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Feasibility Study Using Lemna Minor Treatment of Domestic Wastewater, from an Educational Institution

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Abstract

Conduct an investigation about wastewater domestic treatment processes, which are efficient and at the same time requiring low investment and maintenance cost, using aquatic flora present in the region. Were collected wastewater samples from our Institute in two different periods, in order to cover a full year and to make a more realistic characterization of the conditions of the effluent to be used. Lemna Minor or Duckweed was selected to carry out the removing contaminants process due of its availability and ease use. Basic analyses were established to carry out water characterization, and they were conducted sample analysis of untreated wastewater, and five days treated wastewater using Lemna Minor. The activated sludge treatment to removal BOD, COD and nutrients is very efficient and can be appropriate where high removal of organic pollution is required. Otherwise, activated sludge requires the continuous operation of oxygen blowers and sludge pumps, that involves mayor investments and high costs in maintenance and purchase of reagents, which are the main arguments supporting the choice of cheaper alternative treatments, as would the use of a biological process with native plants of the region. On the other hand, having a whole methodology for implementing the type of wastewater treatment being proposed, this can be implemented in residential colonies, where treated wastewater would be used for irrigation of green areas. An additional contribution is achieved when students are involved in a research work, so that provides training in the research process, developing their skills in science, critical, deductive and inductive thinking, thereby contributing to their professional growth.

Wastewater Domestic Treatment, Lemna Minor, Educational Institution, arid climates

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Introduction

Meeting the need to ensure an adequate water supply for Instituto Tecnológico de Chihuahua II green areas irrigation, this research project arises.

It seeks to design a treatment plant that uses sewage water discharge from the use of this resource in the facilities of our institution.

To carry out this work an exhaustive literature search about treatment processes was performed, looking for those that are appropriate to the waste effluent characteristics and at the same time requiring low investment and maintenance costs (Mahmood Q., et al., 2013).

The process suggested in principle, uses aquatic flora found in the region, for the degradation of organic matter, specifically the use of Lemna Minor or duckweed, probably in combination with Juncus as species associated with duckweed for the winter season.

It has been extensively researched the contamination cleaning potential and capacity of Lemna spp for the uptake and accumulation of mineral (Barba Ho, L. E., 2002), heavy metals (Shazia Iram et al., 2012), radionuclides as well as metalloids.

Additionally it demonstrated, cleaning capacity to remove ammonia and phosphorus from water. L. minor and L. gibba can metabolize phenol and a series of chlorinated phenols (Mkandawire M., Dudel E. G., 2007).

Considerable work has been done on the use of Lemna spp. as a means of treating wastewater of both agricultural and domestic origin (León M., Lucero A. M., 2009), (Arroyave M., 2004).

There is information that showing Lemna elimination capacity for organic material in terms of biological oxygen demand (BOD) and chemical oxygen demand (COD) (Valderrama et al.,), (Ramirez L., Sierra L., 2010), (Martínez P. et al., 2006), (Ozengin N. and Elmaci A., 2007).

It is noteworthy that have been considered various factors to reject the use of Lemna for wastewater treatment. Such factors include the need to remove Lemna excess due to its heavy growth presented in nutrient-rich environments (Canales A., 2010)

It has been found Lemna species have more environmental benefits than mere phytoremediation potential. Initially, a great deal of work has been done on the nutritional value of the species of the Lemnaceae in aquaculture (Zetina Córdoba et al., 2010) and livestock production (Rodriguez C. et al.).

Another point that is considered negative is the narrow temperature range at which Lemna spp. can survive and develop optimally (18-24 ° C). We evaluate the lower limit of temperature at which L. minor could survive in conditions typical of our region, finding that there was a growth decrease but not extinction at such low temperatures of 2 ° C.

A point in favor of our project is the water reduced evaporation in Lemna-covered wastewater treatment that is very important for weather and extreme aridity of our environment conditions.

It is noteworthy that there have been some projects in our community who have tried using Lemna species for the treatment of wastewater from educational institutions, but difficulties have arisen due to nutrient lack and system temperature monitoring.

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An important aspect to this type of research projects is the possibility of involving students who develop research skills, critical thinking and initiative but especially, sensitivity to environmental care through the development of simple and friendly technologies with nature.

