Annexure 18

Application of Natural Methods for Sewage Treatment and Polishing of Treated Wastewater

CONCEPT OF PHYTORID TECHNOLOGY

Urbanization can drastically alter the natural hydrologic cycle, destroying natural areas such as wetlands that are important for water quality and controlling urban storm water runoff. The urban pollutant loads increase with the imperviousness of the watershed. Urban and sub-urban runoff including storm water runoff, non-point source pollution, contributes significantly to the pollution load as shown in **Figure 1 and Figure 2**.

Figure 1: Strom Water Pollution Load

Additionally, the storm water flows and concentrations are episodic, changing rapidly in volume, duration and intensity.

Figure 2: Status of Pollution Load in Nallas

These flows can carry sediment with nutrient loads into urban settings where the pollutant loads are further augmented by increased runoff from impervious surfaces such as parking lots, roadways, rooftops, etc. The resultant runoff can include suspended particulate matter and nutrients (especially N and P) from vehicle exhaust and atmospheric deposition, trace metals from metal corrosion, materials from worn brake lining and tires, salts (deicing salts), and a wide array of complex hydrocarbons (such as motor additives, pesticides, rubber, oil and grease.

Municipal wastewater treatment has been normally carried out by conventional systems. These systems along with advanced technologies being employed at many places are highly dependent upon power availability, skilled manpower and waste load characteristics. In developing countries, some of these could be critical towards efficient waste treatment. These factors are also responsible for varying degree of treatment efficiency that may not produce the desirable levels of standards prescribed by the regulatory agencies/authorities.

Thus, it is important to demand of time to develop a sustainable wastewater treatment system overcoming the above-mentioned limitations of the conventional wastewater treatment technologies. One such system is Phytorid Technology based on “re-engineer” wetlands systems to solve the current runoff and wastewater quality problems. Wetlands have always been part of our ecosystem where we live.

Figure 3: Natural Wetlands as a Treatment Options

Natural wetlands have been used to treat wastewater for hundreds of years. Formal documentation of how these natural wetlands (**Figure 3**) affected wastewater quality began in the 1960s and 1970s. Research found consistent reductions in the pollutant concentrations of wastewater, as it passed through the microbial active wetlands. And by the late 1970s and early 1980s, this research led to the planning, development, and construction of discharges to natural wetlands at many locations in North America, as well as the implementation of wetland technology for both habitat and water quality functions.

Wetlands can be engineered and constructed for the following reasons:
1. To compensate and offset the rate of existing wetland loss (habitat wetlands),
2. To improve wastewater quality (treatment),
3. Provide flood control

Phytorid Technology was developed by NEERI and patented in Indian, European and Australian Countries. This publication is an overview of purely on the scientific research with respect to Indian climatic conditions only and takes part to assist us by becoming “green infrastructure” to wastewater quality problems.

These are constructed as shallow basins or channels with a subsurface barrier to avoid seepage. The Phytorid Technology is a subsurface flow type wherein water is applied to the cells/ beds filled with porous media such as gravel and stones. The hydraulics is maintained in such a manner that water does not rise to the surface retaining a free board at the top of the filled media. These systems may include a wide variety of foliage in the form of aquatic, marsh, ornamental, herbs, grasses and also terrestrial plants known to grow in water logged conditions.

1.1 Definition

Phytorid Technology is a designed system and constructed to make use of selected vegetation to assist in treating wastewater in a controlled environment than occurs in natural wetlands. The use of Phytorid wetlands for wastewater treatment takes advantage of the same principles in a natural system, within a more controlled environment. It utilizes many of the mechanisms of phytoremediation, though the maturity of wetland suggests that it is a discipline unto itself. They can be designed for a variety of treatment objectives, as influent ranges from raw wastewater to secondary effluent.

They possess a rich microbial community in the sediment to effect the biochemical transformation of pollutants, they are biologically productive, and most importantly, they are self-sustaining. These factors make constructed treatment wetlands a very attractive option for water treatment compared to conventional systems, especially when lifetime operating costs are compared.

