URBAN WASTEWATER TREATMENT TECHNOLOGIES

Statistical, Economic and Social Research and Training Centre for Islamic Countries
Higher Council for Environment and Natural Resources
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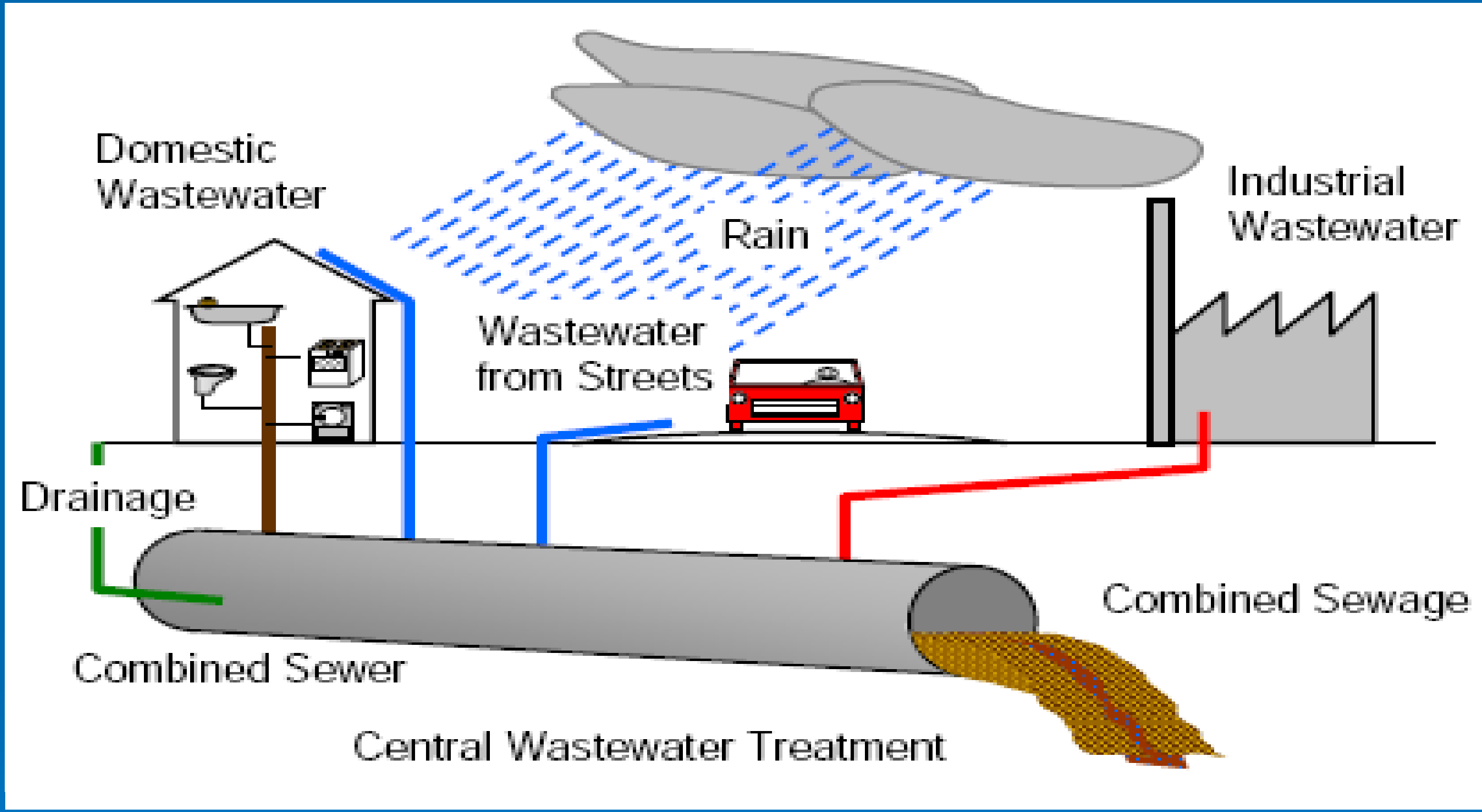
Source of Wastewater



Waste-water originates predominantly from water usage by residences and commercial and industrial establishments, together with groundwater, surface water and storm water.

Major contaminants in municipal sewage

- Suspended solids (TSS)
- Biodegradable organics (BOD)
- Nutrients (N, P)
- Toxic compounds/heavy metals
- Endocrine disruptors
- Pathogens (bacteria, viruses, worm eggs, protozoa,parasites)

Wastewater Treatment Technologies

Unit operations	Methods
Physical unit operations ⇨	❑ Screening ❑ Comminution ❑ Flow equalization ❑ Sedimentation ❑ Flotation ❑ Granular-medium filtration
Chemical unit operations ⇨	❑ Chemical precipitation ❑ Adsorption ❑ Disinfection ❑ Dechlorination ❑ Other chemical applications
Biological unit operations ⇨	❑ Activated sludge process ❑ Aerated lagoon ❑ Trickling filters ❑ Rotating biological contactors ❑ Pond stabilization ❑ Anaerobic digestion ❑ Biological nutrient removal

Physical, chemical and biological methods are used to remove contaminants from waste-water.

In order to achieve different levels of contaminant removal, individual waste-water treatment procedures are combined into a variety of systems, classified as primary, secondary, and tertiary waste-water treatment.

Biological Unit Processes

Biological processes are usually used in conjunction with physical and chemical processes, with the main objective of reducing the organic content and nutrient content of waste-water.

Biological processes used for waste-water treatment may be classified under five major headings:

(a) Aerobic processes;
(b) Anoxic processes;
(c) Anaerobic processes;
(d) Combined processes;
(e) Pond processes.

These processes are further subdivided, depending on whether the treatment takes place in a suspended-growth system an attached-growth system or a combination of both

Activated-Sludge Process

So far it is the most widely used biological process for the treatment of municipal and industrial wastewaters in developed countries.

