



NEW FLOATING MACROPHYTE FILTER SYSTEMS FOR THE MEDITERRANEAN REGION “MACROPHYTES”



Layman Report

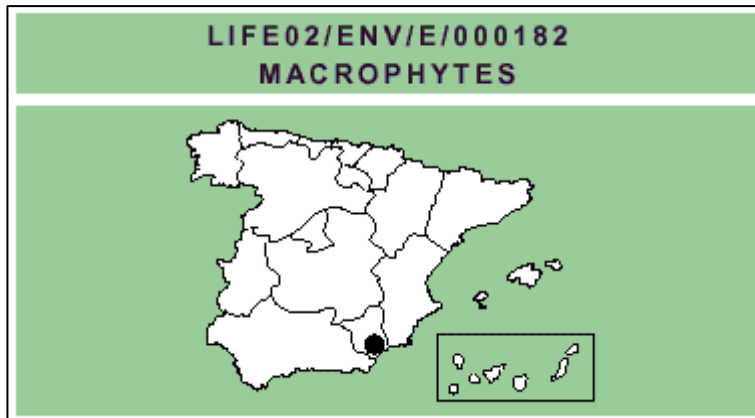
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An innovative system for waste water treatment

Project context and objectives

The southeast of the Iberian peninsula is renowned for having numerous dispersed population centres within a single municipal district engaged in economic activities with varying environmental impacts (tourism, agriculture, cattle farming, etc.,) and particularly, several locations where there is waste water requiring treatment.



A common problem in a large part of Spain is the absence of urban waste water treatment plants or the unsatisfactory operation of those in existence. The water situation in the Spanish Mediterranean basin and, especially, in the Segura, Guadalentín and Mula river basins and in the province of Murcia is unacceptable.

On the one hand, waste from the agro-food industry and intensive cattle farming (pigs) together with waste from other highly contaminating activities (tanneries) seriously aggravate river contamination. On the other hand, we find several isolated population centres that, although they may have drainage systems, cannot connect them to the systems of other towns or villages because of the distances between them. Conventional water treatment plants are expensive and require economies of scale in order to prove viable. The minimum amounts that would be required to build these conventional systems would exceed these populations' financial capacity and waste water treatment needs.

Moreover, the lack of suitable treatment plants further aggravates the water deficit in arid regions, where a large amount of waste water cannot be recycled.

Lorca in Murcia is one of the best examples of this problem. It is one of the largest municipal districts in Spain (1,676 km²). Half the population lives in numerous isolated population centres and in thousands of dispersed detached houses, with no connection to the general drains, giving rise to thousands of septic areas with a tremendous environmental impact. The population structure makes it extremely difficult to build viable drainage systems and water treatment plants to serve entire municipal districts. Most population centres have drains but no treatment plants.



Town of Avilés, (Municipal district of Lorca, Murcia)

Finally, another unresolved but important problem requiring a low-cost solution is organic animal waste treatment. Lorca has almost 1,100 pig farms for both breeding and slaughter, which are also distant from each other and generate a tremendous environmental problem given the lack of suitable treatment.

In order to improve this situation, with the LIFE-Environment Funding, the Fundación 2001 Global Nature together with the Senior College of Agricultural Engineers (ETSIA - Escuela Superior de Ingenieros Agrónomos) of the Polytechnic University of Madrid collaborated with the Lorca Town Hall, as a beneficiary and co financer of the project, initiated the *Macrophytes* project with the following objectives:

- To prove the efficiency of an innovative system for waste water treatment using artificial ponds or canals with floating macrophyte plants.

To this effect, they built 7 floating macrophyte filters for treating waste water from various sources:



3 prototypes in small population centres more than 20 km away from main town centres in the municipal district of Lorca (Murcia): Doña Inés (149 inhabitants), Avilés (394 inhabitants) and Coy (501 inhabitants).

2 prototypes on the property of detached houses and 1 at a hostel-residence belonging to the Fundación Global Nature, within the municipal district of Lorca (Murcia).