The technology is adaptable to a variety of treatment needs (**Figure 4**) through the selective design and combination with other technologies, such as trickling filters, septic tanks, etc. Phytorid Treatment System has significantly lower total lifetime costs and lower capital costs than conventional treatment systems.

FIGURE 4: APPLICATION OF PHYTORID TECHNOLOGY

Additionally, Phytorid Treatment Systems can:

- Tolerate fluctuations in flow and pollutant concentrations,
- Provide flood protection,
- Facilitate water reuse and recycling,
- Can be built to fit harmoniously into the landscape,
- Enhance aesthetics of open spaces,
- Provide recreational and educational opportunities, and
- Environmentally sensitive approach viewed favorably by the general public.

In treatment systems, flows are fed to a gravel bed with pore spaces. Within these pores spaces, bacteria and algae do most of the treatment work in aerobic and anaerobic conditions year round. It has been shown that planted gravel beds achieved greater than 90% removal of chemicals. Several designs can be found in the literature for wetlands treatment. Some of these procedures are rules of thumb (as was the case with natural restored wetlands), based on intuition and analogs, and others are based on data analysis and application of physico-chemical principles. It is necessary for Phytorid treatment, to determine/ define the quantity and quality of water to be treated and the goals of the treatment.

The Phytorid System can be differentiated according to the following criteria:

- ▪ Filter media : Origin, composition, grain size distribution, hydraulic properties, etc.
- • Flow : Horizontal /vertical /or both
- • Operation : Continuously
- o Plantation : Stabilized/ acclimatized, selected species for treatment, aesthetic views, based on the reuse of treated water.

1.2 Treatment Mechanism Involved in Phytorid Technology

- Phytorid Treatment Systems have been found to be effective in treating BOD, TSS, N and P as well as for reducing metals, organic pollutants and pathogens. The principal pollutant removal mechanisms in treatment systems include biological processes such as microbial metabolic activity and plant uptake as well as physico-chemical processes such as sedimentation, adsorption and precipitation at the water-sediment, root-sediment and plant-water interfaces as shown in **Figure 5**.
- Microbial degradation plays a dominant role in the removal of soluble/colloidal biodegradable organic matter in wastewater.
- Biodegradation occurs when dissolved organic matter is carried into the biofilms that attached on plant root systems and surrounding media by diffusion process.
- In further development after filing of the patent 2003, further improvement was undertaken to reduce the residence time of the overall system as also to improve the technology. This development involved use of isolated bacterial consortia in the system to mainly reduce the Suspended Solids load. It also leads to reduction in BOD as well. [The requirement of bio-culture is given at the end of the document.]

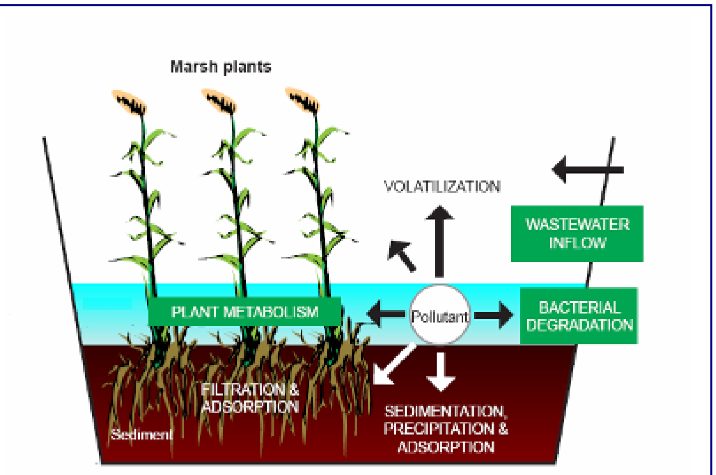


Figure 5: Processes Involved in Phytorid Treatment System

- Suspended solids are removed by filtration and gravitational settlement. A pollutant may be removed as a result of more than one process at work.
- Conversion of nitrogen compounds (Nitrification / Denitrification) occurs due to planned flow of wastewater through anaerobic and aerobic zones.