Finally, it is considered likely that the development of a system of wastewater treatment, like the being investigated, it could be adopted by residential construction companies, which would benefit from the use of their own treated water for its green areas irrigation, stressing the growing shortage of the vital liquid that has suffered in recent years our state.

Methodology

Wastewater characterization

Samples of wastewater from our Institute were collected in two different periods: one at the end of the first half of the year (Table I), and two in the second half of 2013 (annexes), this in order to be able to make a more realistic characterization of the effluent conditions that will be used in the treatment plant as well as to obtain the corresponding capacity and to know the flow is to be handled. Analyses were performed by a particular company and the faculty of Zootecnia y Ecología at the Universidad Autónoma de Chihuahua, showing the most relevant results in Table I.

Determination of the temperature range

Samples of L. minor from the river and Chuvíscar dam were taken and placed on the outside of Chemistry Laboratory in a place where solar radiation occurs during the morning and exposed outdoors but closed to air currents, this to lessen the water temperature drop during the winter months .

The minimum air temperature was reduced to 2 °C without there being a severe impairment in Lemna fronds solely decreased growth.

The year 2013 proved to be particularly warm in our region with maximum air temperatures approximate 40 ° C during the summer, which does not affect in any way the samples of L. minor that remained in constant growth due to adequate supply of nutrients.

Parameter	Units	Method	Results	*MAL
Settleable solids	ml/l	NMX-AA-004-SCFI-2000	1.5	5
Fats and oils	mg/l	NMX-AA-005-SCF-2000	13.3	60
Total Nitrogen	mg/l	NMX-AA-026-SCF-2010	49	60
Detergents	mg/l	NMX-AA-039-SCF-2001	2.4	20
BOD	mg/l	NMX-AA-028-SCF-2001	152	200
QOD	mg/l	NMX-AA-030-SCF-2001	361	400
Total suspended solids	mg/l	NMX-AA-034-SCF-2001	76	300
pH			7.56-8.86	6.5-8.5
Water temperature	°C		22.8-26.1	40
Electric conductivity	µS/cm		741-1322	**dna

Table 1 Wastewater characterization of Instituto Tecnológico de Chihuahua II, May 2013

Conditioning L. minor

Samples of the Lemna Minor species extracted from the Chuviscar dam located south of Chihuahua City were subsequently adapted for use in experimentation.

Plants were washed with chlorine free tap water and transferred to a prepared solution with the nutrients described in Table II, for its conditioning (Worthington A., 1995), (Barba Ho, L. E., Edith L., 2002).

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It established the basic analysis to perform the characterization of water subjected to the treatment process with Lemna (APHA, 1992).

The basic analyzes were determining pH, electrical conductivity, settleable solids , Dissolved Oxygen , Chemical Oxygen Demand, Biochemical Oxygen Demand and Total Nitrogen .

Nutrient	Nutrient
KNO_3	$MnCl_2 \cdot 4H_2O$
$ZnSO_4 \cdot 7H_2O$	H_3BO_3
$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$	KH_2PO_4
$MgSO_4 \cdot 7H_2O$	$Ca(NO_3)_2 \cdot 4H_2O$
$FeCl_3 \cdot 6H_2O$	

Table 2 Nutrients necessary for the development of Lemna species (Worthington A., 1995)

Development of experimentation

To determine the ability of L. minor to degrade organics, wastewater composite samples from our Institute were taken and were handled four different concentrations: 100 %, 50 %, 25 % and 12.5 %, with three repetitions each.

Were used plastic containers of 500 ml and a 10.5 cm diameter (area = 0.008659 m^2). Wastewater samples with different concentrations and with an amount of 5 g of duckweed, slightly higher than reported in literature of 400 g / m^2 (Barba Ho L. E., Edith L., 2002) were placed.

It was allowed to act duckweed for a period of five days, and daily measurements of temperature and pH of the samples were made.

After five days reweighed Lemna samples and chemical analysis were made of samples of treated water.

Results

As shown in Table I and reports shown in the Annexes, the wastewater of our Institute are primarily domestic, with all parameters examined in the relevant standards , presenting loads of BOD , QOD and nitrogen within the proper range to be treated with Lemna species, with acceptable removal of such contaminants (Ozengin N., Elmaci A., 2007).

