Design and Implement a System of Wastewater Treatment Based on Wetlands

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ABSTRACT

The wetlands are considered as a natural passive cleaning of waste water. Is a process characterizes by its simplicity of operation, low or zero-energy consumption and low waste production. These consist of shallow ponds planted with plants. The processes of decontamination are performed simultaneously by its physical, chemical and biological properties.

The objectives of this work are design and implement a system of artificial wetlands as an alternative method for treating waste water produced from the Faculty of Chemistry Science and Engineering that allow to reduce the costs of operation, knowing the degree of water pollution to determine how efficient the wetland and, finally improve the health and environmental conditions of the irrigation water.

So the first step was to know the degree of water pollution and quantity to determine the wetland process variables.

The second step was to determine the kind of plants that allow reducing the water contaminants. The Manning formula was applied to evaluate the free flow and Darcy's equation for the surface flow by wetlands. A micro-scale prototype was design and built based on buckets.

The absorption capacity of several plants (*Bacopa monnieri*, *Nephrolepis exaltata*,*Tradescantia zebrine*) was determined. Also we use a natural filter consisting of Tezontle (first layer), sand (second layer), gravel (third layer), sand (fourth layer), Tezontle (fifth layer), gravel (sixth layer), sand (seventh layer) and, organic substrate (eighth layer).

A wetland decreases more than 60% the cost compared to a water purification plant as everything is based biodegradable materials and not using any energy or sophisticated equipment to water filtration.

Wetlands not only help to purify the water, but also help the conservation of flora and fauna that is dependent on wet conditions, as only biodegradable materials are used there is no pollution to the ground, helping the conservation of the environment. Today we are evaluating the wastewater flow because the prototype only allows treating from 0-1 L/min.

Key words: wetlands, phytodepuration, *Bacopa monnieri*, *Nephrolepis exaltata*,*Tradescantia zebrine* wastewater treatment plant.

1. INTRODUCTION

Because the treatment of wastewater through conventional treatment systems are expensive both in construction and in operation and taking into account that the pollutant removal rates are poor, alternative methods have been designed and constructed wetlands that are specifically designed and built systems for wastewater treatment in conjunction interacting plants, animals, microorganisms and abiotic environmental factors for treating waste water [1].

The artificial wetlands are artificial constructed wetland systems for wastewater (the term wetlands means Phytodepuration are wastewater systems designed to artificially recreate ecological conditions similar to those established in the areas of water).

The system consists of the development of a cultivation of certain plants rooted on a bed of volcanic rock gravel or sealed. The action makes it possible to plant a series of complex physical interactions, chemical and biological weapons through which the influent wastewater is cleaned and slowly progressive.

A wetland can have the following characteristics: treatments are based on physical, chemical and biological nature, requiring no extra supply of chemical reagents. In regard to its functioning as biological treatment, are operated under anaerobic conditions, facultative and/or aerobic in which oxygen is supplied spontaneously by transport from the atmosphere, which represents a significant saving of energy without mechanical aeration.

Wetlands remove pollutants through various processes including sedimentation, microbial degradation, plant action, absorption, chemical reactions and volatilization.

The operation of constructed wetlands is based on three basic principles: the biochemical activity of microorganisms, the oxygen through the plant during the day and the physical support of an inert bed serves as a support for rooting plants; and serve as filter material. Together, these elements dissolved and suspended materials removed in the wastewater and biodegrade organic matter to mineralization and form new organisms.

Wetlands have three basic functions that give them attractive potential for the treatment of wastewater: contaminant physically set on the surface of soil and organic matter, use and transform the elements by microorganisms and achieve levels of treatment consistent with a low power consumption and low maintenance [2].

Constructed wetlands can be classified according to the type of macrophytes (plants) used in its operation: fixed to the substrate macrophytes (rooted) or free floating macrophytes.

Considering the way of life of these macrophytes, artificial wetlands can be classified as:

Treatment systems based on floating leaf macrophytes, mainly angiosperms on waterlogged soils [3]. The reproductive organs are floating or air. The water hyacinth (*Eichhornia crassipes*) and duckweed (*Lemna sp.*) are the species most used for this system.