- Phosphorus is present in wastewaters as Orthophosphate, Dehydrated Orthophosphate (Polyphosphate) and Organic Phosphorus. The conversion of most Phosphorus to the Orthophosphate forms is caused by biological oxidation.
- Although plant uptake may be substantial, the sorption of Phosphorus (Orthophosphate P) by anaerobic reducing sediments appears to be the most important process. Pathogens are removed mainly by sedimentation, filtration and absorption by biomass and by natural die-off and predation.
- Evapotranspiration slows water flow and increases contact times, whereas rainfall, which has the opposite effect, will cause dilution and increased flow.

1.3 Role of Plant Species for Treatment Mechanisms

- The most significant functions of plant species in relation to water purification are the physical effects (as shown in **Figure 6**) brought by the presence of the plants.
- The plants provide a huge surface area for attachment and growth of microbes. The physical components of the plants stabilize the surface of the beds, slow down the water flow thus assist in sediment settling and trapping process and finally increasing water transparency.

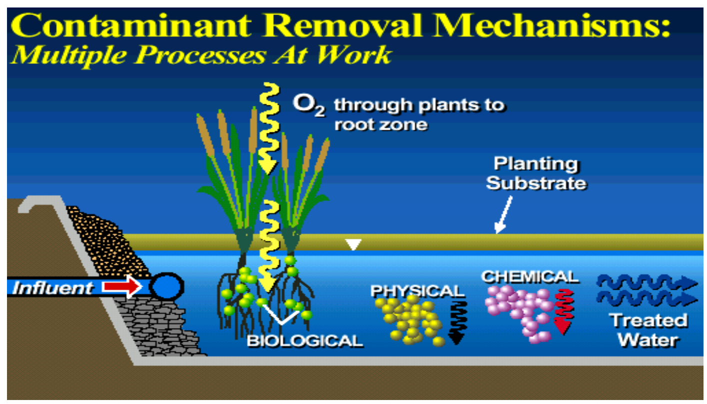


Figure 6: Contamination Removal Processes

- Plants play a vital role in the removal and retention of nutrients and help in preventing the eutrophication of wetlands. A range of plants has shown their ability to assist in the breakdown of wastewater. Cattail (*Typha* spp) are good examples of marsh species that can effectively uptake nutrients. These plants have a large biomass both above (leaves) and below (underground stem and roots as shown in the **Figure 7**) the surface of the substrate.

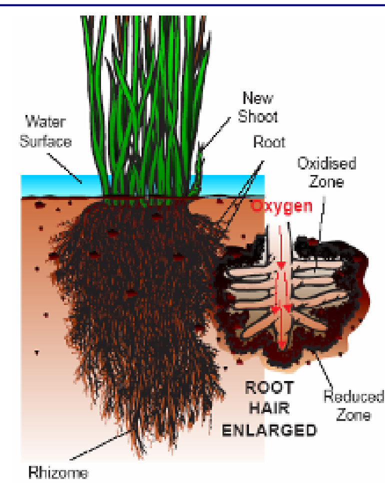


Figure 7: Root Structure for Treatment

- The sub-surface plant tissues grow horizontally and vertically, and create an extensive matrix, which binds the particles and creates a large surface area for the uptake of nutrients and ions. Hollow vessels in the plant tissues enable oxygen to be transported from the leaves to the root zone and to the surrounding soil.

- This enables the active microbial aerobic decomposition process and the uptake of pollutants from the water system to take place.
- Macrophytes stabilize the surface of plant beds, provide good conditions for physical filtration, and provide a huge surface area for attached microbial growth. Growth of macrophytes reduces current velocity, allowing for sedimentation and increase in contact time between effluent and plant surface area, thus, to an increase in the removal of Nitrogen.
- Hydraulic conductivity is improved in an emergent plant bed system. Turnover of root mass creates macropores in a system allowing for greater percolation of water, thus increasing effluent/plant interactions.
- Decomposing plant biomass also provides a durable, readily available carbon source for the microbial populations.
- Plant species provide a large surface area for growth of microbial biofilms (as shown in **Figure 8**) and responsible for a majority of the microbial processes in a treatment system, including Nitrogen reduction.
- Plant species mediate transfer of oxygen through the hollow plant tissue and leakage from root systems to the rhizosphere where aerobic degradation of organic matter and nitrification will take place. The plant species have additional site-specific values by providing habitat to make wastewater treatment systems aesthetically pleasing.

