of experimental units B1, B2 and B3.
Source: Diana Quintana, 2017.

Table 4 shows the results of the physical and chemical parameters characterization after 15 days of treatment with the experimental units and their respective replicates. In biofilters B1, B2 and B3, total nitrogen is reduced to values close to 5 mg/l, 4 mg/l and 15 mg/l, respectively; phosphates are reduced to values close to 1 mg/l in B1 and B2 and 10 mg/l in B3. The pH value remained constant in the experimental units; the total dissolved solids (TDS), conductivity and turbidity decreased in biofilters B1 and B2, which did not happen in biofilter B3 because turbidity increased to a value close to 19 NTU.

The results of the characterizations of the established parameters allowed determining the average percentages of removal of these parameters in each biofilter (equations 2-4), as shown below:

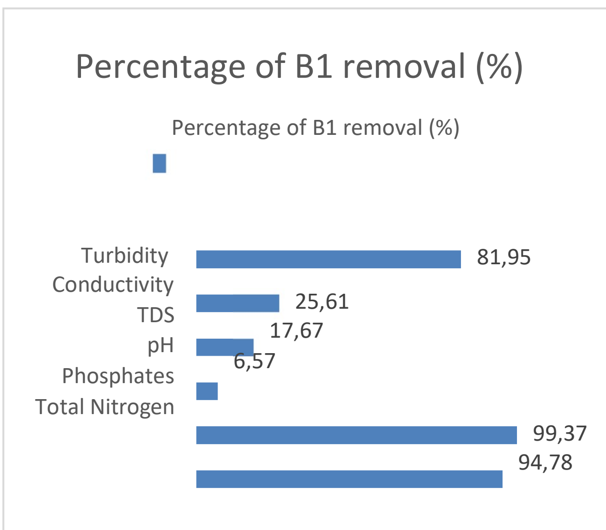

Figure 2. Percentage of removal in Biofilter B1

Source: Performed by: Diana Quintana, 2017.

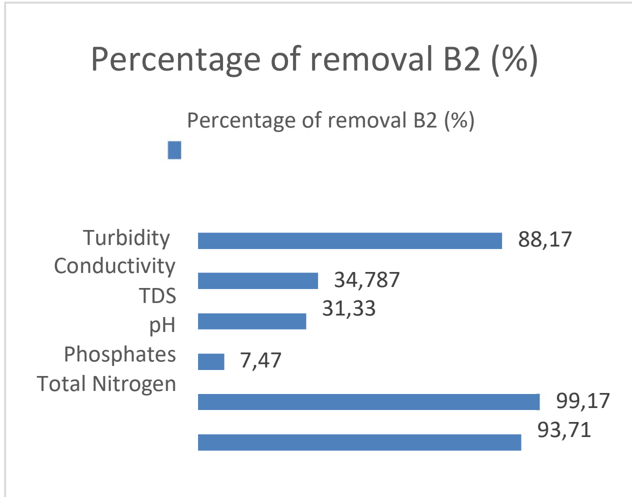

Figure 3. Percentage of removal in Biofilter B2
Source: Performed by: Diana Quintana, 2017.

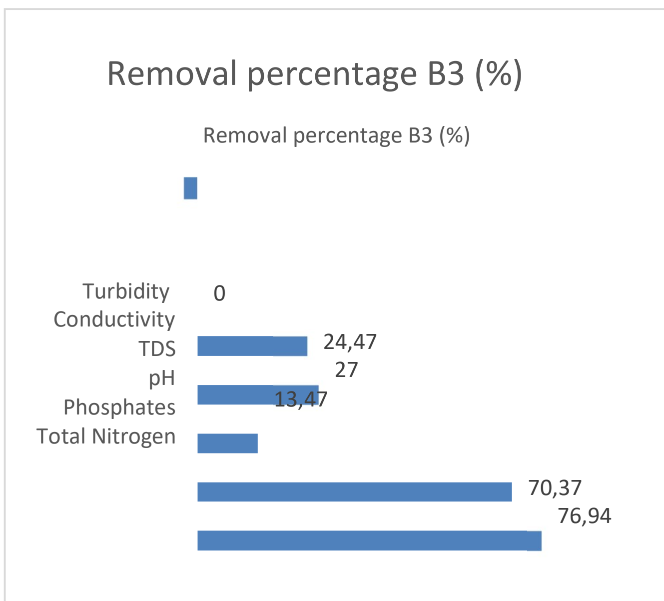

Figure 4. Percentage removal in Biofilter B3
Source: Performed by: Diana Quintana, 2017.