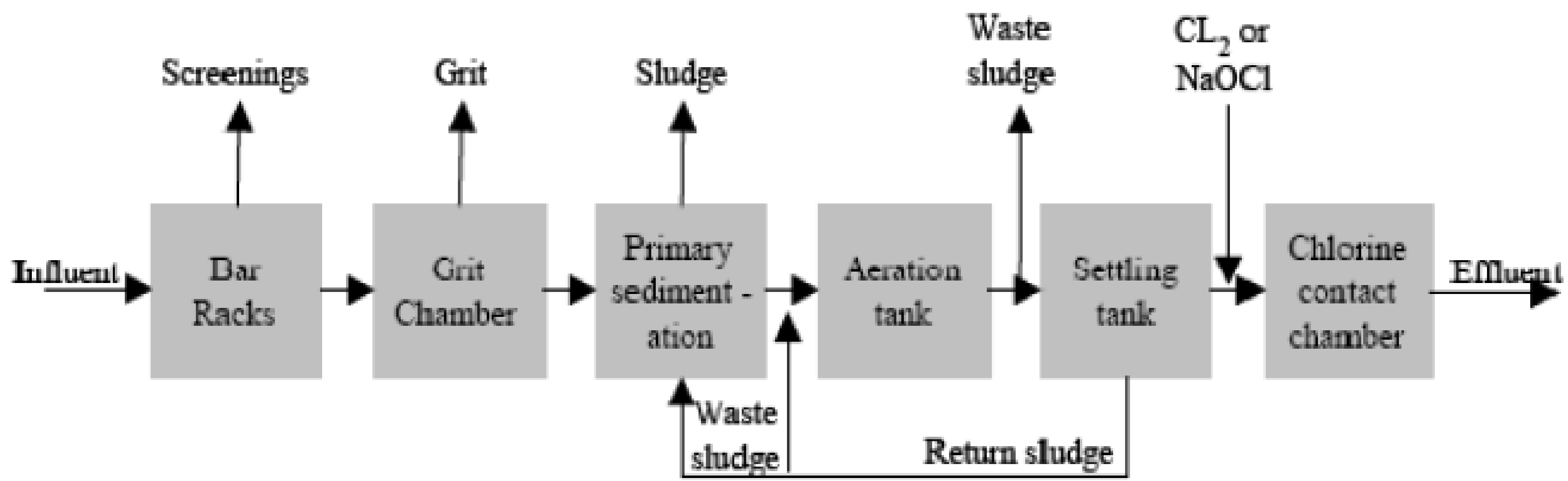
Microbial community (activated sludge) is highly diverse and competitive

Activated-Sludge Process

Liquid-solids separation occurs in sedimentation tank

• A recycle system for returning solids removed from the liquid-solids separation unit back to the reactor to maintaining a high concentration of cells

• Formation of flocculent settleable solids that can be removed by gravity settling



Basic activated sludge process flow sheet

Activated-Sludge Process

Advantages

- Adapted to any size of community (except very small ones)
- Good elimination of all the pollution parameters (SS,COD, N, P);
- Partially-stabilized sludge
- Small area required

Disadvantages

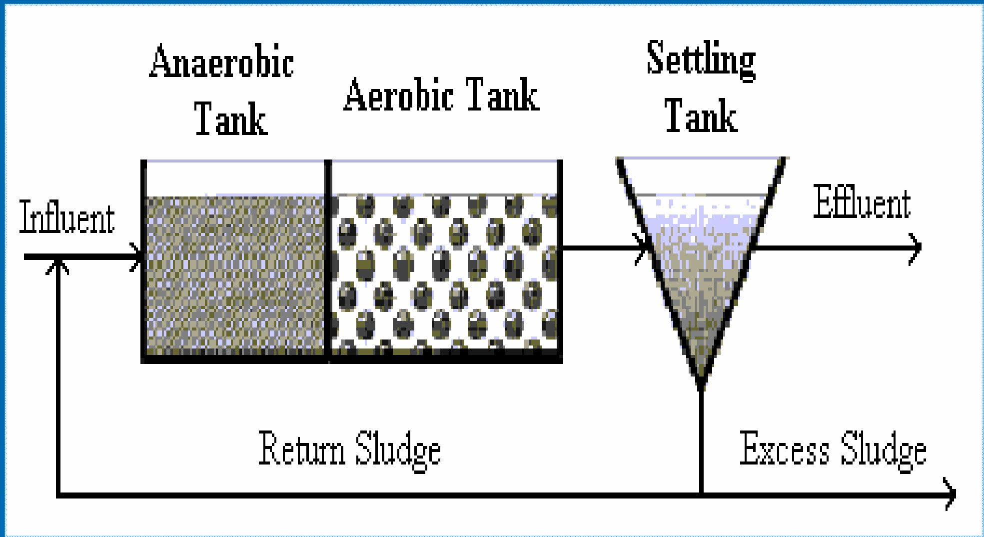
- Relatively high capital costs
- High energy consumption
- Requires skilled personnel and regular monitoring
- Sensitivity to hydraulic overloads
- Settling property of sludge is not always easy to control (bulking sludge)
- High production of sludge

Nutrient Removal

Nitrogen and phosphorus are the principal nutrients of concern in waste-water discharges. Discharges containing nitrogen and phosphorus may accelerate the eutrophication of lakes and reservoirs and stimulate the growth of algae and rooted aquatic plants in shallow streams.

Removal of Phosphorus by Biological Methods

A/O Process (Mainstream Phosphorus Removal)



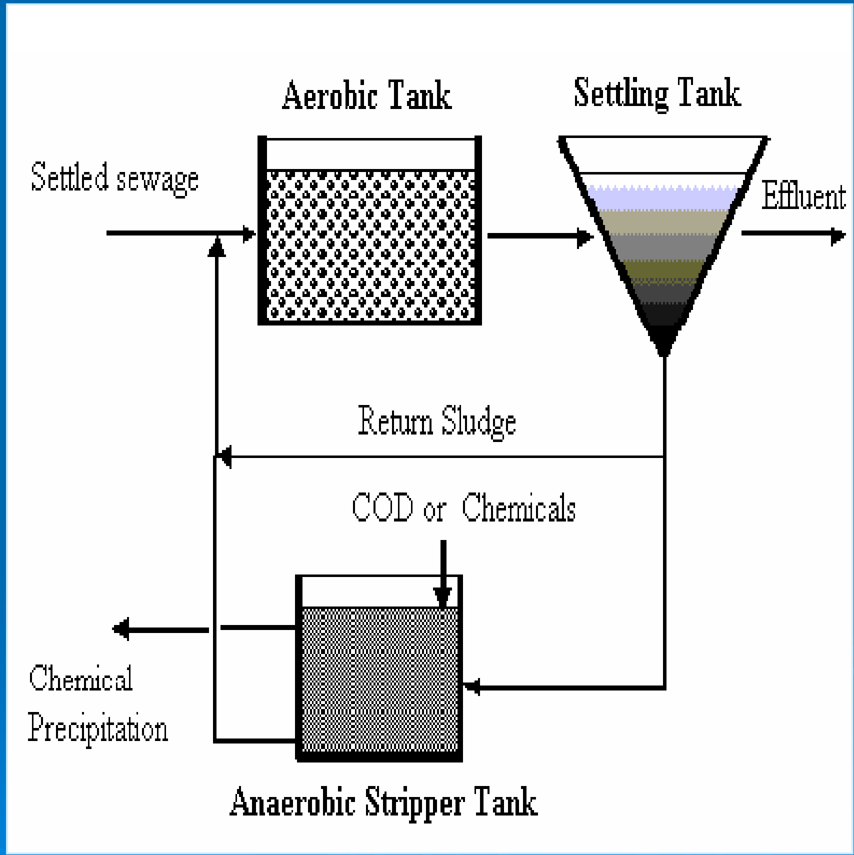
The proprietary A/O process is used combined carbon oxidation and phosphorus removal from wastewater. The A/O process is a single-sludge suspended-growth system that combines anaerobic and aerobic sections in sequence.

