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Proposal for construction of a green filter in the lagoon of Boada de Campos

Wastewater treatment using macrophyte plants systems

The systems that use macrophyte aquatic plants are based on a monoculture or a polyculture of superior plants (macrophytes) disposed in lagoons, tanks or shallow channels. Even if they are normally used for tertiary treatment of the water they receive, they can also be used for secondary treatments. These plants provide the oxygen in the purification process which takes place in the radicle system. These plants degrade, absorb and assimilate in their tissues the pollution, but they are also an extension where the bacterial growth can take place and the solid elements in suspension can be filtrated.

The different treatment systems that use aquatic macrophytes are classified in:

1- The macrophyte system in streams:

This system and the next one use plants that are rooted and tolerant to dams. They are usually perennial and their leaves dry during the winter, breaking out again in spring from the rhizomes, like the *Phragmites sp*., *Scirpus sp*. or *Typha sp*.

In the systems of streams the elimination of pollution is produced by reactions that take place in the water and in the superior zone of contact, in the roots circulate a scarce quantity of sewage, because of that the potential of cleaning is very restricted.

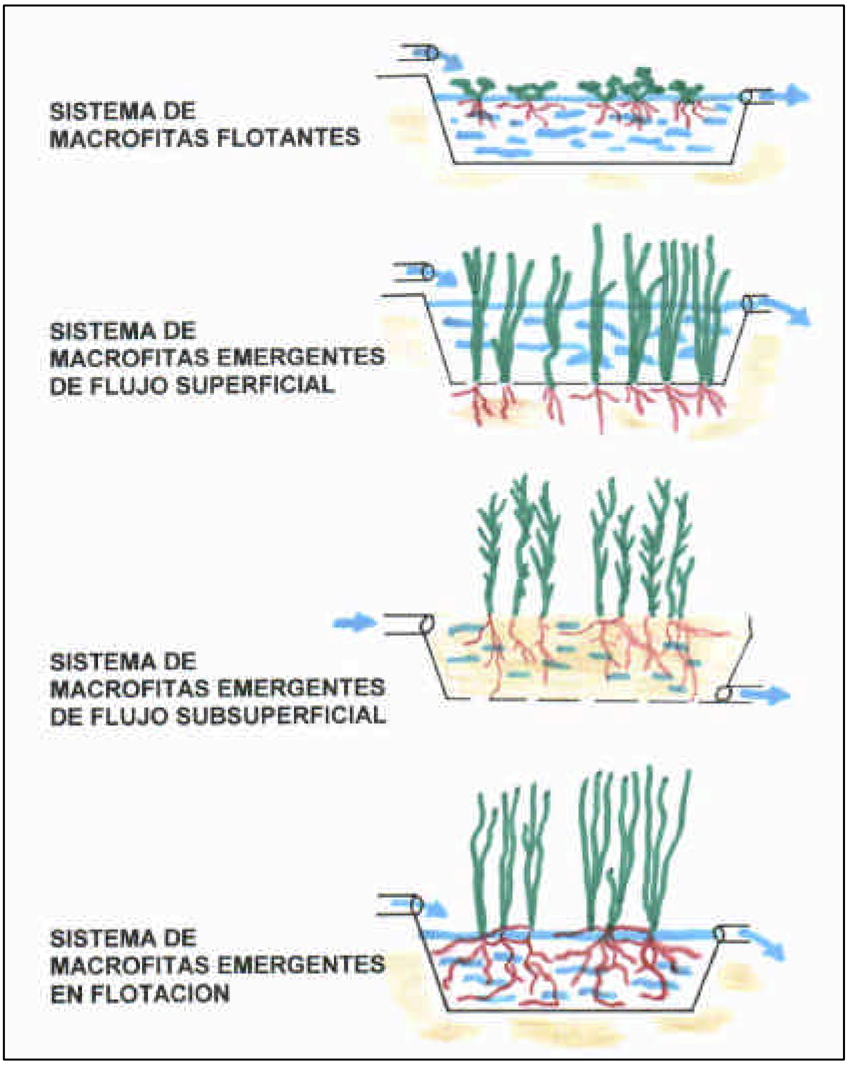
2- System of macrophytes in stream beds:

As the previous one, this system uses a layer of gravel or soil where the water circulates because of gravity. All the sewage passes necessarily through the roots, which increases enormously the cleaning yield. The greatest inconvenience is the fast filling up of the soil as time passes, it's because of the roots or the solid sediments. Eliminating the pollutants therefore means destroying the system.