Figures 2, 3 and 4 represent the average removal rates (%) of the physical and chemical parameters characterized in the treatment systems. The reduction percentages for total nitrogen in biofilters B1, B2 and B3 were 94.78%, 93.71% and 76.94%, respectively, where Totora and oxygenation allowed the reproduction of microorganisms responsible for the transformation of organic nitrogen into ammoniacal nitrogen (ammonification) since they obtain energy by oxidizing the organic matter present in the water. The average temperature recorded in the greenhouse was 25 °C, and the pH remained constant in all experimental units (alkaline), both optimal parameters for the reproduction of nitrifying bacteria that resulted in the formation of nitrites and nitrates (nitrification). Plants eventually assimilated these compounds for protein synthesis during their metabolism and by microorganisms in the system (Curt, 2009, pp. 73-75).

Phosphate removal in biofilters B1, B2 and B3 were 99.37%, 99.17% and 70.37%, respectively, high percentages that explain the capacity of plants to absorb this compound and integrate it into their metabolism during photosynthesis (Korkusuz et al., 2004; cited in Romero et al., 2009); in addition, they can incorporate this nutrient into their plant tissue during growth (Lahora Cano, 2004; cited in Delgadillo et al., 2016). Totora root growth averaged 15 and 20 centimeters during the 30 days of treatment, as shown in the results.

Turbidity removal in biofilters B1, B2 and B3 was 81.95% and 88.17%, respectively; this parameter indirectly represents the suspended solids present in the water, attributing the high percentages of its reduction to the rhizofiltration mechanism by the Totora (Guardián & Coto, 2010, p. 21). On the contrary, in biofilters B3r1, B3r2 and B3r3, there was no removal at all (0%) due to the addition of mineral salts that acted as a stimulant for the reproduction of bacteria, which generated an increase in turbidity.

The processes of mineralization and decomposition of nitrogen and phosphorus in the experimental units did not influence conductivity and total dissolved solids (TDS). As these parameters are closely related, the reduction percentages were less than 40% due to sediments at the bottom of the wetlands (Hernández, 2012, p. 86).

4.2.4 Final characterization of the water of the Colta Lagoon

After 30 days of operation of the biofilters, the physical, chemical and biological characterization of the established parameters was carried out, and the percentage of removal for each replicate was determined, obtaining the following results:

Final characterization of Biofilter B1					
Parameters	**Unit**	**Replica 1**	**Replica 2**	**Replica 3**	**Average removal %**
Total Nitrogen	(mg/l N)	Not detectable	Not detectable	Not detectable	100
Phosphates	(mg/l PO_4^{3-})	0,75	0,80	0,90	95,92
pH		9,60	9,30	9,02	6,9

Temperature	(°C)	18,8	18,8	18,8	
TDS	(mg/l)	700	690	685	30,83
Conductivity	(mS/cm)	1,31	1,34	1,33	35,91
Turbidity	(NTU)	1,20	1,30	1,40	88,29
BOD5	(mg/l)	8,0	8,3	8,4	79,42
COD	(mg/l)	40,0	40,2	40,4	33
Total Coliforms	UFC	30	40	35	81,77
Final characterization of Biofilter B2					
Total Nitrogen	(mg/l N)	Not detectable	Not detectable	Not detectable	100
Phosphates	(mg/l PO_4^{3-})	0,45	0,50	0,55	97,5
pH		9,52	9,55	9,54	4,63
Temperature	(°C)	18,8	18,8	18,8	
TDS	(mg/l)	490	480	489	51,37
Conductivity	(mS/cm)	1,38	1,45	1,50	30,26
Turbidity	(NTU)	1,02	2,0	2,80	82,52
BOD	(mg/l)	6,5	7,0	7,5	82,5
COD	(mg/l)	90	80	92	0
Total coliforms	UFC	25	30	35	84,37
Final characterization of Biofilter B3					
Total Nitrogen	(mg/l N)	2	2,5	1,5	96,67
Phosphates	(mg/l PO_4^{3-})	0,54	0,60	0,65	97,02
pH		9,51	9,30	9,20	6,63
Temperature	(°C)	18,8	18,8	18,8	
TDS	(mg/l)	800	820	870	17
Conductivity	(mS/cm)	1,53	1,60	1,63	23,35

Table 6. Final characterization of experimental units B1, B2 and B3.
Performed by: Diana Quintana, 2017