1 prototype at a pig farm (the GAMUR Cooperative) within the municipal district of Lorca (Murcia) to treat organic animal waste (purines) using this new system.

Prototype built in the town of Avilés

- To promote these new systems in Mediterranean regions where the absence of a severe winter favours the plants' year-round growth, making them especially apt for use in tourist resorts, sometimes far away from town centres and with larger populations in summer when the filters are most active.
- To promote these new treatment systems, which do not require economies of scale, particularly apt for small communities and various sectors (urban, agricultural or industrial), and economical to build and maintain.



Prototype built at GAMUR Cooperative.

Description of the technique applied

Waste water treatment using macrophyte plant systems

Systems that use aquatic macrophytes are based on a monoculture or polyculture of surface plants (macrophytes) installed in shallow ponds, tanks or canals. Although they are normally used for waste water's tertiary treatment, they can be used for secondary treatment. The plants themselves supply the oxygen required for the purifying process, which takes place in the root system. The plants break down, absorb and assimilate the contaminants in their tissue, but they also provide an extensive surface that enables bacterial growth to filter solids in suspension.

The various macrophyte-based treatment systems in existence can be classified as follows:

1 – System of emergent superficial-flow macrophytes:

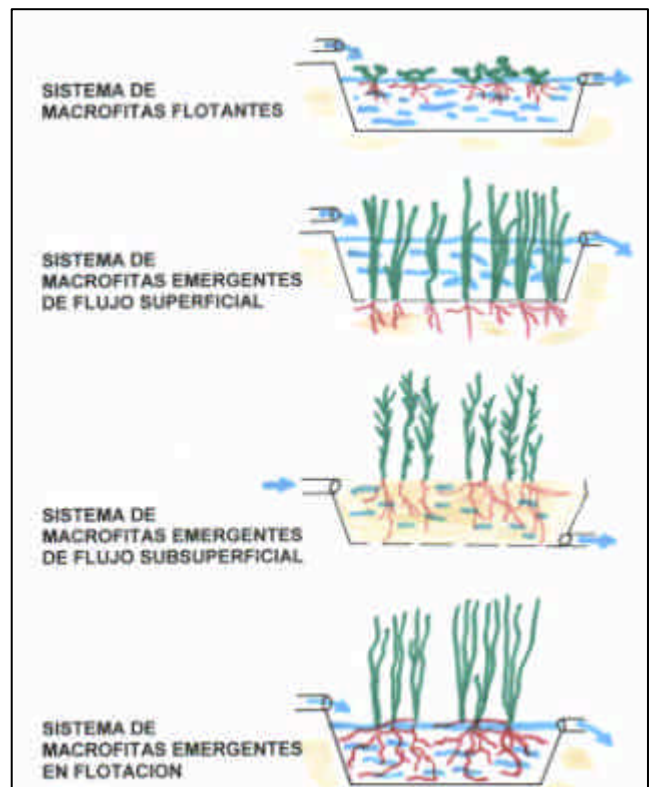
This system (and the following one) use rooted plants that are tolerant to swamping. They tend to be perennial and their leaves dry out in winter, budding in spring from rootstock, such as reeds (*Phragmites sp.*), rushes (*Scirpus sp.*), or cattail (*Typha sp.*). Eliminating contaminants using surface flow systems occurs through the reactions that take place in the water in the contact area above ground, because only a small amount of waste water can circulate through the roots meaning that the roots' potential waste water treatment is considerably reduced.

2 – System of emergent subsurface-flow macrophytes:

Similar to the system above, this system uses a layer of gravel or soil through which the water is made to circulate by force of gravity. Waste water is forced to circulate through the roots, which greatly increases the treatment's performance. Its major inconvenience is that the soil rapidly becomes saturated over time, either by roots and rhizomes or by solid sediments. Eliminating the contaminants thus means destroying the system.