"In A/O Processes there is no nitrification, and the anaerobic detention time is 30 min to 1h for biological phosphorus removal. SRT (solid retention time) of the aerobic zone mixed liquor is 2 to 4 d, depending on temperature."

Removal of Phosphorus by Biological Methods

PhoStrip Process (Sidestream Phosphorus Removal)

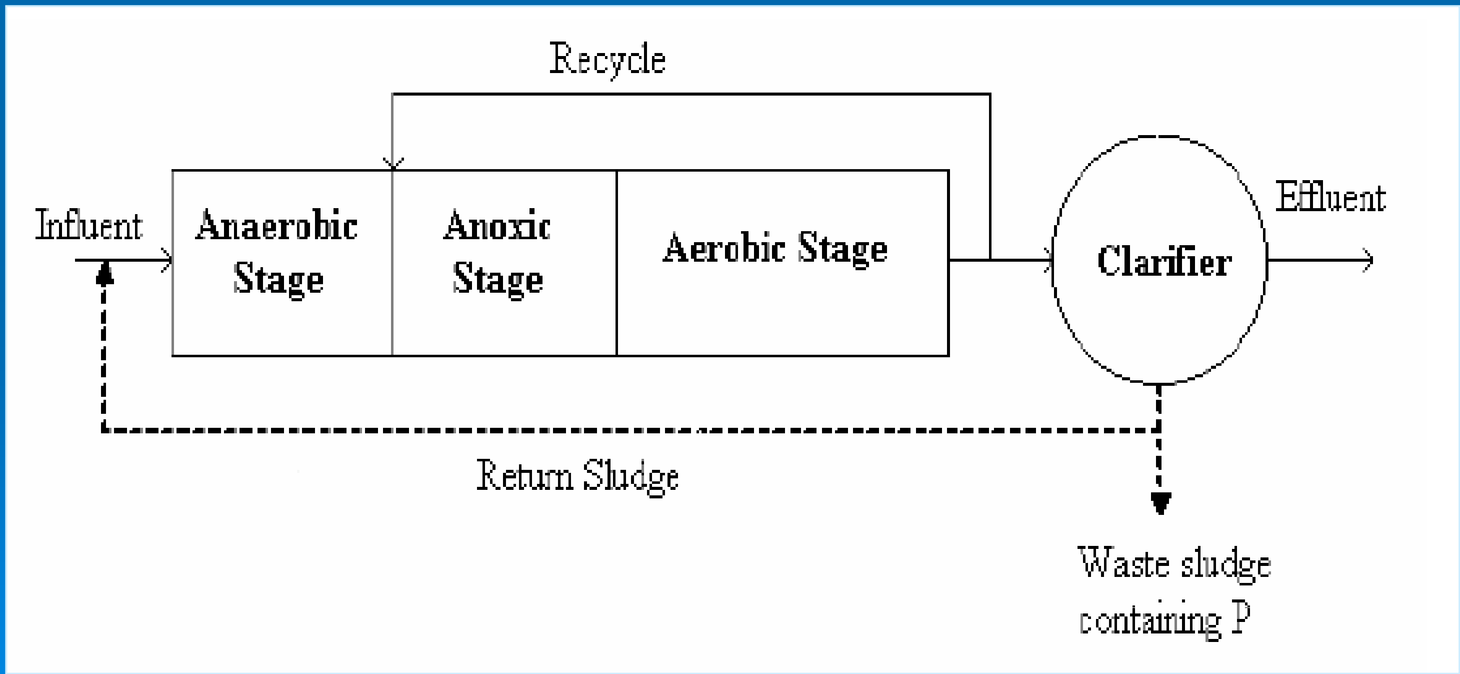
- In fact PhoStrip Process consists of biological and chemical process.
- A part of the return activated sludge is transported to an anaerobic stripper tank. The retention time in this tank ranges from 8 to 12 hours.
- Acetic acid or influent is added to stripper tank to supply phosphorus release. The phosphorus released in the stripping tank passes out of the tank in the supernatant, and the phosphorus-poor activated sludge is returned to the aeration tank.
- The phosphorus-rich supernatant is treated with lime or another coagulant in a separate tank. So phosphorus will be removed in chemical sludge.



Combined Removal of Nitrogen and Phosphorus Biological Methods

A2/O Process

A2/O process is a modification of the A/O process and provides an anoxic zone for denitrification. The detention time in the anoxic zone is approximately one hour.



Combined Removal of Nitrogen and Phosphorus Biological Methods

Bardenpho Process (five-stage)

Bardenpho process contains an initial anaerobic zone where PAOs take up and store VFAs that are either present in the influent wastewater or produced by fermentation in this zone.

Effluent from the anaerobic zone flows into an anoxic zone where nitrate-rich mixed liquor from the downstream aerobic zone (mixed liquor recycle, MLR) is added to provide nitrate-nitrogen to allow denitrification to occur.

Combined Removal of Nitrogen and Phosphorus Biological Methods

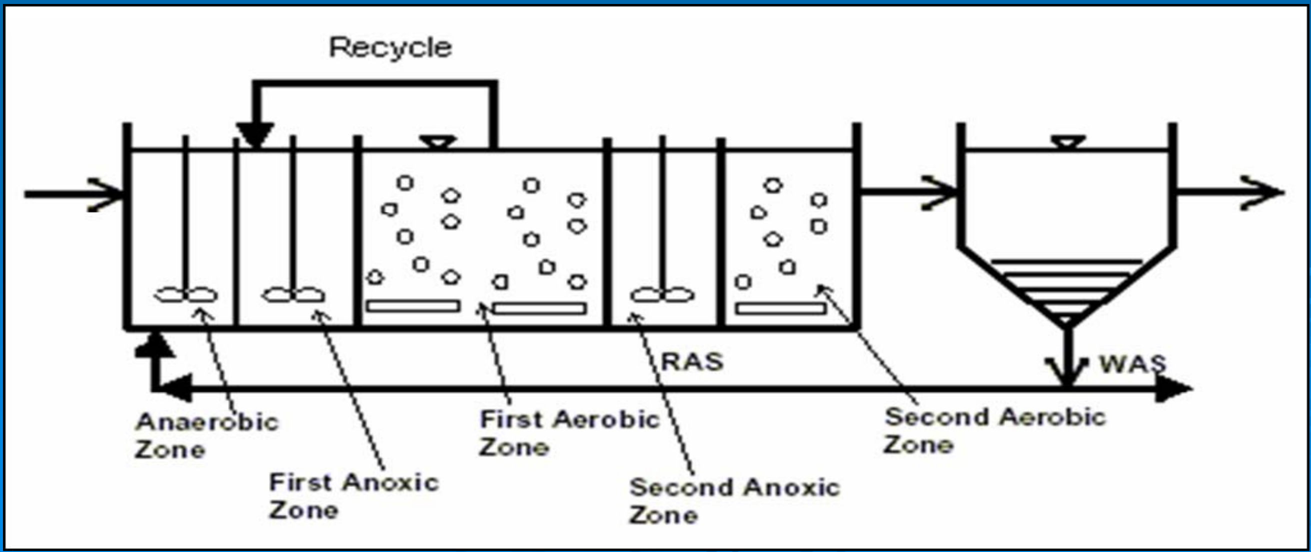
Biodegradable organic matter, present in the influent wastewater, provides the carbon source to drive a rapid rate of denitrification.