Table 6 shows the results of the characterization of the physical, chemical and biological parameters after 30 days of treatment; where in biofilters B1, and B2, the consumption of total nitrogen is observed, i.e., there was a complete removal. In biofilter B3, values close to 3 mg/l were obtained; for phosphates, values close to 1 mg/l were obtained in biofilters B1, B2 and B3. The pH value remained constant (above 9) and alkaline in the nine experimental units; total dissolved solids (TDS), conductivity and turbidity decreased in biofilters B1 and B2, which did not happen in biofilter B3 because the latter parameter increased to a value close to 20 NTU.
BOD5 was reduced to values close to 8 mg/l for biofilters B1 and B2 and 40 mg/l for biofilter B3. However, COD only presented reduction values in biofilter B1 (40 mg/l), which did not happen in biofilter B2 and B3, where values increased between 100 mg/l and 200 mg/l.
Total coliforms were reduced to values close to 40 CFU for biofilters B1 and B2. On the contrary, in biofilter B3 they increased to values above 200 CFU.
The results of the characterizations of the established parameters allowed determining the average percentages of removal of these parameters in each biofilter, as shown below:

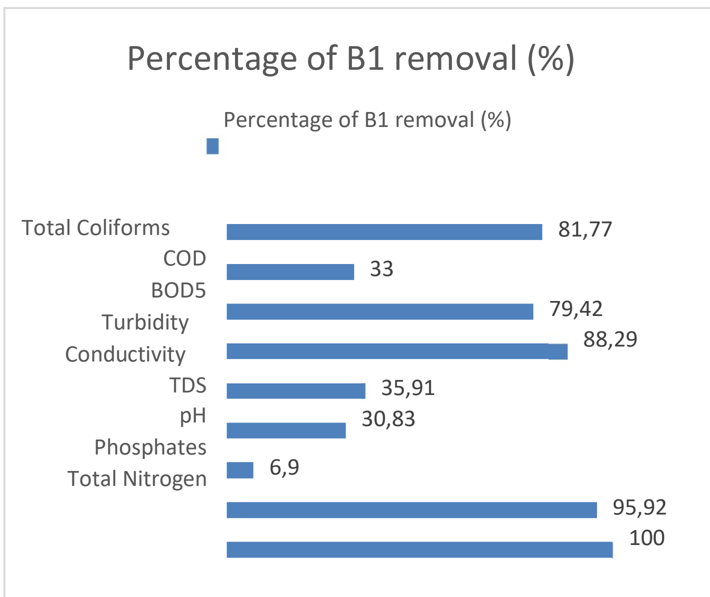

Figure 5. Percentage of removal in the Biofilter B1
Source: Performed by: Diana Quintana, 2017.

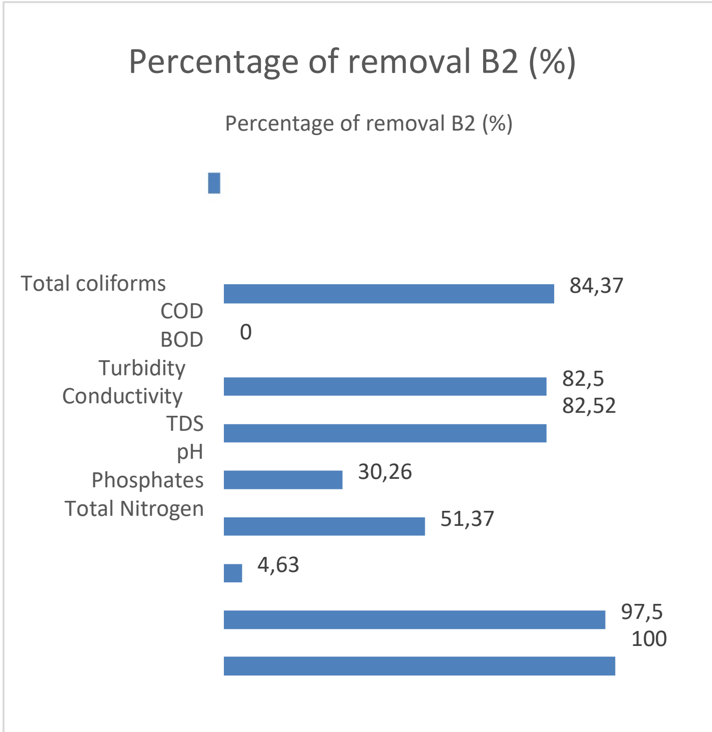

Figure 6. Percentage of removal in Biofilter B2
Source: Performed by: Diana Quintana, 2017.