3 – System of Floating macrophytes

This system uses naturally floating species such as duckweed (*Lemna*, *Wolffia*, *Spirodella*), fern (*Azolla sp.*), water hyacinths (*Eichornia crassipes*), or water lilies (*Victoria regia*). The advantage of these systems is that contact between the roots and the waste water is total and over a large area. However, these species tend not to grow to large height and their biomass production capacity is limited, reducing their total purifying capacity, although they do absorb large quantities of nitrogen and phosphorus. However, they are highly effective when the concentrations of organic mass and dissolved solids are low.



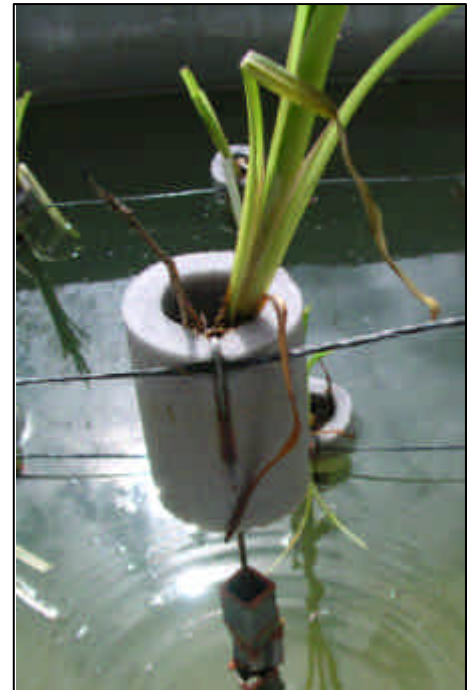
4 – System of floating macrophyte filters

This is the system designed by the *Macrophytes* LIFE project, for which the prototypes in Lorca were built.

This system uses emerging-type macrophytes, which are naturally rooted in the terrain, but which in this case are artificially transformed into floaters. This novel method combines the advantages of floating systems and emerging macrophytes and eliminates or reduces their disadvantages.

The system is capable of conducting effluents' tertiary treatment for conventional waste water treatments plants eliminating eutrophicing elements, particularly phosphorus and nitrogen. It performs a secondary treatment by decomposing organic matter using the microorganisms that adhere to the plants' root systems and also favours the reduction of solids in suspension, which become adhered to the root mass. Some emerging plant species are able to absorb large amounts of heavy metals or decomposing phenols, meaning that they can also be used for treating industrial waste.

Close-up of the floating macrophyte plantation



The system basically consists of a carpet of floating vegetation that occupies the entire surface of a pond or series of canals through which the waste water is forced to circulate. The depth of these ponds or canals ranges between 25 cm and 75 cm. The plants must be autochthonous to the region insofar as possible and arranged in such a way that their roots, rhizomes and part of their stem are under water. Work has been conducted especially using reeds (*Phragmites* sp.), bur-reeds (*Sparganium* sp.), rushes (*Scirpus*, *Schoenus*), water lilies (*iris pseudocorus*) and reedmace or cattail (*Typha* sp.). The latter appear to have provided the best results to date, with high performance in terms of growth and purifying capacity.



Once the system has been built, there is a large amount of biomass that must be removed through periodic harvesting so that the system can continue to pump nutrients. This biomass can then be used as cattle feed or fuel.

Prototype. Pedanía de Coy

Results achieved

Commissioning the 7 pilot prototypes has demonstrated the filtering system's technical and economic viability under different waste conditions, but especially for population centres of between 150 and 1,000 inhabitants. Given their size and location, these residential or business centres are unlikely to have access to conventional waste water treatment facilities at a similar cost.



Throughout the project, the ETSIA of the Polytechnic University of Madrid has provided the necessary scientific monitoring of the constructed filters' correct functioning. Water was sampled and analysed on a regular basis. The outcome of these analyses has been used to determine the purifying capacity of the various floating macrophyte filter systems.

In the case of urban waste waters, the system is capable of eliminating approximately 90% of their organic biodegradable contamination (based on the reduction of BOD5). The system is less efficient at purifying total nitrogen and phosphorus content than organic biodegradable matter, and the reduction values are between 30% and 50%.