3- The floating macrophyte system:

Uses species that are naturally floating, like the *Lemna, Wolffia* and *Spirodella*, the *Azolla sp*., the *Eichornia crassipes* or the *Victoria regia*.

The advantage of this system is that the contact between the roots and the sewage is total and has a large surface. However, these species don't reach a large size and their biomass production is limited, which reduce their absolute cleaning value, even though they absorb huge quantities of nitrogen and phosphorus. However, they are very effective when the concentrations of organic material and dissolved solid are low.



The floating macrophyte system
The emergent macrophyte system in streams
The emergent macrophyte system in stream beds
The emergent macrophyte system in flotation

4- The FMF system (Filter of Macrophytes in Flotation):

This system uses macrophytes which can be found naturally rooted in the ground, but which are here transformed artificially in floating. It's about a novel method that combine the advantage of the flotating system and the emergent macrophytes system, eliminating or reducing its inconvenience. It has been developed and patented by the University of Polytechnology in Madrid. One pilot plant of 3.000 m² is already working in the airport of Madrid-Barajas, treating parts of the water in the airport and parts of the urban areas of the village of Barajas. Three other plants are signed up for the airports of Reus, Alicante and Almería, and another one has been installed in Villacañas (Toledo), for the tertiary treatment of the water receiving the "Laguna Larga" of this district.

The system can do a tertiary treatment of the secondary effluents from the conventional water-treatment plants, removing the elements that cause eutrophication, especially phosphorus and nitrogen. It does a secondary treatment decomposing the organic material thanks to the micro organisms in the radicle system of the plants, and also contribute to the reduction of solids in suspension those staying adherent in the roots network. Some emergent plant species have the capacity of absorbing important quantities of heavy metals or decomposing phenol, so the system can also be used for treating industrial wastewaters.

FMF filter in Barajas (Madrid)
Opened air zone

The system constitutes basically of a carpet of floating vegetation that occupies the whole surface of a lagoon or a group of channels where the water circulate. The depth varies between 25 and 75 cm. The plants should be from the region, and have to be positioned in such a way that their roots, rhizomes and parts of the stem are submerged. Up to now it has been successfully tested especially with *Phragmites sp.*, *Sparganium sp.*, *Scirpus*, *Schoenus*, *Iris pseudocorus* and *Typha sp.* It seems that the *Typha sp.* has given the best results so far, with high yield of growth and purification.

When growing floating in the water, these species form a dense sponge of roots and rhizomes that occupy the whole volume of the vase (lagoon or channel), and obligate the water to circulate in this brush of vegetation, that also support the micro organisms that degrade the organic material. Similarly, leaves pump oxygen into the roots, which favour the process of degradation of the pollutants.

FMF filter en Barajas (Madrid)
Greenhouse zone

Previous FMF carried out by the Fundación Global Nature:

The Fundación 2001-Global Nature is beneficiary of the LIFE project "Wetlands of Villacañas", registered with the code: LIFE99 NAT / E / 006339. The project will last three years and the total budget is 513.000 €.

The three principal lagoons of Villacañas (Toledo): Tirez, Peña Hueca and Laguna Larga, together have the surface of 300 ha. They are declared as SPA (Special Protection Areas for birds) and SAC (Special Areas of Conservation).

The "Laguna Larga" in Villacañas was one of the most polluted lagoons in the region of La Mancha until the actual water-treatment plant of Villacañas was installed. Even though the actual system of treatment works appropriately, and the levels of nitrogen and phosphorus that the lagoon receives are relatively low, a decrease of these were necessary to improve the water quality.

