System typologies

Definitions are numerous and not remotely standardised. For simplicity and clarity, the different Phytodepuration treatments in use are divided here: (1) Phytodepuration treatments via emergent hydrophytes (horizontal or vertical subsurface flow and surface flow), (2) Phytodepuration treatments via floating hydrophytes, (3) Phytodepuration treatments via submerged hydrophytes; (4) integrated Phytodepuration systems.

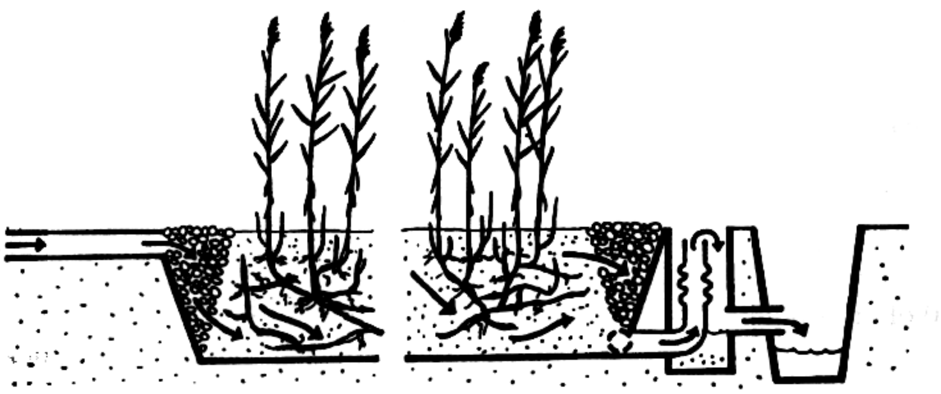
3.1 Phytodepuration systems via emergent hydrophytes

With this typology of treatment, subsurface flow systems can be adopted (horizontal (SFS-h) or vertical (SFS-v)) or surface flow systems (FWS).

SFS-h systems. They owe their name to the route the water takes during treatment: the flow is introduced at the end of the tank, it slowly flows along an almost horizontal route, reaches the exit and abandons the system (fig. 1).

They are characterised by the flow's continuity through the medium that therefore becomes constantly saturated. These are mostly used for removing organic substances, decomposed through anaerobic and aerobics from the bacteria forming the bio-film on the medium and plant roots, the de-nitrification and partial nitrification and **phosphorus** removal. The suspended solids are effectively removed for filtering in the first few metres of the system.

Fig. 1 Diagram of horizontal subsurface flow system



SFS-v systems. This typology foresees waste being introduced into the system through a series of channels set uniformly on the system's surface and left to percolate through the medium. The plants used and the nature of the medium are the same as those used in the SFS-v systems - it is the disposition of the whole system that changes. Inert ground is used in these systems, positioned into layers of increasing particle size and this way the waste, that is percolating, meets increasingly bigger layers of gravel (fig. 2). The flow, that takes place at periodic percolation through the medium, is in this discontinuous state (like intermittent sand filters). The medium therefore goes through alternating conditions of saturation and exposure to the atmosphere that favours its aeration. This method is especially used for increasing nitrification of horizontal flow systems.

In surface flow systems, **purification** of liquid waste is favoured by the presence of leaves, stems and river/lake beds that are useful for bacterial adhesion. As oxygen is transmitted by leaves to the roots, it is not available for bacteria that operate directly on the liquid waste, so the largest source of oxygen is atmospheric surface re-aeration.