Treatment systems based on submerged macrophytes: include ferns, mosses, and charophytes numerous and many angiosperms. They are found throughout the photic zone (at which sunlight reaches), although vascular angiosperms only live to about 10 m depth. The reproductive organs are aerial, floating or submerged.

Treatment systems based on rooted macrophytes emerging in waterlogged soil permanently or temporarily, in general are perennial plants with aerial reproductive organs.

Wetlands rooted macrophytes based on emerging can be of two types, depending on the movement of water used:

1) Surface flow wetland, if surface water circulates among the stems of the macrophytes and,

2) Wetlands subsurface flow, if the water flows below the surface layer of the wetland.

The components of a wetland are water, plants, substrate and the microbial population.

Substrate (granular medium)

In wetlands, the substrate is formed by the soil: sand, gravel, rock, sediment and plant debris that accumulate in the wetland due to biological growth.

The main characteristic is that the medium must have sufficient permeability to permit the passage of water through it. This necessitates the use of granular soil, gravel selected primarily with a 5 mm diameter and few fines.

Substrate, sediments and the remains of vegetation in constructed wetlands are important for several reasons:

- They support many of the living organisms in the wetland.
- The permeability of the substrate affects the movement of water through the wetland.
- Many chemical and biological changes (especially microbial) take place within the substrate.
- Provides storage for many contaminants.

The accumulation of remnants of vegetation increases the amount of organic matter in the wetland. The organic material results in the exchange of matter, fixation of microorganisms and is a carbon source which is both the source of energy for some of the most important biological reactions in the wetland.

The medium is directly responsible for the removal of some pollutants through physical and chemical interactions.

Granular medium size hydraulic flow directly affects the wetland and therefore in the flow of water to be treated. If the granular bed is constituted by high amounts of clay and silt, results in a higher absorption capacity and better filtration, as the adsorption is higher and the diameter of the voids is small. But also this method has a high hydraulic resistance and requires very low flow rates, limiting the flow to be treated. Conversely, if the granular bed comprises sand and gravel, decreases the adsorption capacity and power of the filtering medium, but increases the hydraulic conductivity.

Indirectly, the granular medium contributes to the elimination of pollutants because it serves to support plant growth and colonies of microorganisms that carry out the Bio-degrading activity (Bio-films).

Vegetation

The role of vegetation in wetlands is fundamentally determined by the roots and rhizomes buried. Plants are autotrophic organism's picture, i.e. they collect solar energy to convert inorganic carbon into organic carbon. They have the ability to transfer oxygen from the atmosphere through the leaves and stems to the middle where the roots. This oxygen creates regions where aerobic microorganisms use the oxygen available to produce various reactions of organic matter degradation and nitrification.

Microorganisms

Microorganisms are responsible for conducting biological treatment. At the top of the wetland, dominated by the oxygen released by roots of plants and the oxygen from the atmosphere, Colonies of aerobic microorganisms.

In the rest of the granular bed anaerobic microorganisms predominate. The main processes carried out by microorganisms are the degradation of organic matter, nutrient removal and trace elements and disinfection [2].

The main microorganisms in the bio-film of wetlands are: bacteria, yeasts, fungi and protozoa.
Microbial biomass consumed much of the carbon and nutrients. Microbial activity has the function to transform a large number of organic and inorganic substances into harmless substances and insoluble and alter the conditions of oxidation reduction potential and the substrate thus affecting the processing capacity of the wetland. Moreover, thanks to the biological activity, many of the pollutants are converted into gases that are released into the atmosphere.

The issues that have motivated the growing interest in this technology is that it has large advantages which their investment costs, operation and maintenance are significantly lower than those of conventional treatment systems, its oxygen supply as already mentioned is spontaneous.

But all good as there are some disadvantages to be mentioned not mean that this project is not viable but take into account all aspects. And good the biggest drawback is that they can be fed directly with wastewater of high organic loads and suspended solids. Require pre-treatment, at least, to remove excess suspended solids that could cause clogging of the bed in no time.

The components of a wetland are water, plants, substrate and the microbial population.

