ABSTRACT

The floating system TECH-IA is a transfer technology of Padua University spin-off, called PAN srl. This technique, known as “floating wetland system”, allows the water treatment directly into the water body (stream, river, channel, natural or artificial) and works using different ways to grab the plants and keep them over the water surface. Using these systems we can avoid to use huge surfaces of Constructed Wetlands for phytoremediation. The artificial floating systems are based on structures that sustain no floating plants which are able to extend their roots in the water column, in calm or running waters, and perform the functions of water treatment. When the system is working at its maximum and it can improve water quality as well the aesthetic value of a water body with the presence of flowering species, creating new water environments for fauna and get better urban water spaces. Tech-IA elements are easy to install and manage. The raft is made with a strong plastic material, resistant at different climates, hydraulic and environmental conditions and has eight grids where the plants can be put and tied. The single elements can be easily linked each other and anchored to the river sides.
1 | Introduction

The multitasking floating system is indicated as support for herbaceous and arborescent plants. His main use is within the field of natural depuration in water bodies, the so called phytodepuration. The innovative technical features result from singularity of the product and from the possibility in the field of phytoremediation to utilize directly in water bodies plants that for their nature can not float but that are suitable for cleansing purposes. In this way they could be used in different environment where was impossible to operate till now. This system is efficient when it is used as singular technique of depuration, but it performs very well also is associated with other traditional depuration techniques, to enhance the effectiveness and contribute to clean wastewater.

2 | Phytodepuration

Phytodepuration is a cleansing water natural technique based on interaction among plants, wastewater and bacterial communities. This technique could be used in different way and to treat water pollution we can find extensive, widespread or localized systems. Extensive systems consist in the reuse of polluted water in vegetated soils. Widespread systems are wetlands creation with wooded buffer zones where different species of plants are used in order to eliminate different types of polluntants.

Among the localized systems or constructed wetlands we can have three different techniques (Regelsberger 2005):

a) Systems with horizontal subsurface flow

This type of systems consists in a properly designed waterproof basin that contains a filter material, wetland plants and microorganisms. The bed is fed with wastewater coming from a suitable primary treatment by a simple inlet device. The filling material has to offer an appropriate hydraulic conductivity but also a large surface for the biofilm growing. The water level remains always under the surface of the bed; the wastewater flows horizontally by a slope (about 1%) which is obtained by a sand layer under the membrane liner. The subsurface flow prevents odors and mosquitoes and permits public access in the wetland area. This kind of constructed wetland is particularly efficient in suspended solids, carbon and pathogens removal, as well as for denitrification, while, due to its prevalently anoxic conditions, nitrification is limited.

b) Systems with vertical subsurface flow

In the vertical flow systems the wastewater is applied through a distribution system on the whole surface area and passes the filter in a more or less vertical path. The pre-treated wastewater is dosed on the bed in large batches (intermittent) thus flooding the surface. During the time between the feedings the pores within the filter media can fill up with air which is trapped by the next dose of liquid. The oxygen is required from nitrifying bacteria that are favored from this condition and full nitrification can be achieved, but only a small part of the formed nitrate is denitrified under aerobic conditions. The denitrification and thus total nitrogen elimination can be increased by a partial recirculation of the nitrified effluent into the first chamber of the septic tank. The treated water is collected in a bottom drainage system to be discharged. The water level can be maintained with a height of about 5–10 cm from the bottom of the bed, or otherwise the beds can be totally empty after each feeding pulse. This kind of constructed wetland is particularly efficient in nitrification, carbon and suspended solids removal. Due to its prevalently aerobic conditions denitrification is poor.

c) Systems with free water surface

Surface flow wetlands are densely vegetated basins optionally including open water areas. They need some sort of subsurface barrier to prevent seepage and soil or another suitable medium to support the emergent vegetation. The water flows through the unit at a relatively shallow depth. Particulates tend to settle and to be trapped in the system; in such a way they enter into the biogeochemical element cycles within the water column and surface soils of the wetland. At the same time dissolved elements enter the overall mineral cycles of the wetland system. This kind of constructed wetlands is particularly efficient in the pathogens removal, due to the high exposure of the wastewater to the UV component of the sunlight. For that reason, and also for a good denitrification power, these systems are often used as tertiary treatment polishing stage.

As compensation to the low energy demand of all these systems described above, there is a relatively large area demand. To avoid this problem we can decide to treat water directly inside the basin, channel or river. All this is possible by using systems based on floating plants, wich have particular organs that permit them to solve this function. These systems are made of impermeable tanks, in which wastewater passes through and inside the tanks we can make this selected vegetation grow. But in the cold climate of Northern Italy, most of utilized plants are very small size and this don't allow to treat enough water. Using floating elements that can sostain plants allow to increase the range of plants to be utilized for these aims and above all the ones who have deep root system to intercctare water flow.