Effluent from the anoxic zone flows to the first aerobic zone where oxygen is added to allow nitrification to occur.

PAOs also oxidize the VFAs stored in the anaerobic zone. Effluent from the first aerobic zone flows into the second anoxic zone where additional denitrification occurs.

The effluent from the second anoxic zone flows to the second aerobic zone

where nitrogen gas formed in the upstream anoxic zone is stripped from the mixed liquor prior to following to the secondary clarifier.

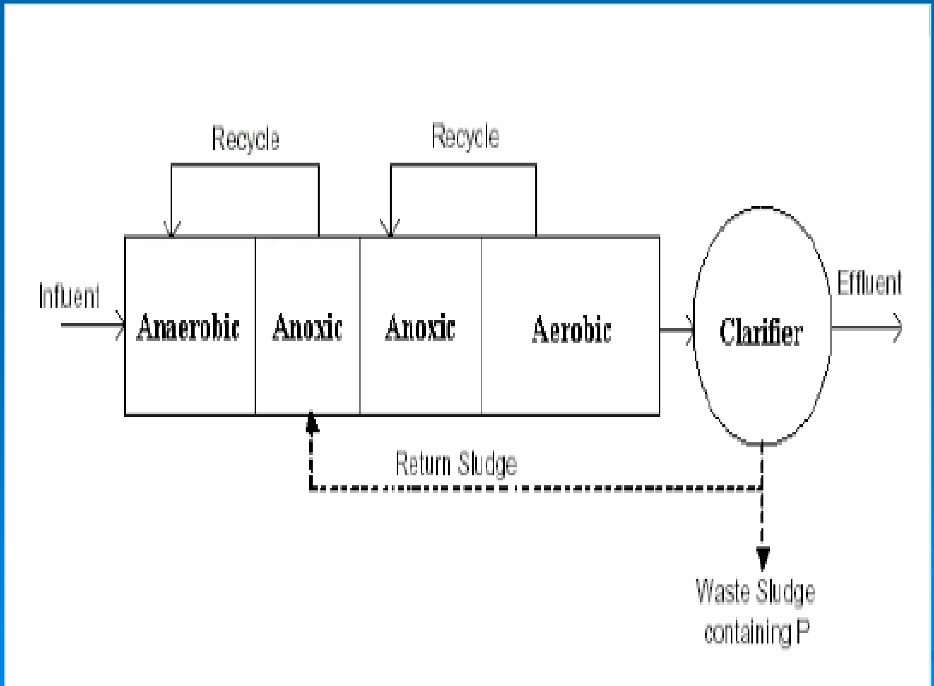


Combined Removal of Nitrogen and Phosphorus Biological Methods

UCT (University of Cape Town) Process

Negative effects of nitrate recycle to anaerobic stage have been observed.

On the basis of these observations, UCT process was developed changing A2/O process. There are two differences between A2/O process and UCT process. First difference is that return activated sludge is returned to anoxic stage instead of anaerobic stage. Second difference is that an internal recycle from anoxic stage to anaerobic stage is added.

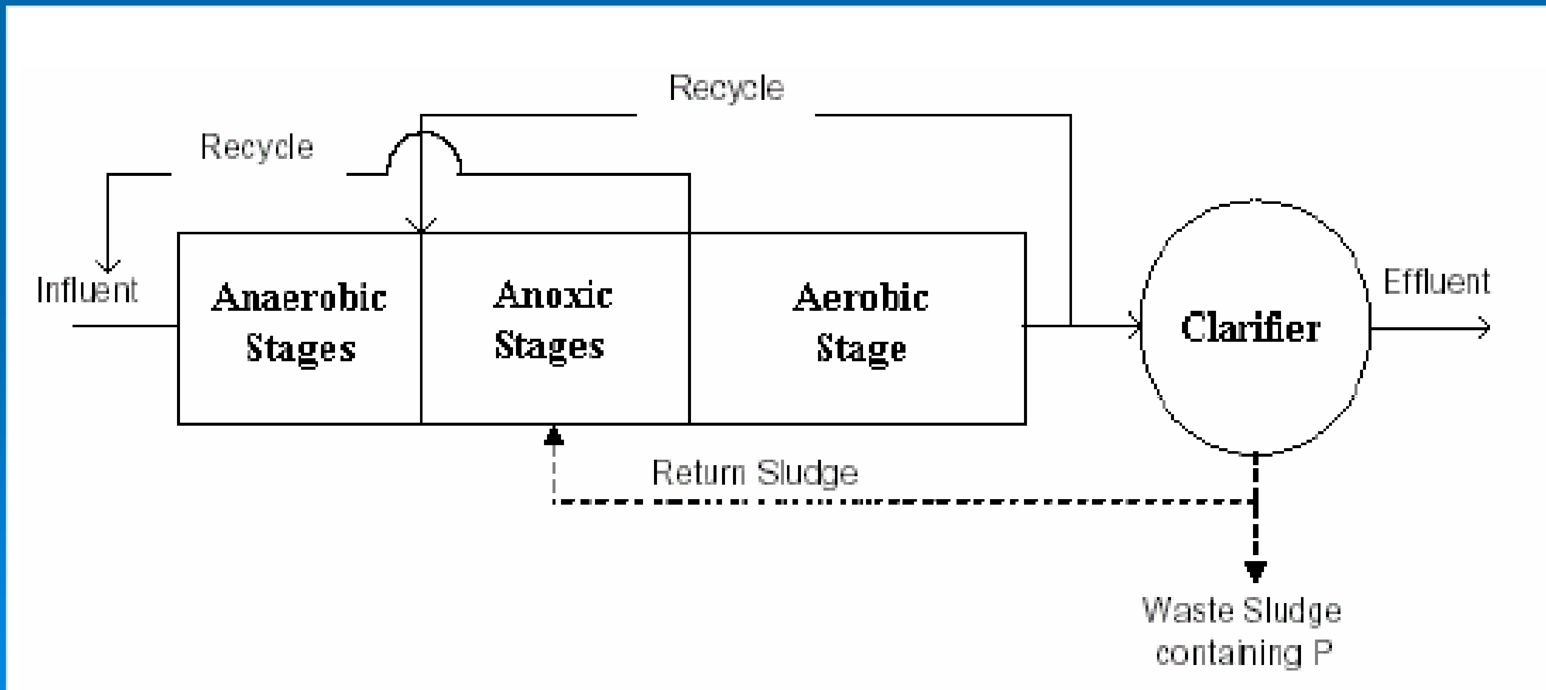


By returning the activated sludge to the anoxic stage, the introduction of the nitrate to the anaerobic stage is eliminated, thereby improving the release of phosphorus in the anaerobic stage. The internal recycle feature provides for increased organic utilization in the anaerobic stage. The mixed liquor from the anoxic stage contains substantial soluble BOD but little nitrate. The recycle of the anoxic mixed liquor provides for optimal conditions for fermentation uptake in the anaerobic stage.