The mobile phase is water in the wetland, for the transport of contaminants and which will produce most of the reactions responsible for debugging.

The substrate (or support medium) act as supporting structure of plants and as a surface for the growth and development of the bacterial mass. Mechanisms facilitate adsorption and ion exchange between the waste water and mineral components of the soil.

Many transformations of nutrients and organic carbon in wetlands are due to microbial metabolism and are directly related to the growth of microorganisms. These include mainly bacteria, fungi, and protozoa. This biomass is forming a *biofilm* around the particles of the bed.

The plants can be of different species and rooting habits and its main functions include nutrient uptake, the symbiotic relationship that is established with microorganisms, the oxygen supply, and filtration and particles.

Constructed wetlands have been implemented in the states of Colima, Chihuahua City, Mexico State, Hidalgo, Nayarit, Oaxaca, Tamaulipas, and Tlaxcala. And is told in all of Mexico with 130 plants implemented this process with a flow rate of 0.61% of treated flow treated.

2. METHODOLOGY

We use the Manning formula applied to free flow wetlands and Darcy´s Law applied to surface flow wetlands.

The method used a free-flow wetland due to ground conditions.

We performed a micro-scale prototype, based on buckets, to test the absorptive capacity of each plant to use.

The plants used were *Bacopa monnieri*, *Nephrolepis exaltata* and *Tradescantia zebrina* (See Fig. 1).

Fig. 1. Planst used in the prototype: (1) *Bacopa monnieri*, (2) *Nephrolepis exaltata* and (3) *Tradescantia zebrine*.

3. RESULTS

A natural filter was added consisting of eight layers:

First layer (Tezontle)
Second layer (Arena)
Third layer (gravel)
Fourth layer (Arena)
Fifth layer (Tezontle)
Sixth layer (gravel)
Seventh layer (Arena)
Eighth layer (organic substrate)

In Fig. 2 is shown the material used.

The filling of the cells with the granular flow in horizontal wetlands begins with the placement of the strip of material larger at the beginning and end of the cells. Then proceed to place the granular medium itself. In wetlands are placed vertical flow of granular material layers according to their size by avoiding mixture therebetween. It is very important to check that the granular material to be placed is very clean and free of fines. There should be a good quality control in this regard.


Fig. 2. Material used in the wetlands prototype.

Waterproofing

A traditional method for waterproofing consists in providing successive layers of clay. The process begins with the installation of a thick layer of lime (2-4 cm) to separate the natural ground of the clay layer. Below are placing clay layers 5-6 cm thick, being necessary to keep it moist all the time, and be compacted to a thickness typically of 0.3 m.

Is currently using a methodology based on having a layer of bentonite clay (*montmorillonite* type) between two *geo*-textiles (sandwich type). Simple replacement compacted clay layers produced by this another typology often a considerable saving in the initial cost of a work of waterproofing and always and above all, significant time savings in the construction process.

When using *geo*-membranes optimal dimensions are determined by the shape and size of wetlands. That is why the cells once built; the installers of the sheets must agree to work to take measures.

This activity is important since it is desirable that the welding of the different fabrics which will be composed of the film are made in sweatshops specialized. This will reduce the number of welds made on-site where quality control may be less.

The assembly of the sheets is typically done with thermal welding automatic machine, and with an overlap between sheets of a few centimeters.

It is very important to check that the granular material to be placed is very clean and free of fines. There should be a good quality control in this regard.

In the Fig. 3 is presented the layers compositions of the support material.

