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Reed beds for Sewage Treatment of Small and Medium Size Colonies

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Abstract - Disposal of untreated sewage into natural water bodies is a major cause of water pollution in developing countries like India. Sophisticated technology based conventional wastewater treatment schemes are costly, requires large amounts of energy, close supervision and skilled manpower. Treatment of sewage using activated sludge process is more costly for small communities generating less volume of wastewater. Constructed wetland systems have emerged as on-site low cost wastewater treatment, which can be adopted by small communities, institutions such as hospitals, schools and project colonies-townships. Constructed wetland systems are efficient in both processing ability and energy requirements. These artificial wetlands require a near zero energy to treat local effluent with no negative side effects. The process is free of both chemicals and odour, provides habitat for wildlife, and increases the diversity and aesthetics of site. The treated sewage can be used for gardening, arboriculture and even discharged in the environment. Constructed wetland systems can be very useful for developing countries like India because of it's cost effectiveness, simple construction and maintenance requirements. This paper discusses aspects of design, construction and operation of constructed wetlands.

Index Terms— Sewage,Wastewater treatment, Constructed wetland, Reed bed, BOD, Macropthyes, Rhizome

1 Introduction

In India about eighty percent of the water supplied to each consumer gets converted into sewage. Most of this domestic sewage is disposed off without primary treatment. Conventional and advance treatment technologies are financially not feasible while Reed bed is alternative economical solution for treatment of domestic sewage treatment with target to achieve the sewage treatment as well as carbon capturing through flourishing of reed and trickle down the incremental temperatures. Reed bed is one of the natural and cheap methods of treating domestic, industrial and agricultural liquid wastes. The launch of Swachh Bharat Mission (SBM) triggered remarkable attention towards the sanitation sector in India. SBM went on to become one of the world's biggest sanitation drives that accelerated access to sanitation. It helped India achieve its target of eliminating open defecation. With construction of more than 9 crore toilets across urban and rural parts of India, not only the legacy problem of access to sanitation has been addressed, but also the establishment of effective faecal waste management systems has received due emphasis. The next targets in the sanitation sector should focus on entire sanitation service chain as well as wastewater treatment. Construction of septic tanks for collection and disposal of sewage is generally practiced for isolated premises like university campus, defence estates, schools, hospitals, townships at the outskirt of cities, and remotely located residential colonies in hilly areas. These septic tanks are poorly maintained. The conventional off-site excreta disposal method-water carriage system followed by a sewage treatment through activated sludge process is an expensive option and not adoptable by these small communities. Construction cost of activated sludge process plant and cost of treatment of sewage is very high and also poses operational problems if not closely monitored. This compels the adoption of the on-site disposal method like septic tank followed by secondary treatment. Even after regular desludging of septic tank the effluent from septic tank still has BOD, in the range of 100 to 125 mg/l or even more. The septic tank effluent is malodorous; containing sizable portion of dissolved organic content, putrescible organic matter and pathogenic organisms and hence need to be treated before its final, safe disposal or reuse to agriculture to minimize nuisance or risk to health of the people.

The luxury of use of fresh water for gardening of huge land of military formations, universities, townships is no more affordable. The use of treated sewage for huge water requirements of gardens, lawns can be met by low cost treatment of generated sewage locally. The sewage has abundance of required plant nutrients. Recycle and re-use of treated sewage rich in nutrients for watering of gardens closes the loop of natural nitrogen cycle. For such requirements further reduction of BOD of septic tank effluent through secondary treatment retaining plant nutrients by constructed wetlands gives a better solution.

2 Constructed Wetland

Constructed wetlands are artificial waste water treatment systems consisting of shallow (less than one meter in depth) channels which have been planted with aquatic plants and which rely upon natural microbial, biological, physical or chemical processes to treat waste water. Constructed wetlands are especially well suited for waste water treatment in small communities where inexpensive land is adequate and skilled labour for operating complex system are hard to find. Constructed wetlands are gaining popularity to treat waste water emerging from various isolated public and private institutions like hospitals, schools, project colonies and university particularly in areas where land is available easily and at reasonable cost. Other features, which make the constructed wetland sys-

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tem attractive, are: high treatment efficiency, low maintenance cost, and easy operation.

