CONSTRUCTED WETLANDS
NATURAL WATER PURIFICATION SYSTEMS

IDEASS ITALY

Innovation for Development and South-South Cooperation

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Horizontal subsurface flow system
serving an agro-tourism facility (Florence, Italy)

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Introduction

Any water purification process seeks to lower the level of contaminants present in the water by means of biological agents. The process occurs spontaneously in all natural hydro systems and guarantees their "self-purifying" capacity.

The Constructed Wetlands natural water purification systems take advantage of a process that occurs spontaneously in nature, optimizing the biological processes to provide higher purification levels.

These systems were applied for the first time in Germany in 1952 following a series of experiments conducted by the Max Planck Institute. Subsequently several European countries (France, England, Austria, Denmark, Italy, Holland, Switzerland) activated specific research programmes and after extensive scientific comparisons the European Guidelines were drawn up.

The obvious economic advantages low operating costs and reduced energy consumption and the optimal purification levels have led some countries to adopt the system on a broad scale, above all for small and medium-sized applications, but also for purifying waste water from technological systems. In the latter case the treated water may be reused in agriculture, industry and for non-drinking purposes generally.
Reusing appropriately purified waste water contributes to a notable reduction in the wasteful use of high-quality (drinkable) water, which is an increasingly costly resource.

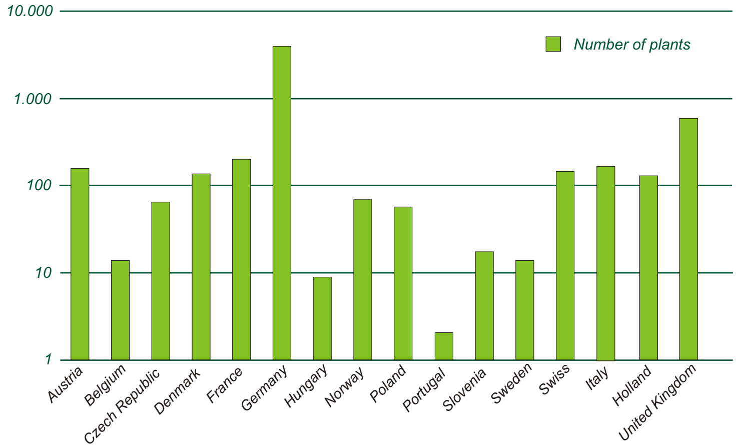
A further factor in favour of the Constructed Wetland systems is their complete blending in with the environment (see photo over). In recent years the European Community has given priority to financing these systems over more conventional high-technology systems.

In addition, the use of Constructed Wetlands systems allows for purification choices that are decentralised and ad hoc for a given area and for specific environmental situations. Avoiding centralisation and large systems helps provide for greater protection of the hydro-geological balance.

The systems are particularly well-adapted for resolving water purification problems in rural and hilly areas where collecting waters in a centralised system would involve high costs and negative environmental impact.

In marginal and degraded areas the use of these systems can provide an opportunity to restore the environment.

The Constructed Wetlands systems in Europe



The application of natural systems allows for resolving the hygienic-sanitary problems of waste while making more frugal use of water.

There are many types of Constructed Wetlands systems, but the ones most widely applied in the European context are the following:

Horizontal Subsurface Flow Systems (SFS-h)

Vertical Subsurface Flow Systems (SFS-v)

Surface Flow Systems (FWS)

These system types may be used singly or in combinations in systems called “multi-stage”.

Each type is constructed differently and provides purification levels particular to the kind of contaminant to be removed.

This allows for appropriate treatment in each individual case, while a combination of the systems makes it possible to treat even wastes that differ markedly from one another.
For example, an isolated house in a rural setting or a small-scale private consumer could use the simplest type, a horizontal subsurface flow system, while a cheese factory or animal farm would require a combined system where the different types are selected according to the purification objectives and the quantitative and qualitative characteristics of the waste.

In Europe at present there are about 11,370 officially-registered Constructed Wetlands systems monitored by research institutes.

Detail of a Surface Freeflow System
for a wine-producing firm (Siena, Italy)

What problem does it solve?