The LIFE project has implemented a green filter in order to improve the water quality, removing the phosphorus and nitrogen excess arriving in the lagoon. This filter has been carried out together with the Department of vegetal Production of the Superior Technical School of Agricultural Engineers in Madrid. During the last years, numerous species have recolonised the lagoon or have increased their numbers in the lagoon probably due to an improvement in the water quality.

Filtering channel in Villacañas in the waterproofing process

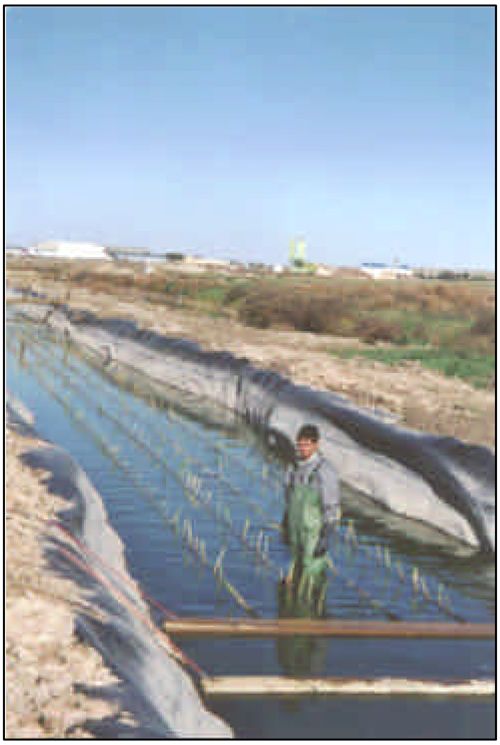
The implemented system is different from the one in Barajas. It has been designed as an only channel of filtration, in such a way that it goes parallel with the old draining channel of the water-treatment plant and doesn't occupy land of high environmental value. Though with about 400 m x 6 m it should have reached the necessary surface of filtration, finally a channel 525 m long x 6 m wide has been dug, providing a surface of 3.150 m², and assuring a security margin of approximately 30 % to prevent possible peak of volume or nutrients.

The depth of the foreseen channel was 75 cm. However, the manoeuvrability of the machinery and the undulation of the land, with the presence of old movements of soil, has forced to work in a depth that oscillates between 1 and 1,5 metres. The filtration channel has a slope on both sides of 1/1, with a fallen length between 1,4 and 1,8 m.

Due to the great height that the macrophytes used can reach (*Phragmites sp*, *Typha sp* and *Juncus sp*), and the uneven density, the flotation could not be assured in a natural manner until a dense carpet of roots had formed in order to support the aerial part and avoid the overturn of the plants. Because of this, young plants or rhizomes are used. They have to be fastened in a floating support separated between 10 and 30 cm. Some plants, as reedbeds, have a fistulous stem (cane) that can float horizontally in the water without the need of support and emit stems starting from the buds situated in the knots and roots. In the case of strong running water, or lagoons in zones with strong wind, the floating supports or the fistulous stems have to be properly anchored.

In this case, nursery plants from the Superior Technical School of Agricultural Engineers in Madrid, ballasted with an iron stick in the roots to keep them straightened up in the water have been used. The supports in which the plants are anchored are installed previously. They consists of stretches of 50 metres of pipes of polyethylene secured in floating planks. These planks are fastened to the ground using flexible "octopus" that allow the free flotation of the planks together with the increase and decrease of water level.

The plantation has been established with a density of 2 plants/m², which means a total of 6.000 plants. With this high density a fast vegetation cover is assured in the whole surface. The plants that have been planted are principally *Typha latifolia*, even though sections of other native species have also been inserted to study how they respond to the climate and water conditions of the area. (*Scirpus* and *Sparganium*).



Plantation of FMF in Villacañas

The filtration channel covers a parallel route to the actual drainage channel of the water-treatment plant, in such a way that in cases of stilting, overflowing, maintenance works, etc., the water can be diverted from one channel to the other, using a floodgateone.

The actual drainage channel of the plant has a length of 1.500 m. It follows a route practically straight during the first 900 meters of run starting from the water-treatment plant. Then it turns over 45°, direction east, to cover 600 meters more, also almost straight, ending in the Laguna Larga.