A reed bed is essentially an open channel, lined with an impermeable membrane, that is filled with gravel and planted with macrophytes i.e. reeds, rushes and used to treat sewage waste water. The reed bed along with inlet, outlet, gravel, liner and level controller is shown in Figure 1. Waste water, black or grey is passed through the root zone of the reeds where it undergoes treatment. Pipes for Inlet and outlet should be positioned below the gravel surface so that the water always remains below the gravel surface, thus excluding human exposure to the waste water, mosquito breeding and unpleasant odour. Subsurface flow wetland can be classified into horizontal and vertical flow beds according to direction of flow.

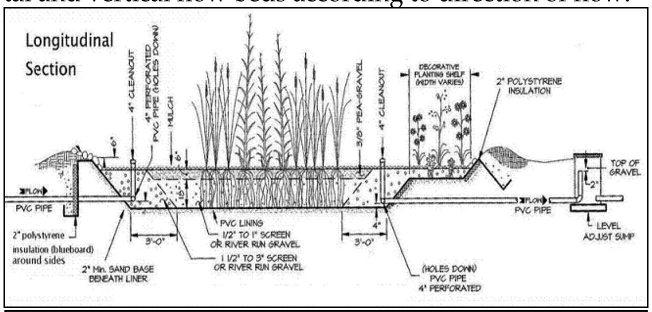

Figure 1: Constructed Wetland

2.1 Final Stage Horizontal Flow (HF) System

In this system, the waste water is fed in at the inlet and flow slowly through the porous medium under the surface of the bed in more or less horizontal path until it reaches in outlet zone. During its journey the waste water comes in contact with a several aerobic, anoxic and anaerobic zones. In aerobic zones occur around the roots and rhizomes that leaks oxygen into the substrate. In horizontal flow wetlands the effluent enters at one end of a bed and flows horizontally under the surface of the bed, micro organisms clean the wastewater as it flows through, treated water leave the system from opposite end.

2.2 Vertical Flow (VF) System

In vertical flow constructed wetland the waste water gradually

percolates down through the media bed and collected by drainage network at the base. The bed drains completely free and it has the ability to nitrify. The major pollutant removal process in vertical filter beds is same as in horizontal filter

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constructed wetlands. However, vertical flow beds are far more aerobic than horizontal filter and therefore fit for nitrification as well as BOD removal.

3 Working of Reed Beds

Primarily treated effluent from the colony via septic tank or greywater is initially filtered prior to entering the reed bed through an effluent filter fitted to the greywater collection tank or septic tank outlet pipe. This is required to avoid clogging of reed bed due to solids from sewage. Post filtration of these large solids/floatables the waste water undergoes many different processes as it passes through the reed bed. Waste water enters the reed bed via the inlet pipe positioned at a height greater than the outlet pipe, and disperses the waste water as evenly as possible into the medium. The treatment environment in the system is mostly anaerobic, with some aerobic microsites on plant roots and near surface areas. The waste water detention/residence time aids with the treatment by allowing sufficient time for the settling and filtering of suspended solids, nitrification/denitrification to occur, fixation onto the substrate, breakdown of organic matter and nutrient removal via micro-organisms and plant uptake. The microscopic life in the bed is a main processor of the pollutants. While living in the substrate and oxygen-rich root systems, these micro organisms metabolize the chemicals in the effluent, effectively mineralizing them. By increasing the processing times / exposure time, even hard to remove pollutants such as polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyl (PCB), dyestuffs, amines and glycols can also be treated.

Water quality enhancement in wetlands occurs by interaction with wetland vegetation, the water column, and wetland substrate. Processes may be physical, chemical or biological. Broadly, aerobic-anaerobic degradation, sedimentation, filtration, nitrification-denitrification, plant uptake, matrix sorption, precipitation are the mechanisms in removal of organic matter, suspended solids, nitrogen, phosphorous and metals. Six major biological processes have been identified as aiding in pollutant removal performance of wetland systems. These are: photosynthesis, respiration, fermentation, nitrification, denitrification and microbiological phosphorous removal.