Worldwide various examples of floating treatment systems exist. Hoeger (1988) has one of the first publication dealing with artificial floating island. Nakamura (1997) reports about the entire ecosystem created around the installation of floating island (habitat for birds and fish, breaking water in littoral zone and landscape improvement).

2.1 | Advantages and applications of constructed wetlands

Within the last 30–40 years various types of constructed wetlands have been developed in several countries. There is a wide acceptance and interest within the population because of the following advantages:

- Simple construction, operation and maintenance
- Low operation and maintenance costs
- High ability to tolerate fluctuations in flow
- High process stability
- Sludge only from primary treatment
- High pathogen removal – good water reuse and recycling options
- Aesthetic appearance
- Creating biotopes

The usual applications of constructed wetlands are:

- Domestic wastewater: treatment of domestic wastewater (blackwater and greywater) meanwhile is a conventional application.
- Industrial wastewater: there are numerous possibilities also for industrial wastewater like chemical industry, laboratory effluents, landfills, acid mines and agricultural wastewaters, e.g. from wineries, olive oil mills, dairies …
- Sludge drying: Special reed beds can be used to dewater and stabilize excess sludge from technical plants and sludge from primary pretreatments
- Furthermore highway runoff, polluted groundwater, surface water and storm water can be treated in constructed wetlands.

3 | The Tech-IA floating system

This structure was developed in 2004 as prototype for the treatment of aquaculture effluents in north-east of Italy. After the research period the prototype was and upgraded; in 2006 the patent demand was presented at the Italian Patent Office (Tech-IA®). The single self floating element of Tech-IA® is realized in EVA (ethylen vinil acetate), rectangular (45*90 cm), with eight windows each of them with grids that allows to sustain the plants. His weight is 1732 gr and may support a weight of 20 kg. Two elements matched give one square meter of raft. The single elements can be easily linked each other and anchored to the river sides, his frame presents six holes allowing the connection among elements and to the benches. The elements can be easily installed in different designs to fit the shape of the water body and intercept the pollutant flow.

The most important feature of this structure are a high mechanical resistance of the material associated with biological, chemical and climatic resistance, a closed cell structure that doesn't absorb water, an easy installation and management and the recyclable material of the item. These structures may sustain adequate plants, which are able to extend their roots in the water column, in calm or running waters, and perform the typical functions: physical filtering of the water flow, dissolved nutrients uptake, support for microorganisms and oxygen release. Treating water directly into water body using floating elements allows adaptation of the phytodepuration system to variations of water level and water flow and it doesn't need wastewater to be drawn from its basin.
The floating element can be vegetated with herbaceous species with colorful blooms and these can be distributed along the seasons, it can be used for ornamental purposes and become a perfect element of urban fitment. The structure was created to be a support in phytodepuration for no floating plants, but it can be used in several other sectors. It could become vegetated island for naturalistic and faunistic purposes, floating vegetated or no-vegetated barriers used for delimitation or signal. But also decorative island in natural, artificial, private or public water body, support for plants that grows in hydroponic system, creation of buoyant platforms and as support for fish farming environments.

3.1 | Vegetation used in Tech-IA system

Floating wetland systems ground their action on bacterial communities and plants, the efficiency is given from the depth of root system and from plants capability to absorb dissolved elements. Lots of studies both Italian and international state that botanical species utilized for phytodepuration have great skill to absorb nutrient elements. The most suitable species for these aims are emergent macrophytes and the most common are the following:

Carex sp.pl.
Herbaceous plant, evergreen, 0.5-1.2 m high, flowering in spring with flowers at the end of the green stems. Full grown plants forms compact bushes. Adapt in shadow or sunny environments.

Glyceria maxima
Herbaceous perennial plant, with erect stems, grown large shrubs full of stems and leaves, 0.5-1.5 stems high, 0.4-0.8 m leaves high. Leaves are linear, strong, evergreen. At the end of the stems, in summer time, are carried the flowers. It’s a vigorous species, right for the full sun and/or shadow environments.

Iris pseudacorus
Herbaceous plant with short rhizome; flowering stems and leaves that rise from the rhizome (0.8-1.2 m high). The great yellow flowers appear in April, and persist till July.

Right to grow in sunny place.

Juncus sp.pl.
Herbaceous perennial plant, evergreen, worldwide spread in wetland and running waters. The stems are cylindrical and flexible, 0.80-1.5 m high, dark green; in summer time the small flowers rise at the end of the stems. Prefer sunny places, and withstand at complete flooding.

Phragmites australis
Herbaceous perennial plant, erect stems rise from underground rhizome. The stems are 2 to 3 m high, green in the growing season and pale brown in winter time. Bloom in Summer with flowers at the end of the stems. Prefer sunny environment, have fast growing and colonize quickly the land around the original rhizome.