The mouth of the channel when near to the lagoon turns into a zone of high environmental interest because of the colonies of wader birds that feed there. Because of this, it was decided to place the filter parallel to the first tract of the actual drainage channel, joining it with two floodgates, in the beginning and in the end of its run, in such a way that the water from the filter flows into the channel, at the turn situated at 900 meters. This way shallow water zone where the old channel flows into the Laguna Larga is not affected.

Because the meadows that enclose the old channel that now bring the treated water to the Laguna Larga have a high botanical value, one single filtration channel longer than the old one and parallel to it was chosen. In this way the saltern meadows are not occupied with various parallel channels, like the ones at Barajas airport which, even though they are shorter, occupy the best zones for the flora.

In parallel with the filtration channel, a footpath has been prepared to facilitate the access and the maintenance of the channel.

Two floodgates have been installed in the filtration channel, at the beginning and at the end, and another one more in the beginning of the old channel. In this way both channels can be managed independently, and can be emptied at will for cleaning, replanting, etc.

Floodgates under construction

Selection of the filtration system for the water that the lagoon of Boada de Campos receives from Villarramiel, Capillas and the Canal de Castilla

In the case of the lagoon of Boada de Campos, like in Villacañas, a FMF system (Filter of Macrophytes in Flotation) has been chosen.

The advantages of the FMF system are:

- Economy and easiness of implemtation
- Higher treatment yield, because whole radicle system is submerged with the effluent and all the effluent circulates in the mesh of treatment.
  (in an experiment where the absorption of nitrogen and phosporus in a culture of *Typha latifolia* was evaluated, in a secondary urban effluent it daily absorption values between 0,5 and 4,66 g N/m² and 0,8 and 0,61 g P/m²).
- Easiness for harvesting the biomass, aerial and submerged. It doesn't mean the destruction of the system as in the case of the systems with rooted plants.

On the other hand, once the system has been established, a great quantity of biomass is produced, and needs to be removed using periodic cuttings so that the system can continue pumping nutrients. This biomass reaches 2,23 kg/m² of dry materia per year considering the aerial part in the case of *Typha latifolia L.*, and can be used as food cattle or for energy purposes (one square meter of channel produces the same calorific value as one litre of petrol. 1 kg/m² of sugars and starch are also stored in the rhizomes, and can be used for the production of ethanol).

The problems in the lagoon of Boada de Campos come from the inflow of nutrient enriched waters and are similar to the ones of the lagoon of Villacañas, though less serious. The contamination level in the water that the lagoon of Boada receives is relatively low, and so it would not be interesting to install big and expensive filters. This water-treatment system is, on the other hand, easy to manage with a minimum maintenance cost, an important factor to be considered in municipalities with low budget and not much labour available.

Channel bearing the water into Boada lagoon

Basic data about the FMF system (Filter of Macrophytes in Flotation) for the secondary and tertiary treatment of the water that the lagoon of Boada de Campos receives

Filtration surface necessary:

If we consider a water sewage, with a flow/volume and a composition more or less constants, the inflow of nutrients in the filter should be sufficient to satisfy the maximum needs for the plants growth. Normally the nitrogen is the most restrictive nutrient, because:

N entering the filter = maximum availability of N for the plants

It's logical thinking that with greater quantity of biomass, there is a greater filtration capacity for each unity of surface. However, the reality is that an increase of the filtration surface over a certain critical value that limits some nutrients, as in the case of the nitrogen, will reduce the yield in the filtration and the growth per unity of surface. Because of this it is fundamental to know this critical surface, so that a balance can be reached between the type of the effluent and the efficiency of the treatment plant.

Quantity of nitrogen that enters the filter daily: C (mg/l N) x Q (l/day)

Maximum demand of nitrogen for the plants (in this case *Typha latifolia* L.):

$S(m^2) \times A\ (g\ N/m^2 \text{ and day}) \times 10^3\ (mg\ N/gN)$

where:

C = medium concentration of the effluent.

Q = medium flow/volume.

S = total surface of the treatment plant.