The die-off of pathogens in a reed bed is due to predation by micro-organisms on the surface of the gravel and roots, unfavourable conditions provided by a long residence time, and the aerobic and anaerobic zones in the reed bed. Therefore, the quality of treated effluent improves with increased residence time.

4 Reed Bed Design Considerations

Constructed wetlands do not have long history of engineering practice and therefore are being designed based on empirical findings. Organic loading rate, hydraulic retention time, basin depth and geometry are influencing design parameters. Reed beds should be designed to have a wastewater residence time of 5 to 7 days. Residence time is generally governed by the surface area and depth of the reed bed. The depth can range between 300-1000 mm deep. Reed beds should have a length to width ratio between 3:1 and 1:1. The reed bed membrane

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can be made from high density polyethylene, ferro-concrete (concrete cattle troughs). HDPE liner a minimum of 0.75 thick may be used for large reed bed construction. Many reed beds contain 10-20 mm gravel as a medium for the main body of the reed bed. Some reed beds have a top layer of sand or soil blend for planting the reeds. The inlet pipe can be perforated T-junctions made from around 100 mm PVC sewer grade pipe, or perforated 300 mm capped, perforated storm water pipe. It is important to prevent surfacing of effluent and the escape of odours into the environment. This can simply be ensured by ensuring that the inlet pipe should always be covered with aggregate. Large 50/100mm diameter rocks must be placed around the inlet and outlet pipes to allow the effluent to disperse easily and quickly, to minimize clogging and make checking for root intrusion easier. Fig 2 shows the lateral view of basic Reed bed design.

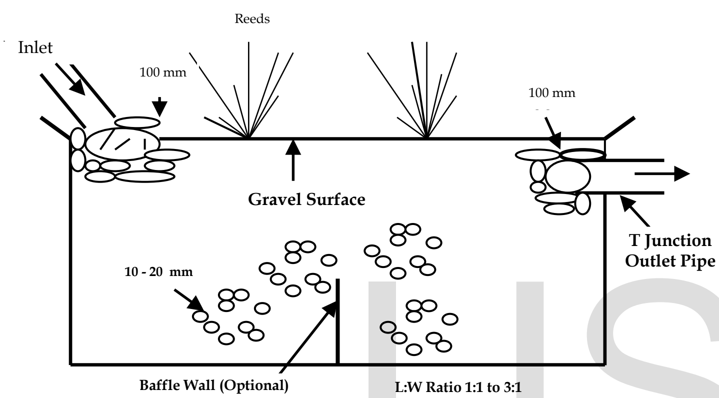

Fig 2 : Basic Reed Bed Design (Lateral View)

Baffles may be constructed in reed beds to minimize short circuiting of the wastewater flow and direct the wastewater up and down through the aerobic and anaerobic zones in the reed bed, creating unfavorable conditions for pathogens and assisting nutrient removal. T-junction for inlet and outlets of Reed Bed is shown in Fig 3.

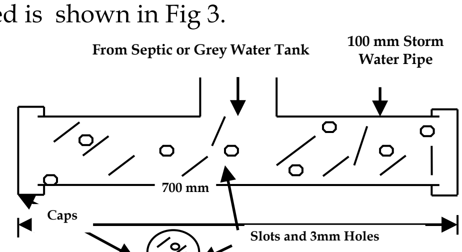

Fig 3 : T Junction for Inlet & Outlet of Reed Bed

4.1 Sizing the Reed Bed

Sizing of the reed beds can be done number of ways like use of simple rule of thumb to automated computer models. However, traditionally the rule of thumb method is mostly used to size of reed beds. This is based on a reed bed surface area of 4 m^2 per person for reed beds treating blackwater or approximately 2 to 3 m^2 per person for greywater reed beds and an outlet pipe height of 500 mm. This would give an approximate residence time of 7 days. Based on best scientific knowledge the 7 days residence time was thought to produce a secondary treated wastewater (BOD 20 mg/l, TSS 30 mg/l) and reduce nitrogen by 50%. However, a recent study has shown that approximately 5 days is required to reduce nitrogen by 50%. Seven days would still be required to produce a secondary treated effluent unless it is a greywater reed bed where the residence time may be less than 7 days. Typical calculations of reed bed surface area requirement for total daily grey water flow of 10 m3 are shown as under.