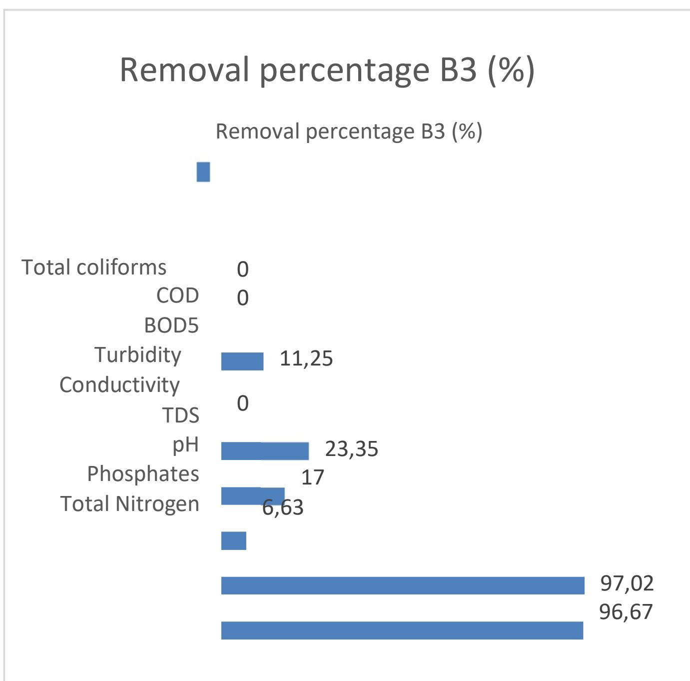

Figure 7. Percentage of removal in Biofilter B3
Source: Performed by: Diana Quintana, 2017.

Figures 5, 6 and 7 represent the average removal rates (%) of the physical, chemical and biological parameters characterized in the treatment systems. For example, the reduction percentages for total nitrogen in biofilters B1 and B2 were 100%; for biofilter B3 it was 96.67%, which is also high. Furthermore, both the average temperature (25°C) and pH (alkaline) remained in the optimal range for the reproduction of nitrifying microorganisms, which indicates that the nitrogen removal cycle continued after 15 days of treatment, transforming these compounds into nitrites and nitrates, the latter vital for protein synthesis during the growth of plant species. Finally, the plants' nitrogen was assimilated and removed from the system, thanks to the mineralization and decomposition mechanisms by the microorganisms (Lara-Borrego, 1999; cited in Hernández, 2009).

The phosphate removal percentages in biofilters B1, B2 and B3 were 95.92%, 97.5% and 97.02%, respectively, which indicates that after 30 days of treatment, there was no greater removal of this parameter since its elimination from the system is limited by the form of phosphorus present in the water, assimilation by plants and biomass (microorganisms) (Karpiscak and Foster, 2000; cited in Romero et al., 2009).

The BOD5 removal percentages in biofilters B1 and B2 were 79.42% and 82.5%, respectively. The average temperature recorded in the greenhouse was 25°C, which favored the development of microorganisms present in the water, responsible for the oxidation of organic matter, and also due to the aerobic environment generated by the presence of the Totora and the oxygenators (B2). These percentages were high in comparison with biofilter B3 (11.25%), where the low removal is related to the decomposition process of the organic compounds added in the solution of mineral salts supplied due to the fact that by increasing the organic matter, the microorganisms require more oxygen to degrade it into inorganic elements, which cause the increase in BOD5 levels (Álvarez & Bécares, 2006, pp. 1-8).

COD removal in biofilter B1 was 33% due to the increase in microbial activity that uses organic matter for its metabolism and the oxidation-reduction reactions within the wetland (Kadlec et al., 2000; cited in Romero et al., 2009). On the contrary, in biofilters B2 and B3, after 30 days of treatment, this parameter increased, the main reason being the dragging of the roots and the detachment of the biofilm located around the rhizomes due to the aeration process incorporated in the biofilters, which upon degradation increase the organic matter, raising the COD level (Quipuzco, 2002; cited in Romero et al., 2009).

Total coliforms reached reduction percentages of 81.77% and 84.37% for biofilters B1 and B2, respectively, knowing that solar radiation, filtration by plants and the presence of predatory microorganisms confer the capacity for their elimination (Delgadillo et al., 2016, pp. 22-25). In biofilter B3, there was no removal of pathogens (0%), but it did increase because the solution supplied favored their development.