Typha latifolia
Herbaceous perennial plant with rhizome. The leaves and the flowering stems rise from the underground rhizome network, the stems could reach 3 m high. The long leaves are linear and dark brown. The mature flowers are brown and typical of this specie. Right to live in many different climate conditions.

More species are been studing to be used in the floating systems, especially for their aesthetic value. One of the most important features are blooms with different colors that can create a good color effect. But it is also fundamental to guarantee a floral cover or at least green cover all over the year, so that the elements will be vegetated with different species with different times of bloom.

3.2 | Depuration performances within Tech-IA system application

Depuration efficiencies of phytodepuration systems depend on the kind of plants used, on local climate conditions, on the type of system adopted, on the maintenance performed and on other several technical, ecological and microbiological factors. For the floating wetland systems, we can consider first of all pollutants given from the nitrogen forms and then also the organic matter (COD and BOD5). Nitrogen matter is important because vegetation absorbs preliminary that one (mainly nitric and ammoniacal nitrogen) dissolved in water column. Organic nitrogen and organic macromolecules have to be transformed in simple elements to be available for plants absorption. This action is performed from bacterial communities which are growing on the root system and that live in symbiosis with plants. It is thus extremely important to use different botanic species so that it is possible to develop different bacterial colonies that will help organic macromolecules degradation.

4 | Installations of floating wetland system

In Italy the floating wetland system was applied for the first time in 2005 to treat water exiting a fish growing farm. A farm in the Sile River Natural Park was chosen, which uses groundwater to raise rainbow trout and discharges the outflow directly into the river. The field research started in May and lasted until March 2006. A single row of a floating vegetated system, a prototype of the Tech-IA element, 1.5 m wide and perpendicular to the water flux, was installed in the final basin between the farm channel (8.0 m wide) and the Sile River and was vegetated with various macrophytes. The floating system performed well in pollution control, abating the concentrations of inflow water due to roots development that intercepted the bacterical colonies that will help organic macromolecules degradation. This action is performed from bacterial communities which are growing on the root system and that live in symbiosis with plants. It is thus extremely important to use different botanic species so that it is possible to develop different bacterial colonies that will help organic macromolecules degradation.
depuration efficiency (monitoring N, P forms and COD), efficiency changes in different seasons, most efficient way to set up these elements and management difficulties. Two barriers were created in the two streams with Tech-IA elements and 624 plants of following species were utilised: Carex elata, Dactilis glomerata, Juncus spp., Phragmites australis and Agropyron spp.. In this installation a good vegetation and root growth was observed and depuration results were conditioned by high inflow and low pollutant concentrations: greatest effect is on COD abatement, lower abatement for N. There are also seasons affect removal of pollutants: out summer values have lower range of variability. The average abatement performance measured during 2006-2008 was 63% for COD, 45 % for total N and 28% for total P (full data are presented in De Stefani 2009).

The last project installed in 2008, is situated in Cazzago San Martino (Brescia district) municipality. Around this area, due to the conformation of the land there aren’t any natural water receptors that can collect wastewater from cultivated fields and this goes directly in drainage.

This collects fields water but also industrial and urban water and brings them to a depurator. During periods when rain is abundant sewerage is overcharged and it discharges part of water in big basins. This system is adopt from several municipalities in this area, but after several years of accumulation, these basins, most of them ex quarries, become absolutely waterproof. One of them is been selected to install a floating wetland system.

The main objectives of this project are to improve water quality in the basin maintaining at the same time the capacity and to reuse this depurated water in agriculture. Furthermore one aim was also to recover this area for environmental purposes. In the system floating elements were bounded together to form long tapes, which became five filtering barriers put perpendicular to the inlet and outlet points. There are 1800 floating elements that form a depurative surface of 900 mq with 1400 plants chosen for thier high cleansing power, big root system and nice aesthetic effect (Juncus sp., Iris pseudacorus, Typha latifolia, Phragmites australis). The surface to be covered is been decided analyzing morphologic features of the basin, water quality inlet and required outlet values. This project is been monitorated for water quality, plants development and possible management problems; here the first encouraging results on abatement performances: 67% for total N, 81% for ammoniacal N, 45% for nitric N, 36% for COD and 40% for total P.
**5| Conclusions**

The floating system developed around the world performed well in pollution control and new water environments creation. The Tech-IA elements are easy to install and manage, allow the formation of different kind of barrier, host various kind of macrophytes and are flexible to be used in different conditions. These type of systems need few maintenance operations (just removal of garbage, woods and green biomass carried by water flow), have a positive impact on biodiversity improvement, in particular on aquatic fauna (nesting site for birds) and was observed that a lot of new plant species colonized spontaneously the new created environment.

The studies will carry on in order to combine water treatment with ornamental uses of this specific system.
References