Combined Removal of Nitrogen and Phosphorus Biological Methods

VIP process (VIP stands for the Virginia Initiative Plant)

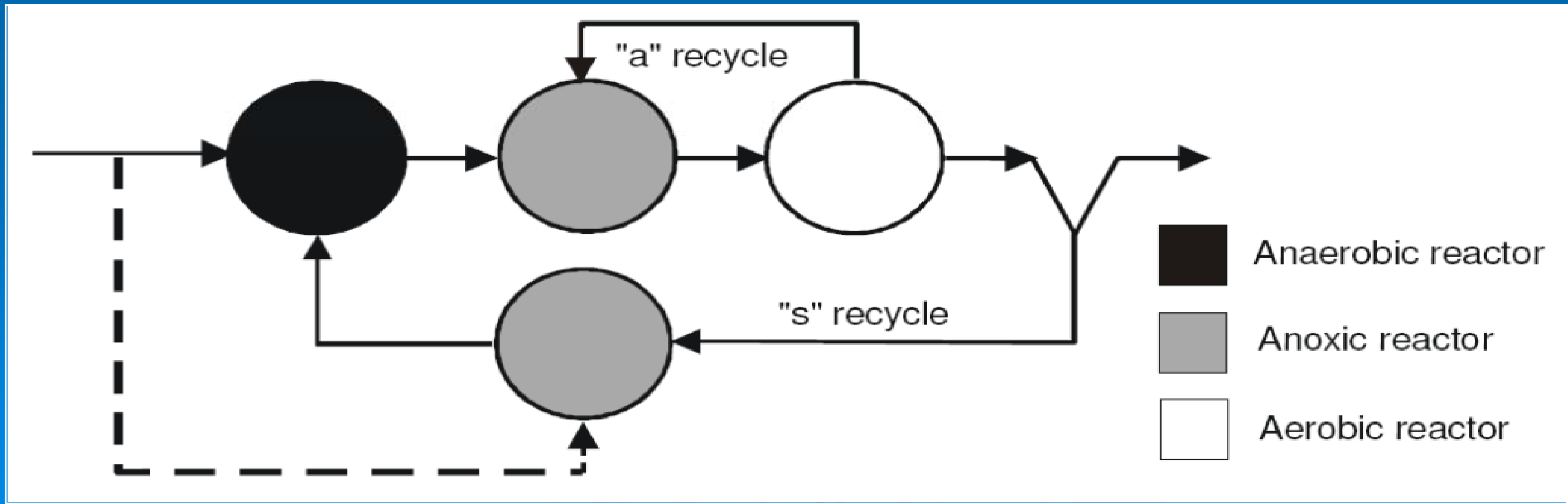
VIP process is similar to UCT process, with one exception. There is anaerobic, anoxic, aerobic tanks in VIP process are divided parts one more than.



Combined Removal of Nitrogen and Phosphorus Biological Methods

JOHANNESBURG

The process is an alternative to standard and modified UCT processes to minimize nitrate feeding to the anaerobic zone. The return activated sludge is directed to an anoxic zone that has sufficient detention time to reduce the nitrate in the mixed liquor before it is fed to the anaerobic zone . Compared to the UCT process a higher MLSS concentration can be maintained in the anaerobic zone which has a detention time of about 1 h.

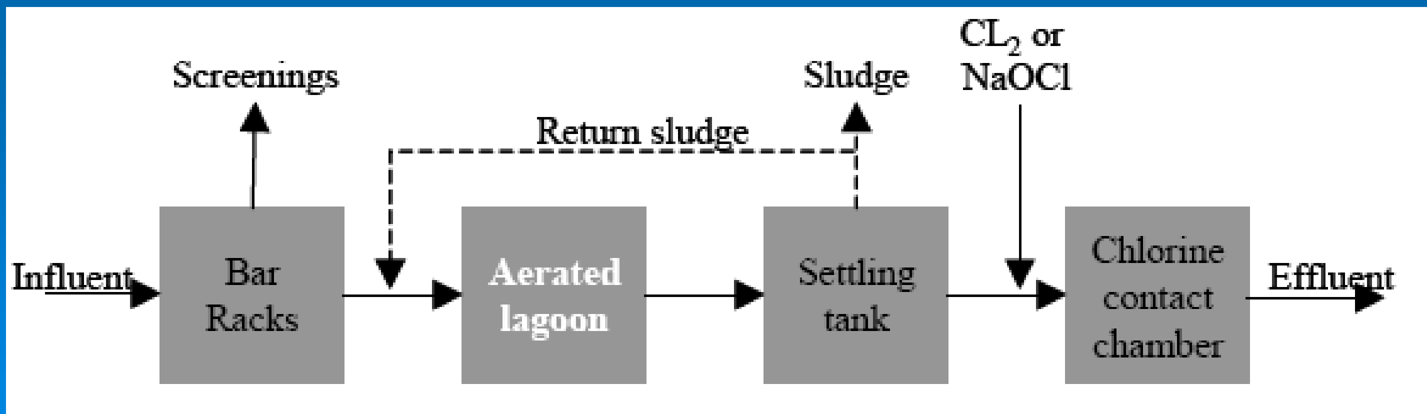


Aerated Lagoons

- An aerated lagoon is a basin between 1 and 4 meters in depth

- The microbiology involved in this process is similar to that of the activated-sludge process. However, differences arise because the large surface area of a lagoon may cause more temperature effects than are ordinarily encountered in conventional activated-sludge processes.

- Waste-water is oxygenated by surface, turbine or diffused aeration.



Trickling Filters

- The trickling filter is the most commonly encountered aerobic attached-growth biological treatment process used for the removal of organic matter from waste-water.
- It consists of a bed of highly permeable medium to which organisms are attached, forming a biological slime layer, and through which waste-water is percolated. The filter medium usually consists of rock or plastic packing material.
- The organic material present in the waste-water is degraded by adsorption on to the biological slime layer. In the outer portion of that layer, it is degraded by aerobic micro-organisms.
- As the micro-organisms grow, the thickness of the slime layer increases and the oxygen is depleted. An anaerobic environment is thus established near the surface of the filter medium.
- As the slime layer increases in thickness, the organic matter is degraded before it reaches the micro-organisms near the surface of the medium. Deprived of their external organic source of nourishment, these micro-organisms die and are washed off by the flowing liquid. A new slime layer grows in their place.