Tests on organic animal waste treatment at ETSIA

In the case of purifying organic animal waste (purines) from pig farms, laboratory testing has shown that after a pre-treatment of the raw waste based on a physical-chemical precipitation with lime and iron chloride, solids in suspension can be reduced by 70-80%, BOD by 50-60%, COD by 37-58%, and phosphorus by 67-73%.

Given the lack of low-cost and efficient purifying systems for organic animal waste (which is often tipped causing a serious problem in many parts of Spain due to the contamination of water and aquifers with nitrates), the scientifically proven efficiency of this novel technique makes floating macrophyte filter systems a viable alternative, on condition that there is a prior physicochemical or other type of treatment.

The system is less appropriate for detached houses because of the risk of waste water containing chemical products (such as bleach used for cleaning bathrooms), which could damage the filter's plants. Implementing the system under such conditions would require instilling knowledge and awareness among houses' residents to minimise the risk of this type of waste water. Therefore, the small-scale filter used at the Fundación Global Nature Centre has been kept in correct operation, unlike the two detached houses' systems.



Environmental benefits of using Floating Macrophytes Filters for waste water treatment

- Cost-efficiency and ease of implementation. Minimum energy consumption. Where the use of a water pumping system has proved necessary, a photovoltaic system has been installed. There is no energy consumption at any of the constructed prototypes since waste water is channelled through the canals by force of gravity.
- Greater purifying performance in comparison to other systems, including other types of green filters, since the effluent circulates through the purifying root mesh. Up to 90% of the organic material is reduced (in terms of BOD5)
- Ease of harvesting both above water and submerged biomass, which does not imply destroying the system as in the case of rooted plant systems.
- It produces a large amount of biomass reaching 2.23 kg/m^2 of dry matter annually for the part above water in the case of the cattail (*Typha latifolia* L.) which can be used as compost, for cattle feed, or fuel purposes (one square meter produces the same calorific power as a litre of petrol).
- CO₂ fixation in the macrophytes' tissue.
- Notable elasticity: it absorbs hydraulic peaks without major difficulty since the filter itself serves as a laminator.
- Minimum controls are required since the process occurs automatically as it is a natural process. It is not necessary to recirculate sludge and there are no problems of bacterial wash. It is not necessary to control the level of oxygen dissolved in the treatment tank. The macrophytes supply oxygen to the water.
- Reduction in the contamination of underground and surface waters derived from the seepage from septic tanks of detached houses and tipping on pathways from population centres and pig farms.
- Reduction of smells and health risks from untreated waters and of the impact on the landscape of septic areas and large water treatment plants.
- The level of noise and visual impact is very low.

Executing the project in the provinces of Murcia and Almería is the most financially viable option since:

- The lack of plant hibernation in winter means that purification can continue throughout the year. It is not necessary to install a greenhouse.
- The tertiary treatment of effluents allows water to be recycled in very dry areas.
- The efficiency in purifying organic animal waste resolves one of the main environmental problems in areas such as Lorca, with a large number of isolated pig farms.
- Macrophyte filters do not require economies of scale as in the case of large water treatment installations. They can be applied to small population centres isolated from one another, as in the case of Lorca.

Filter in Pedanía de Coy



Cost-profit analysis of the results

The cost per inhabitant of installing these filters in the villages of Coy, Avilés and Doña Inés make it viable to apply this system to communities with similar conditions. The construction cost has been estimated at €150/inhabitant for installations for more than 200-300 inhabitants, which is very competitive as compared to large more technically complex water treatment installations. The maintenance cost, especially when shared by various nearby filtering installations, can be extremely low, especially due to the low energy requirement, and has been calculated as being potentially less than €30/inhabitant per year. This calculation takes into account the required labour, transport between various filter points, sowing materials, phytosanitary products, spare stocks (floaters, plants, etc.) and other auxiliary equipment.

Transferability of project results

Publicising and promoting the technique

In order to facilitate projection and transfer of the results of this project, a diffusion effort has been carried out, to be prolonged even after project completion:

Pilot programme:

Building the various prototypes has been the best way of demonstrating the technique's technical and financial viability and the best way of generating awareness among the local population. The project has received an extensive and successful response.