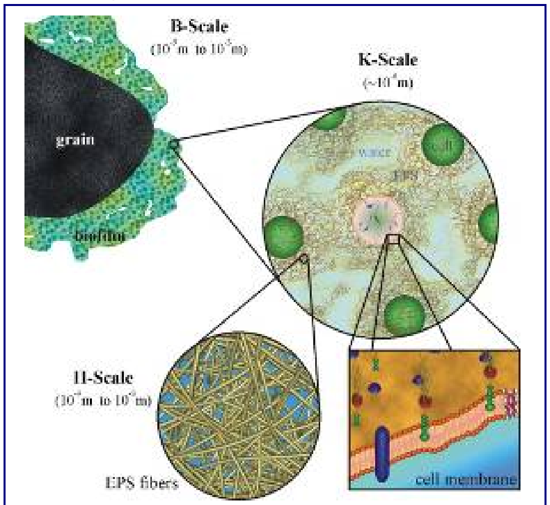


Figure 8: Biofilms Structures

1.4 Identification of Potential Sites for Construction of Phytorid Treatment System

Sites identified for treatment systems need to be assessed for:

- Existing infrastructure to determine the ease of access,
- Ownership and availability of the site,
- Engineering feasibility,
- Hydrology,
- Nature of soils on the site,
- Topography,
- Drainage area, and
- Upstream pollutant loading characteristics (including locations/ proximity of combined sewer overflows, if applicable).

1.5 Preliminary Sizing

- Each regulated water quality parameter requires its own particular treatment area for reduction to the desired level.
- Depending on regulations and retention time, the maximum size of the individual treatment areas is selected.

1.6 Preliminary Economics

This includes the

- Basic capital costs,
- Operating and maintenance costs and
- Comparison of costs for potential sites with those of conventional treatment options.

1.7 Engineering Considerations and Designs

The goal is to maximize treatment volume and efficacy.

- Typically, a distribution box needs to distribute water based on the amount of flow and changes its distribution over time.
- The primary tank in which the solids are dropped, and then the flow proceeds to the various buried gravel beds.
- Within these beds is a very coarse stone with pore spaces for bacteria and algae to do their work.
- The treated flow then moves towards the final collection tank and is pumped to the reuse.
- Aquatic species can be planted on top of the gravel beds depending on whether the water levels in the beds and the frequency of flooding can support these species.

1.8 Stream (Hydrological) Flow and Stage Calculations

- To determine the quantity of wastewater that will flow through treatment, it is essential to calculate both baseline and storm discharges.
- The amount and timing of the water to be treated is the first and foremost item to consider in design.
- This information should include the possible seasonality of flows and anticipated progression of flows over the life of the design.
- This is more important for treatment design when compared with conventional water treatment plants because of the implied life cycle of the process and the nature of urban and industrial growth.
- Conventional water treatment plants are traditionally planned for a 20-year life expectancy, but wetlands can function for a far longer period.

1.9 Treatment Potential

- The treatment achieved in SSW systems depends on the volume and frequency of the inflow and also the characteristics of the inflow.
- The treatment potential depends upon the following factors:
  - Hydraulic loading,
  - Retention, and
  - Vegetation.
- To obtain better knowledge of the water quality aspects for the storm water discharge, it is advisable to conduct fairly good data collection with regard to flows and quality.
- Major pollutant sources for the discharge is determined by assaying biological oxygen demand (BOD_3), chemical oxygen demand (COD), total suspended solids (TSS), Total Kjeldahl Nitrogen (TKN), Ammonia (NH_3), total phosphorous, pH, salinity, alkalinity, and fecal coliforms.
- Baseline sampling is done at the storm sewer outflow (inflow) and upstream, however for an event sampling (when there is sever overflow), three samples should be taken at an upstream water sample and a downstream sample.
- HRT can be obtained using the water quality data for the baseline and total maximum daily loads and water quality-based effluent limits defined by state policy for effluent concentration data.
- The presence of macrophytes is important for pollutant removal functions.