Trickling Filters

Advantages

- Simplicity of operation
- Resistance to shock loads
- Low power requirements

Disadvantages

- Relatively low BOD removal (85%)
- High suspended solids in the effluent (20 to 30 mg/l)
- Very little operational control

Rotating Biological Contactors

A rotating biological contractor (RBC) is an attached-growth biological process that consists of one or more basins in which large closely-spaced circular disks mounted on horizontal shafts rotate slowly through waste-water

The disks are partially submerged in the waste-water, so that a bacterial slime layer forms on their wetted surfaces.

As the disks rotate, the bacteria are exposed alternately to waste-water, from which they adsorb organic matter, and to air, from which they absorb oxygen.

Organic matter is degraded by means of mechanisms similar to those operating in the trickling filters process.

Partially submerged RBCs are used for carbonaceous BOD removal, combined carbon oxidation and nitrification, and nitrification of secondary effluents. Completely submerged RBCs are used for denitrification.

Rotating Biological Contactors

Table 5: Advantages and drawbacks of intensive approaches (according to the Cartel internet site - http://www.oieau.fr/ service guide section)

Filière	Advantages	Drawbacks
Biological filters and RBCs (Biodisks)	• low energy consumption; • simple operation requiring less maintenance and monitoring than the activated sludge technique; • good settling characteristics of the sludge; • lower sensitivity to load variations and toxins than activated sludge; • generally adapted to small communities; • resistance to cold (the disks are always protected by hoods or a small chamber).	• performance is generally lower than with an activated sludge technique. This is mostly due to former design practices. A more realistic dimensioning should allow satisfactory qualities of treated water to be reached; • rather high capital costs (can be greater by about 20% compared to activated sludge); • requires effective pre-treatment; • sensitivity to clogging; • large-size structures if requirements for removing nitrogen are imposed.
Activated sludge	• adapted to any size of community (except very small ones); • good elimination of all the pollution parameters (SS, COD, BOD5, N by nitrification and denitrification); • adapted to the protection of sensitive receiving areas; • partially-stabilised sludge (see glossary); • easy to implement simultaneous dephosphatation.	• relatively high capital costs; • high energy consumption; • requires skilled personnel and regular monitoring; • sensitivity to hydraulic overloads; • the settling property of sludge is not always easy to control; • high production of sludge that must be thickened.

Stabilization Ponds

A stabilization pond is a relatively shallow body of waste-water contained in an earthen basin, using a completely mixed biological process without solids return. Mixing may be either natural (wind, heat or fermentation) or induced (mechanical or diffused aeration). Stabilization ponds are usually classified as aerobic, anaerobic, or aerobic-anaerobic.

The bacterial population oxidizes organic matter, producing ammonia, carbon dioxide, sulfates, water and other end products, which are subsequently used by algae during daylight to produce oxygen.

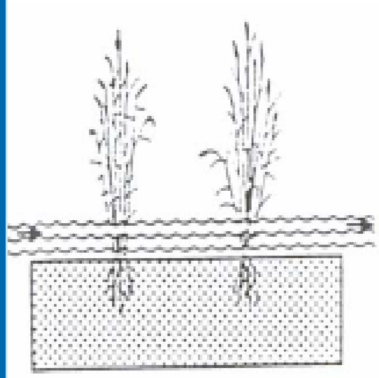
Waste-water retention time ranges between 30 and 120 days. This is a treatment process that is very commonly found in rural areas because of its low construction and operating costs.

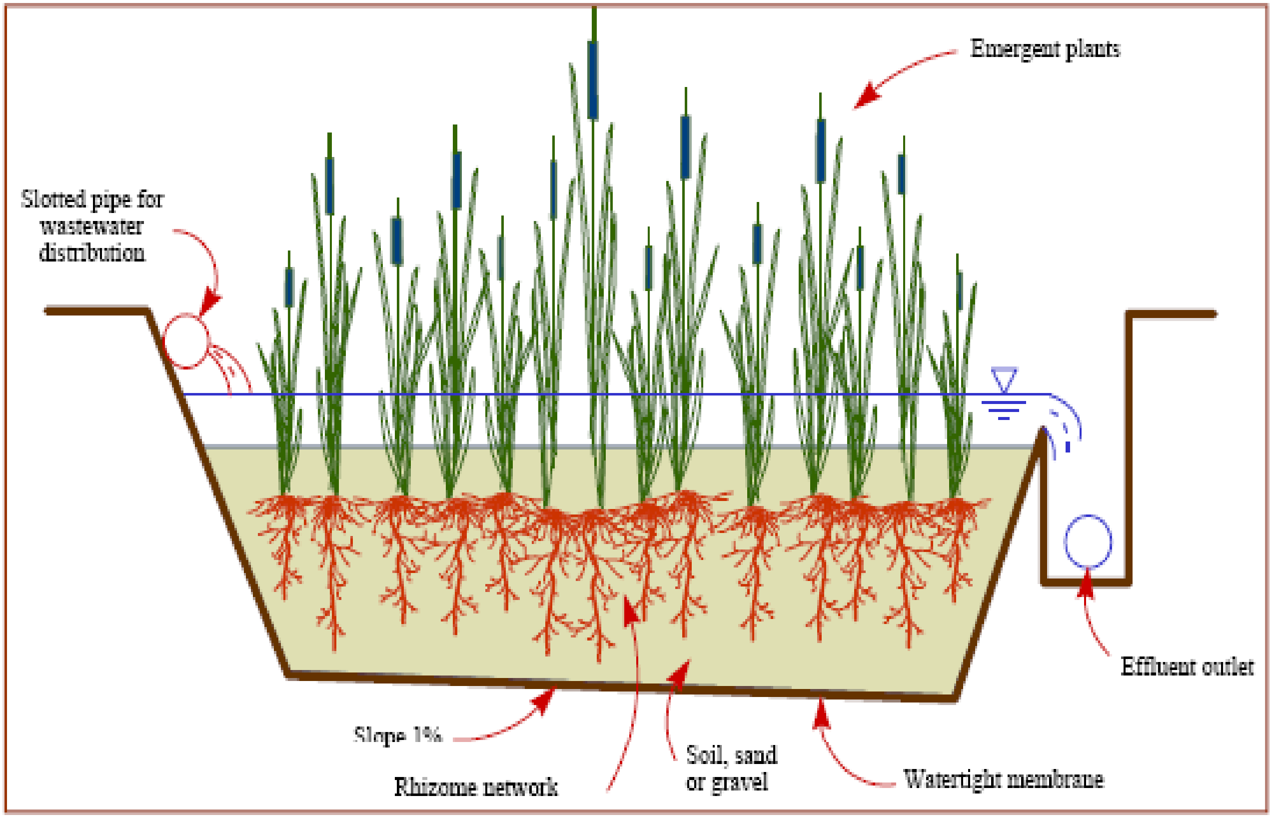
Constructed Wetlands

Wetlands are inundated land areas with water depths typically less than 2 ft (0.6 m) that support the growth of emergent plants such as cattail, bulrush, reeds and sedges. The vegetation provides surfaces for the attachment of bacteria films, aids in the filtration and adsorption of waste-water constituents, transfers oxygen into the water column, and controls the growth of algae by restricting the penetration of sunlight.