As mentioned above, Constructed Wetlands systems for the treatment of waste water is a widely-used choice in most countries in the European Community. University and research institutions continue to test the models and process kinetics developed for different types of waste and different environmental and climatic conditions, in relation to the choice of structures adopted. This research has made it possible to use the systems even for wastes containing high levels of contaminants for example, the percolation elements of urban solid wastes and zootechnical refluents.

Constructed Wetlands, whether used for secondary or tertiary (refinement) waste treatment, are a solid structural solution capable of high-level purification (above all for parameters including COD, BOD5, suspended and sedimentable solids, microbe loads and nitrogen) by way of a simple and uncomplicated operation with much lower environmental impact and energy consumption than other purification systems. In many cases the effluent waters move by gravity so the systems require no source of electricity.
Furthermore, the Constructed Wetlands systems are not affected by variations in the hydraulic charge to be treated, unlike conventional purifiers which require a constant hydraulic charge. This means that for facilities or communities with significant fluctuations in consumption during the year (for example winemaking facilities, food-producing farms, hotels, campgrounds, cities with a tourism trade, etc.), the use of Constructed Wetlands phytopurification does not lead to reduced purification levels.

SOME ADVANTAGES OF USING CONSTRUCTED WETLANDS

- Excellent purification results
- Limited operating costs
- Simple operating mechanisms
- Low or non-existent energy consumption
- Adaptability to load variations
- Maximum oxygenation of the effluent waters
- Maximum blending with the landscape
- Possibility of re-using treated waters and treatment byproducts
- Environmental restoration of degraded sites

Constructed Wetlands in practice

There are various types of structures that can be used for Constructed Wetlands depending on the different needs and according to a set goal for breaking down pollutants.

The following system types have produced the most satisfying results in terms of levels of purification, hygienic and health impact, operating simplicity and adaptability to the various environmental conditions:

- **Horizontal Subsurface Flow Systems**
- **Vertical Subsurface Flow Systems**
- **Surface Flow Systems**

Surface free flow system (FWS) for the treatment and collection of rainwater to be re-used (Grosseto, Italy)

Horizontal Subsurface Flow Systems (SFS-h)

The SFS-h look like basins dug into the earth, about one metre deep and rendered impermeable by a synthetic membrane stretched across the bottom. The basin is filled with inert materials, usually fine gravel and crushed stone, whose granulometry is carefully selected to allow for optimal diffusion of the effluent waters in the basin.

The waste water is introduced into the system via a perforated pipe running the crosswise length of the basin and it then filters slowly through the filling thanks to a slight tilt (between 1 and 5 percent) in the base of the basin. The water always remains under the surface until reaching a drainage pipe that allows it to exit the system.

Aquatic plants from the Phragmites, Thypa and Scirpus genera are commonly cultivated in the systems, with their roots developing in the filling medium. The plants act as natural pumps for transferring oxygen from the atmosphere into the filling medium of the basins, which is inhabited by bacterial colonies capable of decomposing organic material under aerobic conditions and nitrifying it. Ideal anaerobic conditions for the de-nitrification process exist in areas furthest from the roots.

These systems are capable of destroying 99 percent of the microbe load, in particular pathogen bacteria. In addition, the plants absorb any metal present in the waste water, while the filling inerts allow for removal of phosphorous through fixing.

Horizontal subsurface flow system (used as a tertiary treatment)

Vertical Subsurface Flow Systems (SFS-v)

The SFS-v are distinguished from the Horizontal Subsurface Flow Systems by the fact that the effluent waters are distributed within the basins intermittently and the hydraulic flow is predominantly vertical.

Another difference is the use of a different type of filling medium made up of several layers of various grades of gravel and sand, from a layer of sand at the surface through to a layer of stones laid over the drainage system at the bottom.

The vertical system's method of feeding into the system by sprinkling allows for more oxygen to be introduced into the effluent waters and thereby for improved capacity to break down organic material.