Residence time = Reed Bed Volume X Porosity/Daily Wastewater Generation.

Take detention period of 5 days and gravel bed porosity to be 0.4.

$$5 = \text{Volume} \times 0.4/10$$

$$\text{Volume} = 125\ m^3$$

Surface area of the reed bed = 125/0.5 = 250 m^2 ,(length= 27 m and width= 9 m, depth= 0.5 m). This total bed area works out to be 2.5 m^2 per person each generating about 100 litres of grey water every day.

5 Construction of Wetland Systems

5.1 Reed Bed Trench/Channel

To install a basic bed, it is required to dig an appropriate sized trench for the application and fill it with a liner to prevent any waste-water from seeping into the ground. The beds should be deep enough to accommodate at least 30 cm of water depth. Fill the bed with gravel, sand etc. Another few centimeters of substrate above this 30 cm area is suggested to accommodate the variance in the water levels that result from rains or heavy use of the waste-water system.

5.2 Media

Gravel allows faster flow of wastewater, but has lower microbiological activity. For this reason gravel is mostly used as a secondary or tertiary treatment substrate. By planting reeds or typha in gravel, one can use it as a primary treatment bed. These plants allow for more micro organisms to colonize the substrate, providing a perfect niche for genetic life. Soil is often used in a primary or secondary treatment bed. Soil has the added benefit of being able to encourage metal ions, phosphate and sulphate to be deposited. Different soil blends can be used to treat specific site requirements. A small amount of clay in the substrate can trap different chemicals while the micro organisms digest them, this can help cope with large, infrequent amounts of effluent being passed through the system. Peat filtration of sewage removes any odour and eliminates any insect activity in the constructed wetland.

5.3 Reeds

There are many varieties of reed that can thrive in just any climate. It is better to use locally occurring native species that exhibit rapid and luxurious growth. Macrophytes i.e. reeds, sedges, play an important role in the treatment of water within a reed bed. These macrophytes directly take-up nutrients, pump oxygen into the substrate and provide a food source for the micro-organisms responsible for breaking down pollutants from waste water.Until recently, Phragmites australis (the Common Reed) and Tyhpa orientalis were the main reeds used in wetland filter systems, mimicking the natural habitat of flood plains and estuaries. These species are generally found locally and can either be sourced from existing treatment reed beds. These reeds have the most extensive root system for micro organisms to colonize. This root system increases the porosity of the substrate in which it is grown, resulting in a formatting of aerobic, anoxic, and anaerobic conditions. However, with the continous research and understanding of reed beds growing continuously many new plant species are being used, such as, Lomandra hystrix, Baumea articulata and Schoenaplectus mucronatus. The rhizome's should be planted at a density 5 rhizome's per square meter. The stems of the collected reeds should be cut to a length of approx 20 cm. The rhizome's are planted at a depth of approximately 100 to 150 mm below the gravel surface. A typical collected Reed and Rhizome is as shown in fig 4. While establishing the reed bed, removal of weeds will likely be required until the reeds have completely colonized the bed. Ideally 70% or more of the bed will be covered with reeds. The other 30% should include some combination of sphagnum or typha for best results. After 3-5 seasons the reeds need to be cut and allowed to regrow from their rhizomes.

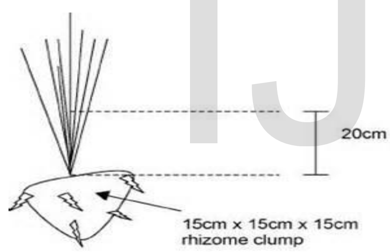

Fig 4 : Collected Reed and Rhizome

6 Maintenance Aspects

Wetland systems are extremely passive and require little management in producing a good quality effluent (typically BOD and TSS of less than 30 mg/l). Yearly emptying of the preceding septic tank, which would be necessary in a traditional soak away system, and maintaining the reed bed by cutting back the growth every few seasons is all that is required. It is recommended harvesting in late spring and then again in early to mid-autumn prior to senescence. Senescence is a time during the winter months when the reeds stop growing and die-back to the roots. If possible, the reed bed should be decommissioned during harvesting.