TREATMENT EFFICIENCY

Phytorid Technology reduces typical pollutant loads from sewage as given:

Pollutant	Performance (%)
Total suspended solids	90 – 95
Biochemical oxygen demand	90 – 95
Chemical oxygen demand	85 – 95
Total nitrogen	60 – 85
Phosphate	50 – 80
Fecal coliform	85 – 95

1.10 Design and Construction of Phytorid Treatment System

Phytorid to be design for Influent Characteristics as mentioned in the following table.

Sr. No.	Parameters	Influents	Units
1.	pH	5.5-8.5	-
2.	TSS	300	mg/L
3.	BOD	400	mg/L
4.	COD	800	mg/L
5.	O&G	50	mg/L
6.	N (TKN)	20-50	mg/L
7.	P	8-10	mg/L

Phytorid can meet the following characteristics at the effluent as mentioned below.

Sr. No.	Parameters	Effluents	Disinfection	Units
1.	pH	6.8-7.5	6.5-7.3	-
2.	TSS	15-25	10-15	mg/L
3.	BOD	10-30	<5	mg/L
4.	COD	30-80	<20	mg/L
5.	O&G	<5	<2	mg/L
6.	N (TKN)	5-8	<3	mg/L
7.	P	2-5	<2	mg/L
8.	TC	10×10^{6}	$<10^{3}$	per 100m

1.10.1 Site Selection

- The suitability of a site for constructing a treatment wetland may depend on the condition of one or more factors such as substrate, soil chemistry, hydrology/geomorphology, vegetation, cultural/socioeconomic impacts including environmental justice issues, the surrounding landscape, land use/zoning considerations and potential impacts to safety and health.
- Project proponents should carefully examine these factors and consult with applicable agencies in determining the most appropriate site(s) for their projects.
- A distance of 5 to 10 m from the residential building in case of domestic sewage is recommended, depending on the type of pretreatment.
- In case of industrial effluents, site-specific plan from residential areas is required. If properly designed and built, treatment systems do not create any odour or nuisance in the vicinity.
- The location is to be selected in such a manner that drinking water sources are not impaired.

- As far as possible, the site must be safe from flooding. Normal water logging does not create a problem as after the water level recedes, plant can start operating.
- The selected site should be protected from unauthorized access.
- It must be possible to dispose of the treated effluent at the selected site as per standards set by the concerned regulatory agency.
- The following precautions shall be taken such as
  - Treatment System has to be marked clearly/ labled as wastewater treatment systems.
  - The site should have sufficient space for maintenance.
  - Natural slope should be used, to avoid the need for pumps.
- The application of Phytorid Treatment System and the design depends on the availability of suitable filling material for the filter beds.
- It is basically recommended to use locally available filter material to reduce the construction cost.

1.10.2 Pretreatment System

- Sand settling devices, grease traps, gratings and sieves have to be used according to the characteristics of the raw wastewater.
- In nallas, alternative system should be kept and designed.
- Industrial effluents have to be characterized fully before deciding upon adequacy and type of pretreatment.
- All effective pretreatment systems can be combined with Phytorid Treatment System to work effectively.