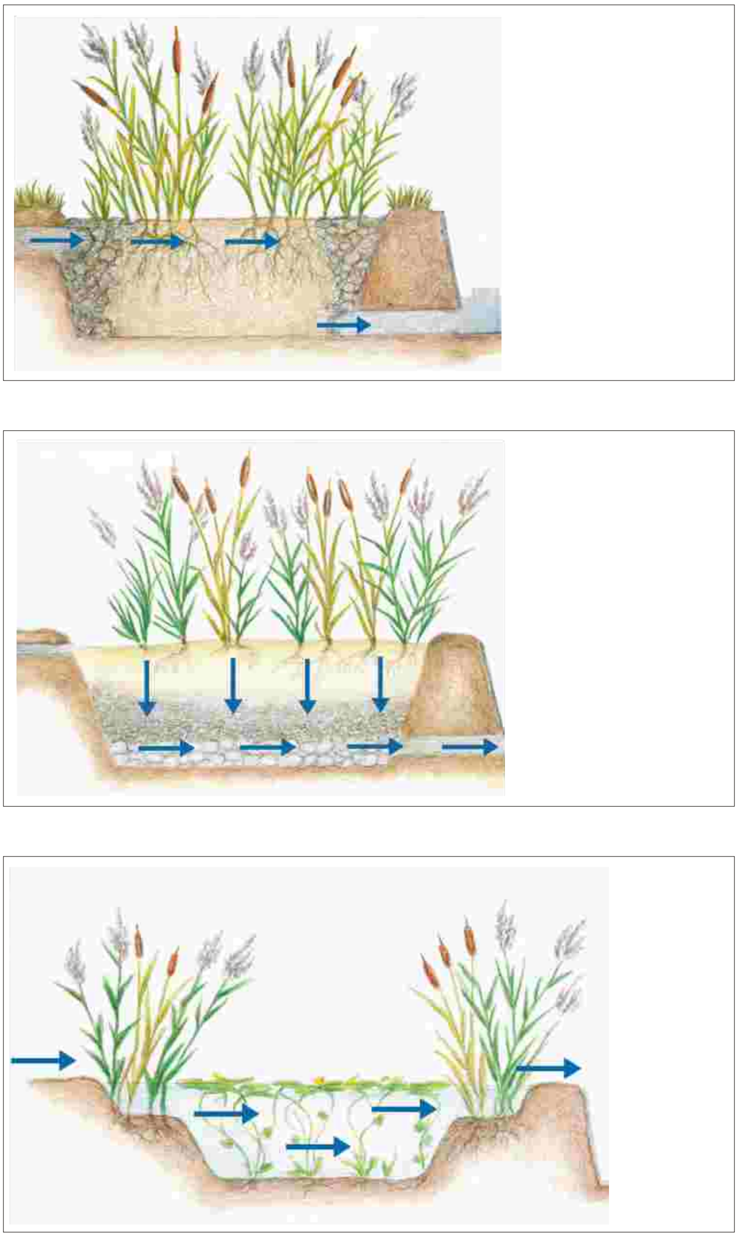
In these systems as well, the waters remain under the surface of the basin and the same plants are used as for the horizontal flow systems.

Surface Free Flow Systems (FWS)

These consist of a shallow basin waterproofed with a synthetic membrane in which the waters run freely at the surface. They vary in height between a few centimetres and one metre.

The system is conceived in such a way as to create the appropriate environments for a variety of plants, from aquatic plants that live underwater to floating plants, from helophytes plants that live on the banks to hydrophile plants with exposed roots.

Vegetation is chosen according to a series of criteria that allow for the most faithful possible reproduction of the biodiversity of a naturally wet area while guaranteeing maximum purification potential.



Schematic illustration of a horizontal subsurface flow system (above), a vertical subsurface flow system (middle) and of a free flow system (bottom)

Each species of vegetation performs a series of specific functions within the system. These include oxygenating the water in which they are found and absorbing nutritive substances (phosphate, nitrate, etc.) present there that are necessary for the plants' growth. All kinds of plants provide a suitable substratum that foster the development of micro organisms important for the purifying processes of naturally wet areas.

The vegetation commonly used for these systems belong to the genera Phragmites, Typha, Scirpus, Iris, Nymphaea, Juncus, Carex, Alisma, Myriophyllum, Ceratophyllum, Butomus, Potamogetum, etc. In any case it is good practice to use autoctonous plants that do not alter the natural environment and are not detrimental or invasive to the neighbouring areas.