6.1 Cleaning of Affluent Filter

Before wastewater enters the reed bed it is required to be filtered. Effluent filters are fitted to the outlet of septic tank or collection tank. It is to reduce the concentration of suspended solids entering the reed bed. These filters can be cleaned when necessary.

6.2 Checking Blockages of Pipes

Blockages should be rare if large rocks are placed around the inflow and exit pipes. When the macrophytes are growing well it is necessary to check intermittently that their roots are not blocking the inflow and exit pipes.

6.3 Maintaining the Water Level

Level should be altered using the swivel pipe outlet device. Lowering the height of the water in a reed bed for a period of two weeks or more can stimulate root growth and aid in treatment by the upper layer of gravel, oxygenating the exposed surface area and de-clogging the reed bed. It may be required to lower their water level for 2 weeks periods in the summer months. Water level should be lowered in summer when micro-organism activity is at its greatest and higher in winter when micro-organism growth slows down. A drop in water height of 200 mm should be sufficient and only be lowered over the course of a few days to avoid a surge of wastewater exiting the reed bed.

6.4 Harvesting of Reeds

It will not be necessary to harvest the above ground reed material in the first year but after one growing season the reeds can be harvested twice annually. This involves cutting the reeds to a height of 20 cm above the ground surface.

7. Advantages of Reed Bed Technology

Reed Bed technology is a natural, low cost, eco technology suitable for natural wetland ecosystems which is environment friendly and has the potential to be an alternative to supplementary waste water treatment. This technology if adopted at large scale will reduce the climate change effects, water shortage and lower the temperature by plantation. Reed Bed technology will recharge ground water and also make shallow water quality enhanced for the usage in several purposes.
It can play an important role in utilization of natural process in which there can be interactions among plants, animals and environment. The interactions will include photosynthesis, excessive plantation, afforestation, decomposition and many others. This technology will be less expensive, simple to operate and function with minimal maintenance cost. Sewage treatment system will not only help reduce pollution but will also provide usable water for growth of various plants and trees in the area to conserve and preserve the ecosystem.

8 Discussion

Constructed wetland system for the treatment of sewage is economical and environmental friendly for small scale use. They are recognized in chemical- and odor-free treatment, creation of habitat, low setup and maintenance costs of the system, as well as a number of other natural benefits. The BOD of effluent after secondary treatment through reed beds can be as low as in the range of 20-30 mg/l which may be used for secondary purpose like gardening. Septic tanks with sub-surface flow wetlands have been in use in many areas of our country but not in a well designed and constructed form. Properly designed and constructed systems do not require chemical additions or mechanical equipment. Constructed wetlands can have relatively low construction cost in areas where media and land is readily available. Maintenance of constructed wetlands is important to prevent clogging the rock bed and influent and effluent structures. The wetland plants fill in spaces between the rocks and provide aesthetic appeal. The construction of wetlands does not require electro-mechanical machinery, major concrete work except some concreting at inlet and outlet structures. The entire work will be little earth work embankment for shallow sealed basin, placing the HDPE layer/liner, media placement, and planting the reed rhizome. Therefore, construction cost of constructed wetlands will much lesser and commissioning is much easier.

The experience of full scale horizontal followed by vertical wetland constructed for the treatment of 31 m3/d septic tank effluent from hostel and residential complexes of Katmandu University, Dhulikhel is encouraging. The average organic removal efficiency(COD) of horizontal and vertical beds were 74.17 % and 56.45 % with hydraulic retention time 1.58 days and 1.21 days respectively. The overall COD removal through septic tank followed by horizontal-vertical constructed wetlands is 92.84%.

9 Conclusion

Septic tanks are constructed as a sole primary treatment unit where conventional sewerage system is not available. Secondary treatment option like activated sludge process is not affordable to small communities generating less volume of sewage. Constructed wetlands are capable of effectively removing organic matter, suspended solids, nitrogen and phosphorus. They can reduce heavy metals, trace organics and pathogens. The outflow from such wetlands can be recycled and re-used for watering of lawns, gardens and hedges of such small estates thus minimizing the fresh water requirement. Re-use of nutrient rich treated sewage will complete the natural nitrogen cycle.

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