There are several types of constructed wetlands: surface flow wetlands, subsurface flow wetlands, and hybrid systems that incorporate surface and subsurface flow wetlands. Constructed wetland systems can also be combined with conventional treatment technologies.

Free-water-surface or surface flow CTW



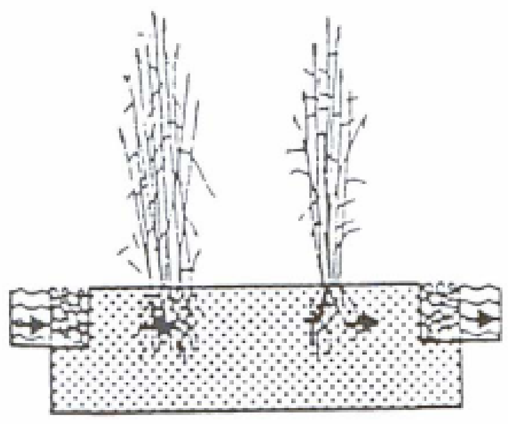


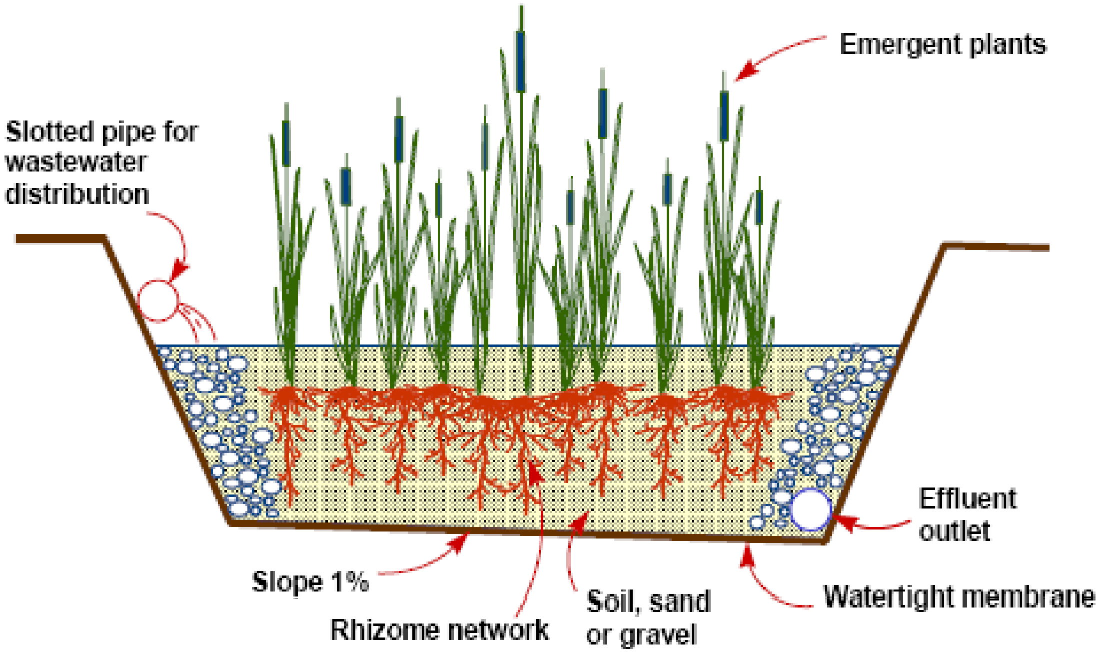
Water flows <u>over</u> soil media and < 50 cm deep. Mostly planted with sedges, reeds, rushes. This is a land intensive system (5-10 m^2 per PE).

Sub-surface Flow CTW

A subsurface flow (SSF) wetland consists of a sealed basin with a porous substrate of rock or gravel. The water level is designed to remain below the top of the substrate. In most of the systems in the United States, the flow path is horizontal, although some European systems use vertical flow paths.

Horizontal-subsurface flow or rootzone CTW

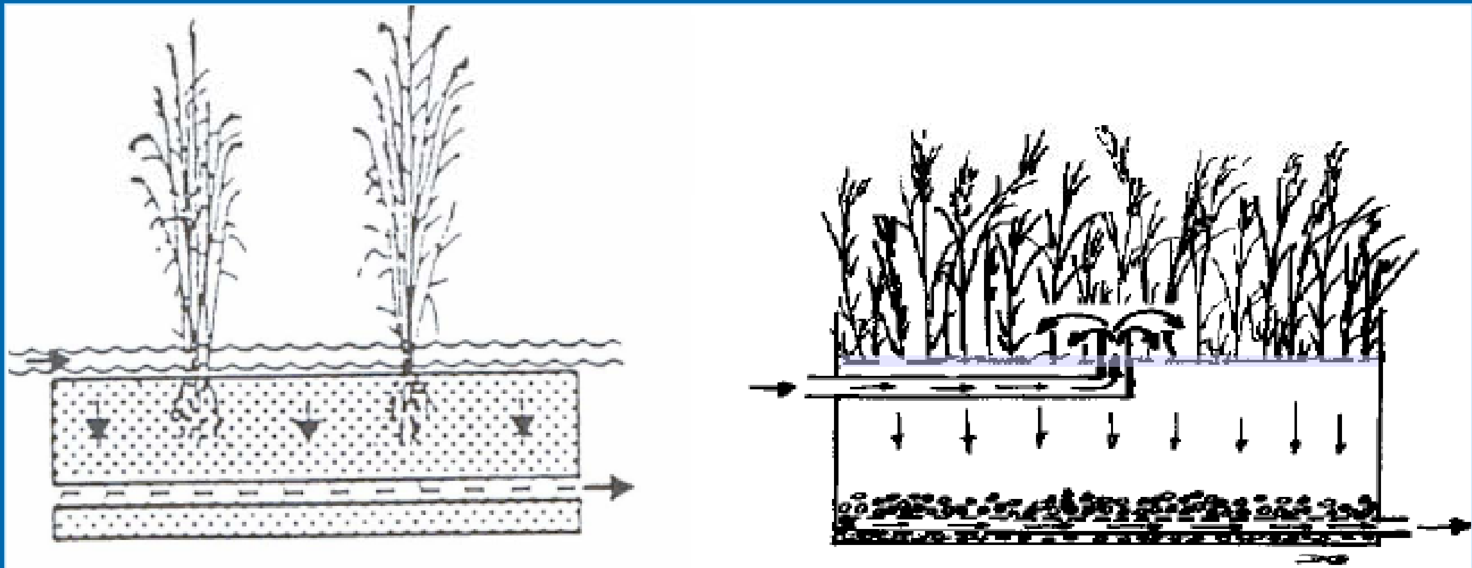




Water flows below a medium of sand, gravel, soil and/or rock. Grasses and trees are commonly used. Amount of land reduced (3-5 m^2 per PE).