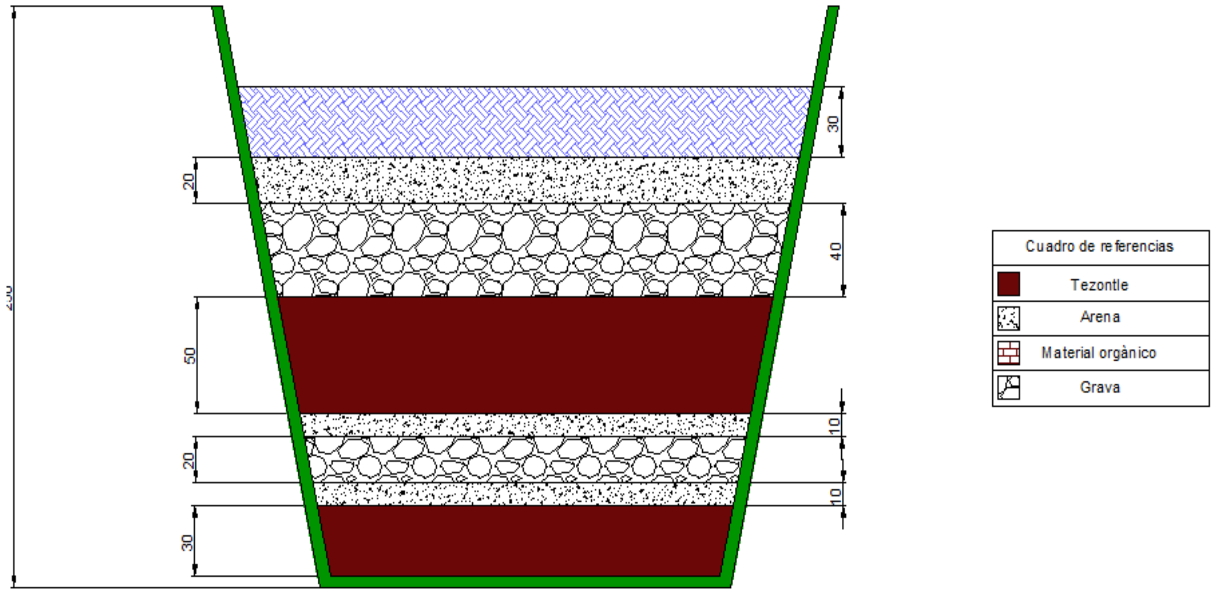

Fig. 3. The final design of layers in the wetland prototype.

This alternative was implemented effluent treatment for reducing costs.

It was designed with the future implementation data shows a micro-scale design of a wastewater treatment plant based on wetlands, testing the ability of absorption of three different plants.

With the above conditions is improved and environmental health irrigation water.

Vegetation

The planting of vegetation is the final step in building a constructed wetland system. This activity is carried out once the granular material has been placed and leveled, have connected all the pipes and manholes, and carried out the hydraulic tests. When planting is done the cells and must have water.

The planting of seedlings that have been previously grown in the nursery is very successful but is the most expensive option. It also works well planting rhizomes obtained from other systems of constructed wetlands.

The seedlings were inserted into small holes made manually in the granular medium which is then capped. A ground biomass of the plant must be immersed in water. Planting can be done to staggered with a density of 3 plants per square meter. In the Mediterranean area plantations that have been made between March and October have been successful. However, the best time to plant is between April and May. In fact, if reed plant in April with a density of 3 plants per meter square, in late August has almost total coverage.

In the case of these rhizomes are used should be as minimum 3 internodes. Also inserted into small holes so that one end should be immersed in water and other projects above the level of granular media.

Has been performed once the planting is desirable that the water is one or two centimeters above the level of the medium granular to prevent weed growth. Then, when the plants have reached a good development, the level is located at 5 cm below the surface of the medium granular (this is the level at which it normally operates). It should be noted that if water is above the granular medium odors can be generated and a high presence of insects, with what is sometimes not possible to maintain a certain pooling during periods of time.

However, it is advisable to have waterlogged the system for at least the first two months. When wetlands are puddles is very important to have parts of plants that are submerged and are in contact with air. Otherwise the plants eventually die.

In Fig. 4 is shown the final dimensions of the wetland prototype used.