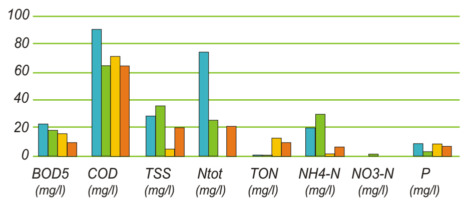
Results

The choice of system to use depends on the purification needs of the effluent or waste water. Generally the SFS-h systems are used for removing biologically and chemically biodegradable material and suspended solids; they have a removal efficiency on the order of 90 percent for those contaminants.

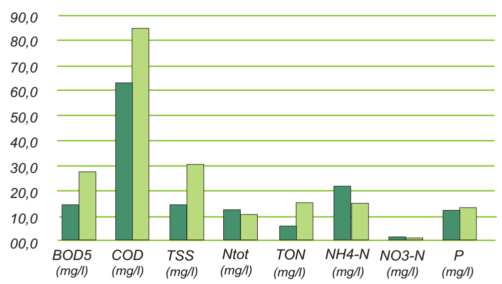
The figure below shows the average data gathered on about 260 examples of systems located in various European countries, in terms of quality of the effluent waters and main parameters.
Because they oxygenate so well, the vertical flow systems are suitable for obtimizing the nitrification process and thus for breaking down nitrogen.

The surface flow systems (FWS), used only after the treatments described above, allow for further breaking down of residual contaminants.

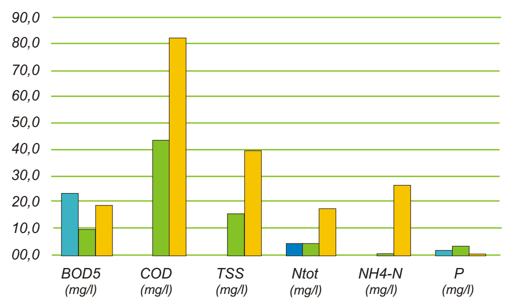
Some significant data on the quality of effluent waters emerging from FWS applied as a third treatment are shown in the following figures:



	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	Ntot (mg/l)	TON (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	P (mg/l)
n. AE < 100	23	91,5	29,5	75	1,3	20,7		9,4
100 < n. AE <250	19,4	65,5	36,9	24,7	0,4	29,9	1,9	3,8
250 < n. AE < 1.000	16,5	71,7	5,5		13,2	1,6		9,6
1.000 < n. AE < 2.000	10,4	65,5	21,1	22	10,3	7,1		8,1



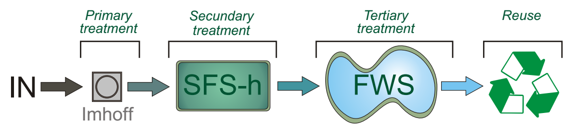
	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	Ntot (mg/l)	TON (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	P (mg/l)
n. AE < 100	14,1	62,5	14,2	12,3	5,6	21,5	1,2	12,0
100 < n. AE <250	27,2	84,5	30,3	10,2	15	14,5	0,4	13



	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	Ntot (mg/l)	NH4-N (mg/l)	P (mg/l)
100 <n. AE<250				5,0		2,1
250 <n. AE<1000	10,5	44,0	16,0	5,0	0,9	3,8
n. AE<2000	19,2	83,0	40,0	18,2	27,0	0,9

Multi-state systems are used with increasing frequency in order to provide increased breakdown of contaminants and thus optimise the performances of natural purification systems.

The typical layout of a multi-stage system is shown in the following diagram:



PRIMARY TREATMENT

Imhoff tank as a sedimenter for eliminating the coarsest parts of the waste water;

SECONDARY TREATMENT

Horizontal subsurface flow system (SFS-h) for breaking down most organic matter and suspended solids emerging after the primary treatment;

TERTIARY TREATMENT

Surface free flow system (FWS) for perfecting purification (especially denitrifying) and collecting the purified outflow.