From the results obtained by analyzing the initial weight of samples Lemna before being used for the absorption of pollutants from wastewater (organic matter and nutrients) , see Table III , and then reweighing after standing 5 days in containers with different wastewater concentrations , can be seen an increase in weight of all samples. A very similar value of about 2.5 g appears in three of the four samples, but cannot observe any trend or correlation between increased weight of Lemna and the increase or decrease of wastewater concentrations, which suggest make another test run increasing the contact time (at different number of retention days).

Parameter	Samples a (100%)	Samples b (50%)	Samples c (25%)	Samples d (12.5%)
Initial average weight	5.234	5.283	5.296	5.301
Final average weight	7.818	6.084	7.709	8.003
Weight difference	2.584	0.801	2.413	2.702

Table 3 Wastewater samples at different concentrations treated with 5 grams of L. minor

Chemical analyzes of wastewater samples without dilution (100 %) , which were subjected to treatment with Lemna (Table IV) show a decrease of certain parameters.

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The biochemical oxygen demand had a decrease of 12 %, the chemical oxygen demand 20.8 % while total nitrogen decreased 4.3 %

All these values are lower than those reported in the literature, which reaffirms the need for further experiments where different retention times are tested.

Parameter	Samples a (100%)	Untreated sewage, December 2013	% Removal
BOD	142	159	12
QOD	308	372	20.8
pH	7.76	8.2	
D. O.	7.16		
Fats and oils	9.97		
Total Nitrogen	47	49	4.3

Table 4 Analysis performed to residual water samples treated with lemna minor, December 2013

Annexes

Parameter	Units	Method	Results	*MAL
Settleable solids	ml/l	NMX-AA-004-SCFI-2000		5
Fats and oils	mg/l	NMX-AA-005-SCF-2000		60
Total Nitrogen	mg/l	NMX-AA-026-SCF-2010	43	60
Detergents	mg/l	NMX-AA-039-SCF-2001		20
BOD	mg/l	NMX-AA-028-SCF-2001	156	200
QOD	mg/l	NMX-AA-030-SCF-2001	359	400
Total suspended solids	mg/l	NMX-AA-034-SCF-2001		300
pH			7.72-8.21	6.5-8.5
Water temperature	°C		21.9-23.6	40
Electric conductivity	µS/cm		109-162	**dna

Table 5 Analysis performed to untreated sewage, November 2013

Parameter	Units	Method	Results	*MAL
Settleable solids	ml/l	NMX-AA-004-SCFI-2000		5
Fats and oils	mg/l	NMX-AA-005-SCF-2000		60
Total Nitrogen	mg/l	NMX-AA-026-SCF-2010	49	60
Detergents	mg/l	NMX-AA-039-SCF-2001		20
BOD	mg/l	NMX-AA-028-SCF-2001	159	200
QOD	mg/l	NMX-AA-030-SCF-2001	372	400
Total suspended solids	mg/l	NMX-AA-034-SCF-2001		300
pH			8.01-8.28	6.5-8.5
Water temperature	°C		19.8-22.1	40
Electric conductivity	µS/cm		103-174	**dna

Table 6 Analysis performed to untreated sewage, December 2013

We believe important to note that the development of experimentation would have been impossible to carry out without the reagents and materials which were provided with support PROMEP, having this resource for further testing. The Institute performed most of the analysis presented in Table III and IV except for the determination of total nitrogen, as the required equipment is damaged. For this reason, use was made of an agreement of academic cooperation established between our Institute and the Universidad Autónoma de Chihuahua, which gave us their support at this point and so we are extremely grateful.

Conclusions

It is need to perform additional tests to obtain similar results to those reported in the literature, where the percentages of removal are between 50-95%, while the results obtained in this study range from 4.3 to 20.8% (see Table IV).

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On the other hand several dams and canals were monitored near the metropolitan area of Chihuahua City, where Lemna was found in the period from October to June, noting that in the rainy season (July to September) despite having favorable temperature conditions, Lemna was swept by the currents generated by the increased level of dams.

Lemna remained dormant during the months of December to February in the established place outdoors, behind the chemistry lab. This latter finding confirms the possibility of survival of Lemna in the winter at low temperatures around 2 ° C.

With the above observations it is planned to have a kind of nursery to provide the necessary duckweed to the treatment plant during the year.

Finally, there is a need for a prototype, if in the future will have to carry out the project of building the treatment plant.

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