Typical depurative mechanisms in phytodepuration treatments

Chemical-physical processes (like adsorption, precipitation, filtering and ionic exchange) and biological type processes (deriving from cooperation between aquatic macrophytes and bacterial colonies attached to them or dispersed in the surrounding **habitat**) should be added to Phytodepuration treatments. Table 1 shows active depurative mechanisms in phytodepuration treatments against different forms of pollution.

Tab. 1: Depurative mechanisms in phytodepuration treatments

Pollution	Depurative mechanisms
Suspended solids	Sedimentation Filtration/adsorption Biological degradation (hydrolysis)
BOD and COD	Sedimentation Filtration/adsorption Biological degradation (aerobics and anaerobic)
Nitrogen	Ammonification followed by biological Nitrification/de-nitrification Assumption by plants Volatilisation ammonia
Phosphorus	Precipitation with cations (Fe, Al, Ca) present in the medium Adsorption on clay or organic substance present in the medium Assumption by plants
Heavy metals	Ionic adsorption/precipitation/exchange in the medium Assumption by plants
Pathogenic micro-organisms	Sedimentation Filtration/adsorption Predation and natural death UV radiation Release of antibiotic substances by plants

Suspended solids (sedimentable and colloid)

The suspended solids are basically removed for sedimentation or filtering, ie through physical type mechanisms. Colloids are eliminated by adsorption by other solids, or hydrolytic type biological degradation (provoking the enzymatic break-up of organic macro-molecules that is a preliminary stage of the bacterial metabolism).

Sedimentation takes place in all systems similar to biological ponds and has long been favoured for its hydraulic retention, low hydraulic waste and reduction - due to hydrophytes - of the effects of wind on water and solids accumulated on the bottom of the basin. It is best that there is a suitable volume of accumulated mud in the basin, so as to minimise emptying works. The basin should have suitably high edges so to compensate accumulation of solids with a rise in the waterline. When treatment is via floating hydrophytes, it is advisable to periodically collect the **biomass** produced, especially before winter, in order to avoid too many solids accumulating due to the death and break-up of hydrophytes.

Filtering takes place mostly in systems where liquid waste transits through the hydrophytes' growth medium (phytodepuration basins via emergent hydrophytes, sub-surface flow). In such systems, it is necessary to check that the quantity of solids involved does not clog the medium or cause unwanted routes of surface outflow to form.

Filtering can also take place in surface flow phytodepuration basins, via floating, submerged and emergent hydrophytes, thanks to the hydrophytes' root system in the column of water.

Adsorption can develop in all systems concerning chemical-physical action by plants and the medium on colloidal (physical adsorption) and dissolved (chemical adsorption) solids.

Another typology of suspended solids that can be removed in phytodepuration treatments is micro--algae, present in the effluent in ponds due to light being screened by hydrophytes (especially floating species).

BOD AND COD

Treatment systems for "Wetlands" contribute to a significant reduction of **BOD** levels, through physical sedimentation of solids within the wetlands' system of channels and via direct physical filtering of solids (through plants or biological processes with micro-organisms in the rhizosphere).

Organic substances that enter a phytodepuration system can be in the form of solid sedimentables or dissolved substances. The suspended fraction is removed for sedimentation or filtering, while the attached and suspended micro-organisms are responsible for the degradation of the dissolved fraction.

Biological degradation of organic substances by micro-organisms can take place in aerobic or anaerobic conditions. When oxygen is present (aerobiosis), heterotrophic bacteria oxidize organic molecules achieving the necessary energy for their vital functions.

There is aerobic degradation in the oxygenated portion of the column of water and **rhizosphere and** anoxic degradation near the oxygenated areas where the absence of molecular oxygen is associated with a source of combined oxygen (mostly nitrates and sulphates). Lastly, there is also anaerobic degradation in areas deprived of oxygen, whether free or combined, but especially in sediments. Selecting the most suitable plants is important then - the expansion of the aerobic area depends, in fact, on the diffusion of these plants' root systems.

Nitrogen

Nitrogen in wastewater is crucial when treating it. Nitrogen in seawaters and **phosphorus** in fresh water can lead to excessive algae growth and **eutrophication**.

Mechanisms for removing various nitrogenous forms are numerous and include the volatilisation of ammonia, the nitrification/de-nitrification process, and assumption by plants and adsorption of inactive and vegetal supports.

Phosphorus

Typical mechanisms for removing phosphorus are: direct assumption by plants, with consequent collection; biological and chemical accumulation in sediments. Effectiveness is generally best in sub-surface flow basins, because - as opposed to surface flow - they increase chances of contact between liquid waste and sediment.

A plant's direct assumption of this substance is less than that of nitrogen. This is due to its lesser ability to accumulate and limited concentration of phosphorus in the vegetal tissues, as shown in table 2. As problems concerning **biomass** disposal and the temporary state of nutrient accumulation in the removable part of hydrophytes also affect phosphorus, it is necessary to remove phosphorus by collecting the vegetal biomasses. This way death of the hydrophytes (with or without roots) is avoided and most of the phosphorus assumed by the surface waters, is released.

Tab. 2: Absorption of nitrogen and phosphorus and production of biomass of certain aquatic macrophytes

Hydrophytes	biomass		nitrogen		phosphorus	
	density [gSS/m^2]	productivity [gSS/m^2×gg]	composition [gN/KgSS]	assumption [gN/m^2×gg]	composition [gP/KgSS]	assumption [gP/m^2×gg]
FLOATING:						
Eichhornia crassipes	2000-2400	16-30	10-40	0,53-1,60	1,4-12,0	0,10-0,31
Hydrocotyle sp.	700-1100	8-16	15-45	0,15-0,88	2,3-7,5	0,04-0,21
Lemna sp.	130	2-7	25-50	0,1-0,33	4,0-15,0	0,03-0,11
Salvinia sp.	240-320	2-12	20-48	0,1-0,47	1,8-9,0	0,03-0,12
EMERGENT:						
Typha sp.	430-2250	2-17	5-24	0,16-0,72	0,5-4,0	0,02-0,11
Juncus sp.	2200	15	15	0,22	2,0	0,03
Scirpus sp.	-	-	8-27	0,03	1,0-3,0	0,01
Phragmites sp.	600-3500	3-16	18-21	0,06	2,0-3,0	0,01

Heavy metals

Little is known about removing these pollutants with phytodepuration systems. Mechanisms are similar to those shown for phosphorus and include direct assumption by plants, collection and biological storage of hydrophytes (following death and slow decomposition), and, especially processes of adsorption, precipitation and ionic exchange in sediments.

Removal of heavy metals is generally most effective in sub-surface flow phytodepuration basins compared to surface flow, since chances of contact between liquid waste and sediment are high.

Pathogenic micro-organisms

Different phytodepuration systems remove virus and bacteria effectively. Viruses can be removed via adsorption or made harmless due to unfavourable environmental conditions (long retention times). Bacteria can be removed via sedimentation, filtering, due to ultraviolet radiation and natural decadence (natural die-off caused by adverse environmental conditions).

Another significant effect is when root systems release metabolite plants as they have an antibiotic effect on bacteria.

Ultraviolet radiation has an important effect on uncovered surface water systems (where hydrophytes don't block the surface and allow solar rays through). With sub-surface flow systems, in particular, wastewater flowing through the medium is in contact with both the anaerobic environment of the saturated land and aerobic micro-zones adjacent to the root system. This process produces metabolic stress both on anaerobic and aerobic bacteria.

It should also be noted that in many aquatic ecosystems, internal faecal bacteria contributions exist due to bird and mammal populations within these **habitats**.