1.10.3 Filter Media

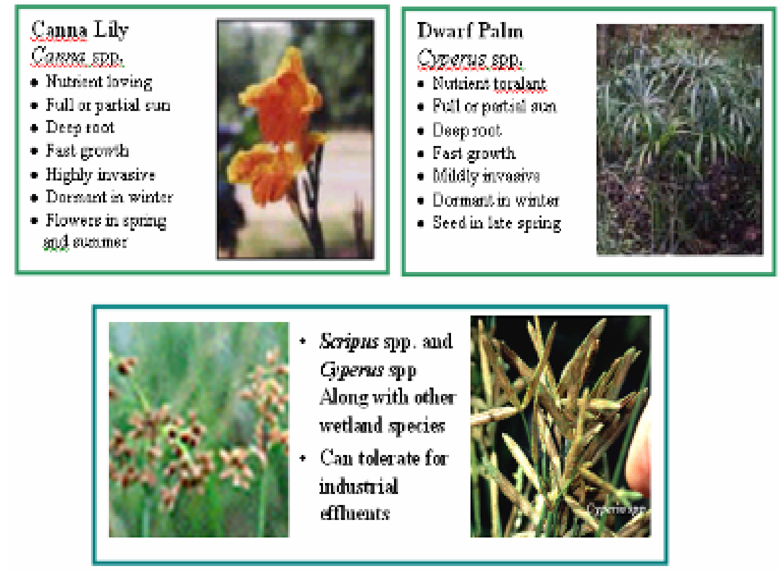
- The filter media effective for the biological treatment must consist of multiple grade of gravel, and a comparable media.
- Specific design of the correct filter media according to the available material is the most important step in the design process.
- Irregular shapes of the gravel / pebbles should be chosen, if available, for the infiltration area in horizontal system and for the drainage area.

1.10.4 Construction Details

- All the construction for the phytorid system should be waterproof. Inside baffles can be constructed of brickworks.
- Freeboard of at least 20 cm distance from bed surface to the upper edge of the lateral sealing is to be provided.
- Should have free access to all operational points like manholes, pumping stations, maintenance locations and sampling points. The access has to be constructed in a way, that crossing of the filter bed is avoided.
- Treatment System shall be designed in such a way that they are integrated into landscape as much as possible.
- Protective measures against the undesired water inflow are indispensable such as bunding all around.
- Inlet structures should be constructed that they distribute the incoming wastewater uniformly to the filter beds
- Verification is to be carried out to prove the correct function of the inflow structures. Hydraulic calculations of the infiltration section / area have to be done with a safety of one order of magnitude.
- Inlet and outlets can be planned with PVC pipes.
- Perforated PVC pipes should be inserted in the filter beds for filter cleaning or sampling.

1.10.5 Plantation and Stabilization

- Plant selection and placement are determined by the system design. Selection of plant species should be based on the final water quality discharge /reuse.
- Primary benefit of these plants is that they beautify the garden and provide color. Using plants that flower in different seasons will keep the treatment system beautiful all year long.
- Stabilization of plant species should be done for the period of 30-45 days along with root enhancer.
- The following plant species should be stabilized and planted in the Phytorid beds/ system
    - *Canna indica* (Indian Shot),
    - *Colocasia esculenta* (Green Taro),
    - *Cyperus alternifolius* (Umbrella Palm),
    - *Iris pseudacorus* (Yellow Iris),
    - *Juncus bufonius* (Toad Rush),
    - *Pennisetum purpureum* (Purple Fountain Grass),
    - *Scirpus validus* (Softstem Bulrush),
    - *Strelitzia reginae* (Bird of Paradise)
    - *Zantedeschia aethiopica* (Calla Lily)
    - *Lythrum salicaria* (Purple Loosestrife)



TYPICAL DESIGN FEATURES

The general concept design for the Phytorid system is presented in **Figure 1**. However, the design can vary based on land availability as also the level of treatment desired. The schematic also depicts modular concept of combining beds into series or parallel configurations, particularly for higher capacity treatment plants.