System allowing water reuse.

Operational aspects

As described above, thanks to their simplicity to build and maintain, the systems are particularly appropriate for small and medium-sized communities and rural environments. There is no need for specialised labour to manage the operational aspects the systems require.

The most important aspects concern the regular draining of the septic tank, placed upstream from the phytopurification system, and the control of the water level in the bed (serves also to prevent the growth of weeds) and the condition of the vegetation.

Controlling the water level consists fundamentally in the following:

keeping the roots and rhizomes of the hydrophites in contact with the water;

preventing the growth of invasive weeds that tend to take over, especially in non-saturated areas of the bed during the first few months the system is operating.

The only maintenance of the plants involves seeing that they grow normally and providing periodic manual clearing of vegetation, normally every two/three years; the process seems to revitalise the plants and stimulate stronger and more uniform new growth.

The FWS system requires even less operational management, as the system is designed to evolve in the most natural manner possible. Mowing or scything every three years is expected.

Horizontal subsurface flow system (Siena, Italy)

Advantages

In addition to the advantages already mentioned, Constructed Wetlands make it possible to:

- **recover nutrients that would otherwise have a negative environmental impact;**
- **promote a recycling logic that encloses the cycle of some nutrients like nitrogen and phosphorous inside the production areas;**
- **purify waters to reuse them for irrigation purposes; this creates a closed cycle of water usage and leads to significant savings of drinking water supplies which may be set aside for consumption only.**

Constructed Wetlands are a solid choice for treating waste waters and are capable of improving the purifying capacities of existing structures, as well as reducing the pollution of waterways and the contamination of water sources.

International interest

It is definitely a highly advantageous choice to use natural treatment systems in the context of countries lacking extensive economic resources or advanced technology.

Installing the systems does not require the use of trained personnel nor sophisticated construction techniques. The Constructed Wetlands systems may be set up using locally available untrained labour and locally available resources not usually the case for conventional purification systems.

Free water system (used as a tertiary treatment)

Running the systems requires very little economic input: the Constructed Wetlands do not, in the majority of cases, require energy sources given that they function by gravity and through natural purification processes. Such simple maintenance makes for significant reductions in costs.

In conclusion, choosing to use Constructed Wetlands systems means in socio-economic terms the possibility of enjoying the benefits derived from sustainable management of water resources, limiting the impoverishment of waterways and optimising consumption with positive consequences for the economy of the region and the country and without having to rely on structures that are too costly to operate.

Countries turning toward the use of Constructed Wetlands as part of a policy of greater economic and environmental sustainability, as well as for the advantages mentioned above, include Slovenia, Tunisia and Egypt.

Using Constructed Wetlands in other countries

The use of constructed wetland water purification systems is not subject to any legislative restrictions: it is not a matter of a finished product but rather of coming up with a project that requires no special technology to implement and can be easily set up by local firms. Furthermore, as they are not based on a concept of models or standards, the project should be designed ad hoc for each situation.

The professionals who form the design teams should be highly educated as biologists, chemists or engineers for example and should receive specialized training in designing and dimensioning the Constructed Wetlands systems.

Detail of a multi-stage system consisting of a horizontal subsurface flow system (right) and a vertical one (left) at the service of a tourist structure - 140 equivalent inhabitants (Florence, Italy)

Managing the systems does not require trained personnel and can be done by the entity that benefits from it by virtue of its minimal costs.

In case of specific problems it is wise to contact specialized technical personnel and, if necessary, the entity responsible for the system design, with whom could be stipulated a type of assistance contract for the users. In fact, it will be the users who gain the benefits of using the system, for example by re-using treated water.

Some of the institutions that could be involved in drawing up the feasibility study for applying the systems include research institutions, universities and specialists or technicians in the area of integrated and eco-sustainable water management.