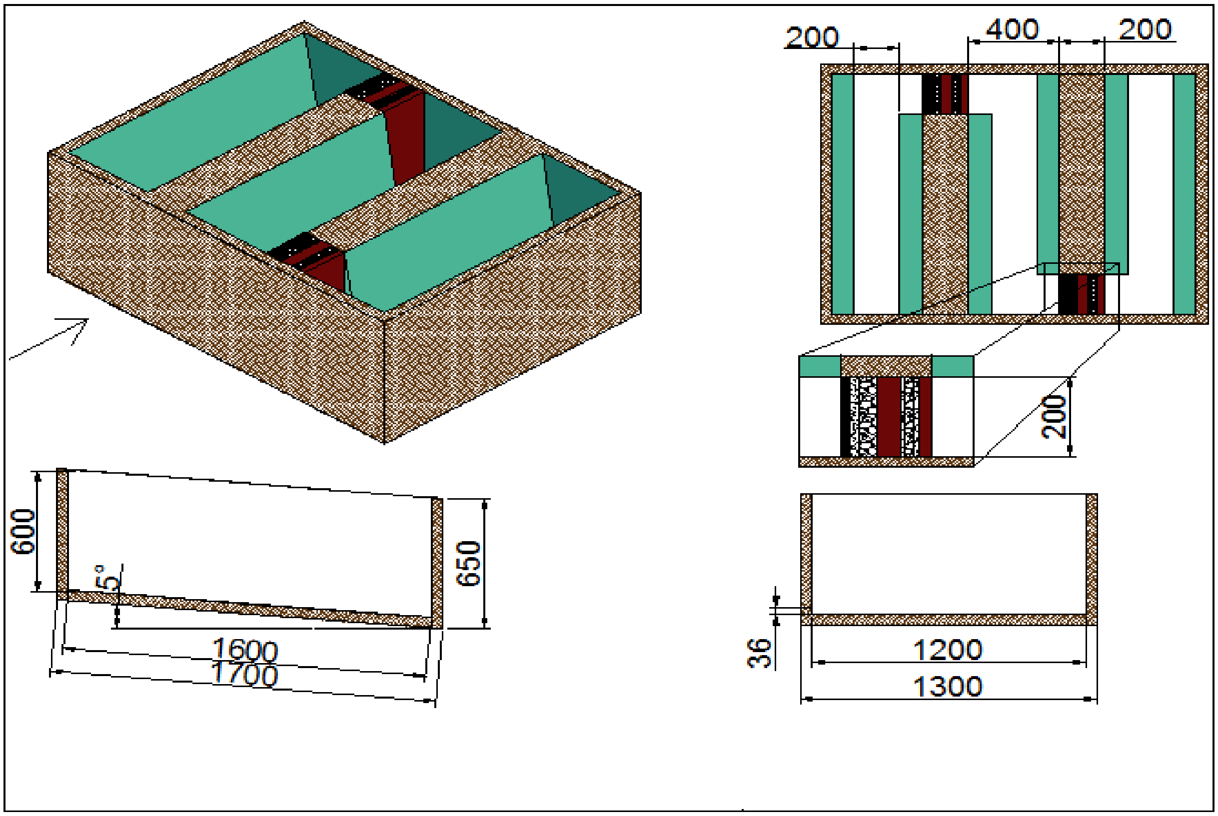

Fig. 4. Final dimensions of wetland prototype.

In the hydraulic design was observed that the flow through the wetland must overcome the frictional resistance of the same system. This resistance is imposed by vegetation and the sediment layer and the medium, the roots of plants and accumulated solids.

The best solution in terms of construction, the wetland is to provide a fund with an inclination sufficient to allow complete drainage and finally apply Darcy's law and the Manning equation applied to artificial flow wetlands.

4. CONCLUSIONS

Wetlands are technologies wastewater treatment simple to operate with low sludge production and no power consumption. Not require the addition of chemicals and energy to aerate the water or recycle. The infrastructure needed for its construction is very simple and affordable; maintenance is relatively easy and inexpensive.

This paper will deal with practical aspects needed to design, build and operate wetland systems.

A wetland decreases more than 60% the cost compared to a water purification plant as everything is based biodegradable materials and not using any energy or sophisticated equipment to water filtration. Wetlands not only help to purify the water, but also help the conservation of flora and fauna that is dependent on wet conditions, as only biodegradable materials are used here is no pollution to the ground, helping the conservation of the environment.

Water is one of the most valuable resources of man and we must remember that human hands can end it.

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