A = maximum value of nitrogen absorption (4,66 g N/m^2 and day)

as: N entering the filter = maximum demand of N for the plants, and therefore:

$$C \times Q = S \times A \times 10^3$$
$$S = (C \times Q) / (A \times 10^3)$$

If we take the average values of the data of the effluent channel that bring the water to the lagoon, collected in the years 2001 and 2002, the calculations would be:

C = 6,7 mg/l N
Q (total daily flow, approximate) = 800 m³/d

A = 4,66 gN/m² and day

$$S = (6,7 \text{ mg/l N} \times 800.000 \text{ l/d}) / (4,66 \text{ gN/ m}^2 \times 1000) = 1.150 \text{ m}^2$$

$$\mathbf{S = 1.200\ m^2}$$

The total daily flow has been calculated as an average of the artificial contribution during the autumn months in the last years. This flow has approximately, a volume of 60.000 m³, that together with the rainfall and the run off from the surrounding lands, are always very variable factors between years, averaging a volume of water in the lagoon that can oscillate from 65.000 m³ to more than 250.000 m³.

Dimensions and location of the filtration channel

The filtration channel can be done with a width between 4 and 6 metres. If the width is increased it allows to shorten the distance covered. In this case it is not recommended to have a bigger width than 4 metres because of the ownership limits.

Considering a width of 4 m, to get a filtration surface of 1.200 m² we would necessarily have a 300 m long channel.

The foreseen depth of the channel is 0,7 metres, with a slope to both sides of 1/1. This means that the bottom of the channel would necessary have a width of 2,6 metres.

In parallel to the filtration channel and to both sides, two footpaths will be prepared in order to facilitate the access and the maintenance of the filter.

Waterproofing in the channel

To avoid the rooting of the plants, the channel has been waterproofed with overlapped layers of polyester (rolls of 125m x 8 m).

The 8 metres of width of the sheet are enough to cover the bottom of the channel (2,6 m), the slopes (1 metre in each side) and the sheet anchorage (from 1,5 to 2 metres in each side).

The total surface of waterproofing, considering the slopes and the anchorage zones is:

8 m x 300 m = 2.400 m² (3 rolls of polyester)

Plantation

The plantation will be established with a density of 2 plants/m². This high density assures a fast vegetation cover of the whole surface.

About 2.400 plants will be planted. The plants chosen will be *Typha sp.*, even though it is also foreseen to insert small groups of other native species (*Scirpus*, *Phragmites*).

As in the case of Villacañas, nursery plants cultivated in the Superior Technical School of Agricultural Engineers in Madrid will be used, ballasted with an iron stick in the roots to keep them straightened up in the water. To anchor the plants 50 metres of pipes of polyethylene secured to floating plank will be installed in advance.

Location of FMF

The filtration channel will be done in the actual drainage channel of the lagoon. The availability of land could affect the arrangement of the filtration surface, but not the whole quantity (only one larger channel or various shorter ones, parallel). If the surrounding lands of the actual channel were available and the distance of the filter could be shortened, the width would have to be increased, which is not recommended either, because it would make tasks such as cleaning, planting or vegetation harvesting more difficult.

Management considerations. Floodgates

Two floodgates will be installed in the filtration channel, at the beginning and at the end. In this way the channels can be managed independently, can be emptied at will, allowing their cleaning, replanting etc.

The filter we have described here is more effective during the warmest months of the year, when the pumping of nutrients have a certain importance. This filtration period can be extended with the installation of a greenhouse over the filter, which exceeds the limits of this project.

The periodical harvest of the biomass is fundamental for eliminating the nutrients in the system, but the dynamic of nutrients in the treatment plant should previously be known. If an annual harvest of the vegetation once the leaves are dead is carried out, 40-45% of the nitrogen and phosphorus contained in the plants can be collected, the rest having already gone through to the rhizomes as reserves to initiate the next vegetative period. If this harvest is brought forward (to the end of September or the beginning of October), the nitrogen and the phosporus absorbed by the plant can be extended up to 70%, as they have not gone through the roots yet. In any case, and if the system is protected with a greenhouse, the number of annual cuttings can be increased to two or three.

Experimental microprotothypes in the E.T.S. of Agricultural Engineers in Madrid