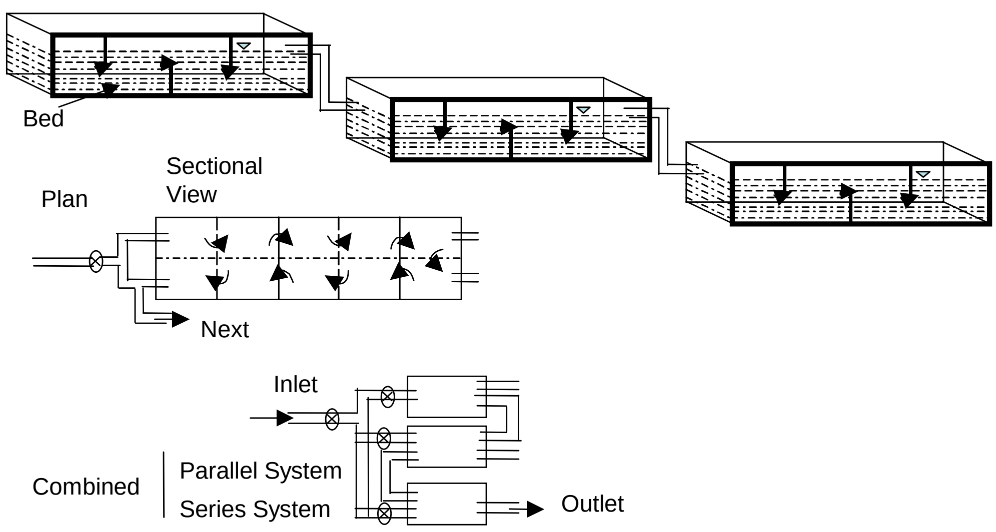


Figure.1: Cross Sectional View of Phytorid System

The sub-surface flow type, Phytorid system is proposed for the treatment of sewage or domestic wastewater which will consists of a basin or a channel with a barrier to prevent seepage, but the systems/ cells/ beds contain a suitable depth of porous media. A primary treatment facility would also be constructed along with basic for effective removal of solids and thus reduces the marginal BOD. The porous media also supports the root structure of emergent vegetation. The design of the Phytorid system assumes that the water level in the cells will remain below the top of the filter media.

The vegetation to be utilized for the said Phytorid system is very important. Various species of aquatic plants have been utilized to attain maximum efficiency in the treatment of domestic wastes. These include species like *Phragmites australis, Phalaris arundinacea, Glyceria maxima, Typha spp., Scirpus spp.*, other common grasses etc.

In a demonstration plant for treatment of nallah water it is proposed to take the sewage to Phytorid system and then treated water is either used for gardening or can be discharge into nallah at the downstream. Alternately it can also be given to nearby users who need water. A novel designing concept of using modular Phytorid systems on both sides of the nallah by drawing a controlled amount of sewage to each bed using an overflow system has been developed. In order to avoid flooding of Phytorid beds an arrangement of automatically openable gates within nallah will be provided. A typical design concept for a Phytorid system for nallah water treatment is depicted in **Figure 2**. The design specific to this project will be modified to include only phytorid bed downstream to the existing collection tank at the site.

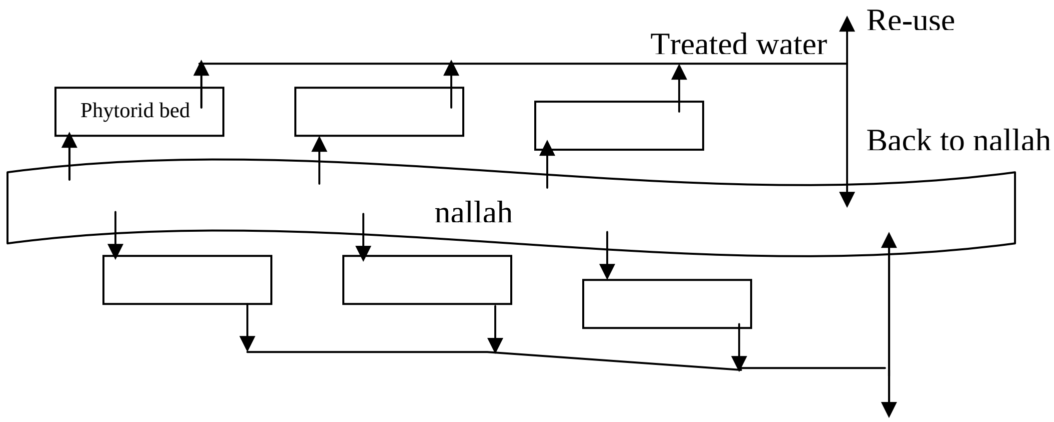


Figure 2: Modular arrangement of Phytorid beds on nallah side

Such arrangement will help in augmenting the plant capacity in future as the need arises and more water demand gets created.