Awareness and general communication activities:

Aimed at the population in general (local, regional and national)

From the project's outset, campaigns in the mass media have ensured the technique's



widespread promotion. Local press have reported on almost all of the activities carried out in connection with the project, from the beginning of construction works and inauguration of the various prototypes to the hosting of the Training Course and International Meeting on Phytodepuration. Televisión Española's national news programmes reported on the construction of the prototype for treating organic animal waste (purines) at the GAMUR Cooperative. The national press also published articles on the "Macrophytes" project. The national daily newspaper La Razón published 2 pages in colour on this technique.

Recording of the prototype built at GAMUR for TVE's national news.

The project's Web Page and CD-Rom have been well-received. The Web Page incorporates all of the information on the construction of the prototypes and the promotional campaigns; <http://macrophytes.info> has an average 1,500 monthly hits, mostly of Spanish origin, but also international.

Aimed at local residents and visitors (tourists)

The 18 explanatory panels erected within the vicinity of the constructed prototypes showing how floating macrophyte filters operate are an important way of generating awareness among the local population.

Explanatory panel erected near the GAMUR prototype



The leaflets on the project (5200 copies) were distributed among interested residents, providing extensive promotion on a local scale. The leaflet was also printed in English for distribution to foreign residents on the Mediterranean coast and to universities and other entities abroad.

The two informative days aimed at promoting the use of filters in population centres were successful and generated numerous requests for building these filters on a reduced scale (2-3 families), which are currently under evaluation.

Aimed at national and international engineers:

A 25-hour training course took place between 19th and 23rd July 2004 on Floating Macrophyte Filters. 50 participants including students and engineers of water treatment systems attended the course and gave a positive appraisal of its content.



Between 19th and 22nd July 2005, the International Meeting on Phytodepuration took place, attended by 67 participants from institutions and research agencies from Spain and abroad (Germany, Estonia, Guatemala, Iran, etc.) 40 communications of a scientific nature were given, encouraging a multidisciplinary exchange of the latest achievements in water treatment systems using green filters. These scientific articles were collected in the Meeting's Record of Events. Available from the project's Web Page.

International Meeting on Phytodepuration

The project published a manual on Phytodepuration (2,000 copies) consisting of 144 pages divided into 9 chapters, written by professors of the ETSIA of Madrid's Polytechnic University and by the FGN technical team. A DVD was made (539 copies) on the *Macrophytes* project in addition to a CD-Rom (400 copies).

The phytodepuration manuals, CD-Roms and DVDs were distributed to the attendants of the International Meeting and were sent (240 copies) to Spanish public, private and tertiary sector entities and institutions involved in waste water treatment. The manual, contents of the course for engineers, and in general all the information available on CD is also available from the project's webpage.

Potential transferability

This filter system can be easily reproduced in the temperate and warm regions of the Mediterranean coast, North and South. In this region, temperate winters mean that the filters do not have to be used under greenhouse conditions since the plants continue to grow, making these systems even cheaper. Additionally, the filter's purification capacity is greater in summer, with the maximum plant growth coinciding with peak populations when tourists arrive to the coasts.

These prototypes' replicability for treating organic animal waste (purines) at pig farms is of major interest given the lack of simple, efficient purification systems for such cases.

The system is perfectly exportable to other European or global areas, especially temperate and warm zones. The system is very simple, can easily be learned by unqualified personnel and is straightforward to install.

Throughout the European Union, this system could be applied to small communities, although colder areas would require the use of a greenhouse to maintain operation in the winter months; in these cases, the cost would increase.



Filter in GAMUR

At present, Fundación 2001 Global Nature is building 4 macrophyte filters, in this case floating ones (using water hyacinths) in the Dominican Republic, thanks to two "Cooperation for Development" projects. Given the advantages of this technique due to its low cost, ease of use and efficiency, it has proven an alternative for treating urban waste waters in small towns in developing countries where conventional methods prove too expensive and complex.



Construction of a Filter with macrophytes floating in Dominican Republic (November 2005).