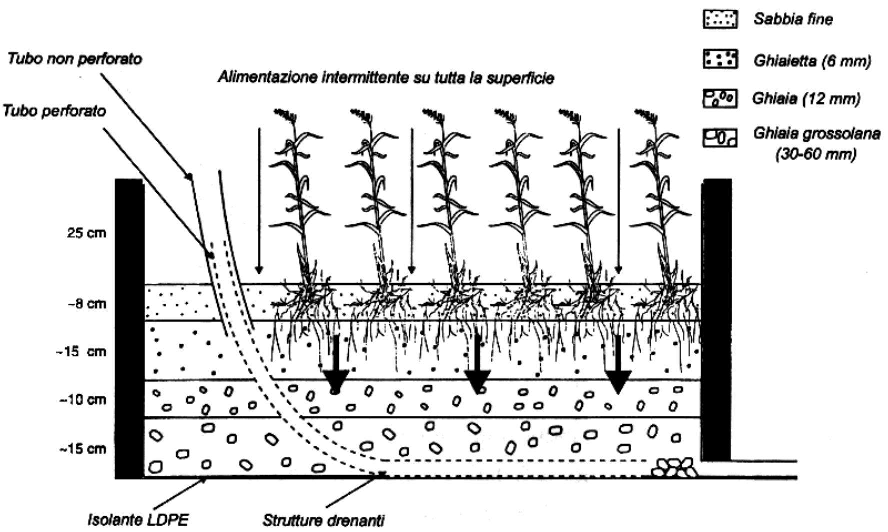


Fig. 2. Diagram of vertical subsurface flow system

Non perforated tube, perforated tube, intermittent supply over entire surface, fine sand, fine gravel (6mm), gravel (12mm), large gravel (30-60mm), LOPE isolation, drainage structures

FWS systems. They are tanks or channels that are generally waterproofed where the water surface is exposed to the atmosphere. The constantly submerged soil is support for the plant roots. In these systems the flow is horizontal and the (hydraulic) head is generally limited to around a couple of dozen centimetres. Use of these systems is limited to the tertiary treatment and revitalising waste treated with natural oxygenation.

Subsurface flow systems (fig. 3) are generally smaller than surface flow systems as the surface available for bacterial activity is greater - they also have less problems of odours and bugs and greater efficiency at low temperatures. Surface flow systems, however, cost less to realise and are more hydraulically reliable.

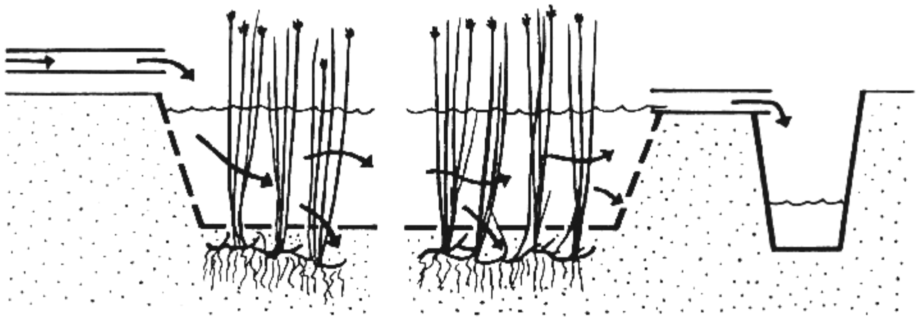


Fig. 3. Diagram of surface flow system and emergent rooted macrophyte

3.2 Phytodepuration systems via floating hydrophytes

Phytodepuration treatments via floating hydrophytes (fig. 4) (floating hydrophyte shown: Eichhornia crassipes) can be carried out in artificial **habitats** normally made of naturally or artificially, waterproofed basins and without a suitable substratum of hydrophyte growth. The waste to be treated is kept at a (hydraulic) head of between a couple of tens of centimetres and a few metres (according to plant typologies and type of treatment required).

These systems aim at removing organic substances and nutrients, and refining secondary effluents.

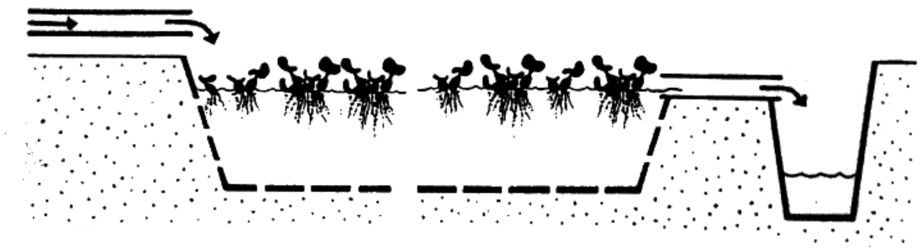


Fig. 4. Diagram of surface flow system and floating macrophyte

The depurative ability of the systems that use hydrophytes with root systems (Eichhornia crassipes, Pistia stratiotes) is due to oxygen being carried from the leaves to the roots, the roots' adsorbing action towards the solid suspended colloidals, the depurative power of the aerobic **biomass** on the roots and the plant's direct assimilation of nutrients.