To learn more

To learn more about constructed wetland systems further information may be found on the internet sites:

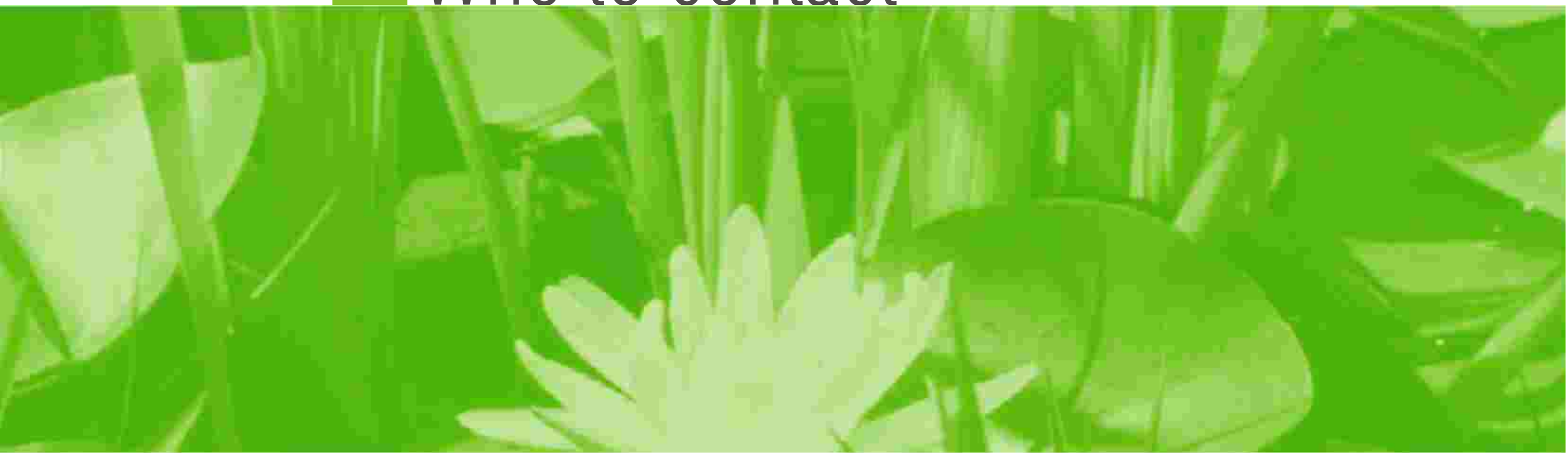
www.iridra.com

www.arpat.toscana.it/pubblicazioni
link: catalogo pubblicazioni anno 2003

A bibliography, scientific publications, minutes from international congresses and data from monitoring carried out on Italian systems may be downloaded.

A Constructed Wetlands system using horizontal subsurface flow
(150 equivalent inhabitants) (Tosco-Emiliano Appennines, Italy)

Who to contact



ARPAT
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In addition, ARPAT is willing to provide consultancies and technical assistance for the design, operating methodology and start-up of the systems. An ARPAT technician is available for drawing up monitoring data on the system extracted from analyses carried out by such local actors as universities, research institutes, operators of the purification systems:

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Horizontal subsurface flow system (Siena, Italy)

ARPAT
Agenzia regionale per la protezione ambientale della Toscana

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The aim of IDEASS is to strengthen the effectiveness of local development processes through the increased use of innovations for human development and decent working conditions. By means of south-south cooperation projects, it acts as a catalyst for the spread of social, economic and technological innovations that favour economic and social development at the local level. The innovations promoted may be products, technologies, or social,economic or cultural practices. For more information about the IDEASS Initiative, please consult the website: www.ideassonline.org.

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UNDP's Anti-Poverty Partnership Initiatives (APPI) Programme is a tool designed to assist governments and social actors to establish and apply national policies for reducing both poverty and social exclusion, based on local integrated and participatory development practices.

The human development and anti-poverty programmes run by UNDP, IFAD, ILO and UNOPS promote integrated and participatory local development processes within the framework of national policies, with the support of public, private and civil society actors. These programmes provide the framework within which donor countries and communities in the industrialised countries can collaborate in an organised way, through descentralised cooperation.It is in this framework that south-south cooperation projects will be carried out via the Initiative.

The OIT/Universitas programme (decent work through training and innovation) encourages the use of innovative solutions to problems in human development,especially in the world of work. To achieve this, it carries out research-action activities and trains decision-makers and personnel working in local development.