Inlet and outlet zone with coarse gravel or rocks for better distribution of wastewater

Vertical-flow or infiltration CTW

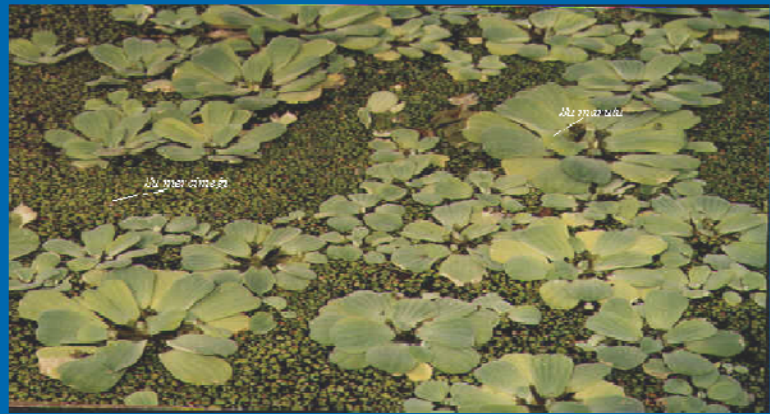


Water is pumped on the surface and then drains down through the filter layer. Amount of land minimal (2-3 m[2] per PE).

Plants in Constructed Wetlands

Water Hyacinth

Water Lettuce - Duckweed



Reed Mace (Typhia latifolia)

Irıs Pseudacorus

Plants in Constructed Wetlands

Sedge

Cyperus alternifolius

Juncus species

Scirpus

Constructed Wetlands

Advantages of CTW

- Low-medium investment cost
- Low O&M costs
- Simple operation and maintenance –unskilled labour
- Little or no energy inputs
- Can be integrated into landscaping

Disadvantages:

- Mosquitoes (in Free Water Surface Systems)
- Start-up problems
- Space requirement
- Variable performance possible (~ climate)
- Lack of good models for design and operation
- Low prestige

Constructed Wetlands

Constructed wetland on the isle of Texel (NL) for further polishing of tertiary treated wastewater and ecological upgrading (Water Harmonica concept) (Toet, 2003)

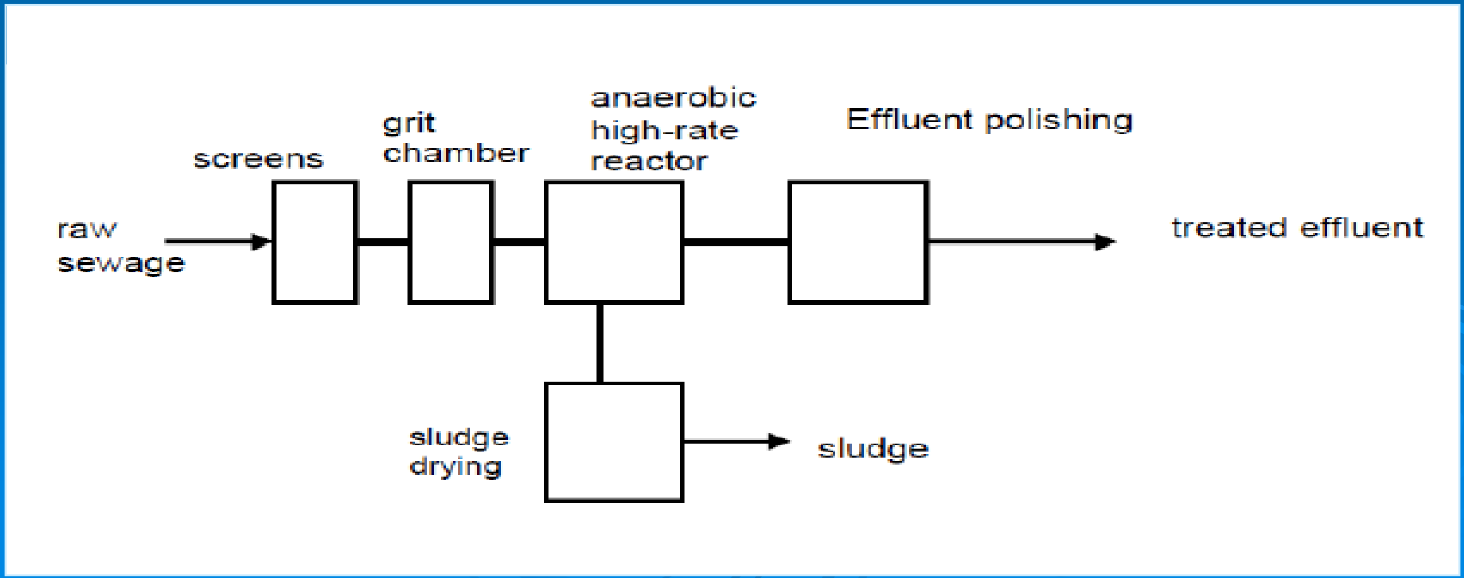
Constructed Wetlands

For Human Use; recreation walking, fishing, art (photography)

Completely Mixed Anaerobic Digestion

- Anaerobic digestion involves the biological conversion of organic and inorganic matter in the absence of molecular oxygen to a variety of end-products including methane and carbon dioxide.

- The two most widely used types of anaerobic digesters are standard-rate and high-rate. In the standard-rate digestion process, the contents of the digester are usually unheated and unmixed, and are retained for a period ranging from 30 to 60 days. In the high-rate digestion process, the contents of the digester are heated and mixed completely, and are retained, typically, for a period of 15 days or less.



Completely Mixed Anaerobic Digestion

Advantages

- Production of energy-rich methane
- No energy demand for aeration
- No removal of nitrogen and phosphorus (this is an advantage if effluent is to be reused in agriculture)
- High organic loading rates can be applied
- Suitable for high-strength wastewater (high BOD)
- Low production of excess sludge; the digestate is highly stabilized and can easily be dewatered

Limitations treating domestic sewage

•Not effective in removing nutrients

•Only partially effective in removing pathogens

•Difficulties in removing finely dispersed solids

•Low activity at temperatures < 10-15 °C

•At low temperatures the hydrolysis rate of particulate matter becomes the rate limiting step

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