Although they don't cater for **biomass** biological treatment of sewage, systems that use hydrophytes with poor root systems (Lemna sp., Wolfia sp., Azolla sp., Salvinia sp.), lend themselves well to refining effluent in ponds, biologically rich in micro-algae and removing nutrients. Hydrophytes present, in fact, even though somewhat small, can densely cover the water face so as to prevent the prevention of solar rays: these conditions cause the death of algae and their consequent anaerobic degradation.

The main applications use water hyacinths and water lentils. The water hyacinth is one of the most productive plants that exist and its role in these systems is fundamental. It participates directly in the depurative processes, absorbing vast quantities of nutrients and creating a suitable microclimate in the basin for the more important depurative processes.

Use of these systems is strictly limited due to high management costs due to frequent collection of the vegetable **biomass** and from its ecological demands that are characteristic of tropical climates and therefore little resistant to temperatures lower than 10 °C. Other typical problems are bad odours and proliferation of larva from bugs.

The water lentil has a wider habitat and also supports lower temperatures. It doesn't however achieve the hyacinth's depurative results, in that it doesn't provide a suitable area of support for the growth of micro-organisms. Use of these systems is, in fact, limited to tertiary treatment of waste.

3.3 Phytodepuration systems via submerged hydrophytes

Phytodepuration treatments via submerged hydrophytes (fig. 5, submerged hydrophytes: Elodea canadensis) are achieved in artificial **habitats** similar to Phytodepuration treatments using emergent surface flow hydrophytes. The systems are not very well known, but they aim to remove nutrients and refine secondary effluents. Submerged hydrophytes, in fact, only live in well-oxygenated waters with limited organic loads.

The most recognised depurative mechanisms are complete aerobic degradation of organic substances, volatilisation of ammonia and chemical precipitation of **phosphorus**, due to favourable pH conditions following photosynthetic activity, with oxygen production and reduction in the standard of dissolved organic carbon.

Possible problems concern algae growth that can prevent light reaching the photosynthetic parts of this hydrophyte.

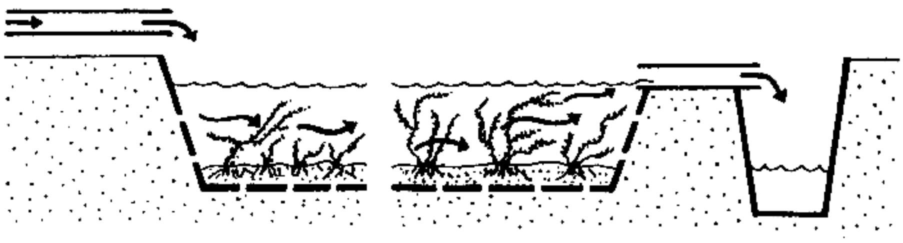


Fig. 5. Diagram of surface flow system and submerged macrophytes

3.4 Integrated Phytodepuration Systems

To optimise the performance of each depurative phase and limit obstruction, integrated Phytodepuration systems can be used. They are simply configured multi-stage treatments, where a Phytodepuration refinement basin follows (with floating, emergent or submerged macrophytes) a rougher one (with floating or emergent macrophytes) supplied with a primary effluent from a primary sedimentation or Imhoff tank.

These systems (that can comprise many basins both as a series or alongside on another) tend to resemble natural environments, as they are generally multi-species.
The choice of species and single treatments must be made based on those characteristics that are progressively assumed by liquid waste, that, moving from one tank to the next, becomes less and less polluted.