5. Conclusions

The efficiency of three Floating Macrophyte Filters (B1, B2, B3) and their respective replicates, used in the treatment of water from the Colta Lagoon, were compared based on the initial, intermediate and final characterizations of the concentrations of total nitrogen and phosphates of each biofilter. In addition, the data obtained were subjected to statistical tests, with which efficiency curves were also made to determine the most effective treatment.

The Floating Macrophyte Filters (FMF) were conditioned according to a documented review, which allowed determining the criteria for the sizing of the experimental units; accordingly, a greenhouse was built to control the environmental temperature, inside which the proposed biofilters were structured, each with a capacity to treat 88 liters of water, on which Totora plants, aeration systems and a solution of mineral salts and biologically active phytohormones were placed.

The control parameters established during the experimentation were two: in biofilter B2r1, B2r2 and B2r3 oxygenation (7 days a week, 24 hours a day), which allowed the reproduction of aerobic microorganisms, and in biofilter B3r1, B3r2 and B3r3 a solution of mineral salts (0.22 l/biofilter) was added to stimulate the growth of the Totora and its roots; In biofilters B1r1, B1r2 and B1r3 no control variables were used since they were the target of the research.

The Floating Macrophyte Filters (FMF) efficiency was determined by performing a DCP statistical analysis, which showed the biofilters that obtained the highest percentage of removal of eutrophying nutrients. Thus, after 30 days of treatment, total nitrogen in biofilter B1 achieved a reduction equal to 86%, followed by biofilter B2 with 83.28% and finally biofilter B3 with 30.72%; for phosphates, biofilter B2 presented a value equal to 91.8%, followed by biofilter B1 with 88.4% and finally biofilter B3 with 19.8%; that is, both B1 and B2 are efficient in the treatment for the removal of nitrogen and phosphorus. It should also be emphasized that biofilter B1 was only formed with Totora as a medium for absorption without any control variable, its removal as high as biofilter B2 (with oxygenation); in addition, the importance of the floating structures should be taken into account, which allowed direct contact of plant roots with the water to be treated.

Finally, the removal percentages for BOD5 were equal to 86.2%, 83.77% and 30.03% and for COD were equal to 87.41%, 72.64% and 39.95% in biofilters B1, B2 and B3, respectively, which also demonstrates the efficiency of the experimental units in the removal of organic matter.

6. Recommendations

Adequate time is required for the cattail to adapt to environmental conditions before its implantation. Since these have developed under different climatic conditions, the time can be determined by the researcher and by the development observed in the plants.

It is advisable to control the proliferation of algae within the Floating Macrophyte Filter (FMF) systems, especially if the aquatic systems are exposed to the sun; the uncontrolled growth of algae causes their metabolism to decrease the presence of dissolved oxygen in the water while competing for it with the macrophytes used in the research, in this case, Totora.

The greenhouse temperature should be considered before the Floating Macrophytes Filters operation because on hot days, they can exceed the optimum temperature for the growth of the Totora, causing thermal stress in the plants and their subsequent death. Therefore, it is advisable to build curtains that allow air passage during the day to generate a thermal balance.

The use of substrates of inorganic origin is recommended, such as mineral stones that allow the adsorption of solid contaminants, microorganisms, organic matter, and nutrients, among others, that cannot be absorbed directly by the plants, thanks to their large internal surface and long lifetime, avoiding unnecessary expenses since they are easy to obtain and their use time is prolonged.

Oxygenation is considered an important control parameter since it allows the reproduction of aerobic microorganisms, which are essential for the degradation of pollutants present in the water, such as suspended solids and organic matter, and the use of oxygen diffusers homogeneously distributed in the water is recommended.

Suppose it is desired to generate new data on the absorption capacity of pollutants in eutrophic lake waters by applying aquatic macrophytes. In that case, it is recommended to use plant species developed in greenhouses under the field conditions to which the research will be subjected, to be subsequently compared with plant species native to the water area to be treated.

It is recommended to generate new research in the field of aquatic macrophytes as phytodepuration plants, not only for the removal of eutrophying nutrients such as nitrogen and phosphorus but also for the removal of other pollutants from wastewater of different origins in order to present the Floating Macrophytes Filters as a non-conventional system oriented to be a technology that will improve the quality of life of people and the conservation of aquatic ecosystems.

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