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Comparative Assessment and Performance Evaluation of Horizontal Flow Constructed Wetland Using Vetiver and Canna species

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Abstract: ***Water is one of the important resources which is very necessary to the life of all living beings including mankind. But as population grows the need for water also raises and scarcity of water arises. To overcome this problem one should recycle and reuse the available water on the surface of the earth. One such system which helps to recycle the water which is gaining importance from the environmental view is wetlands. Natural wetlands existing in the nature, they purify the wastewater which is entering into it and gets filtered after flowing through it. Constructed wetlands are the modifications of natural wetlands and are artificially created using different rooted emergent species. Two such species used in this study are Vetiveria zizanioides and Canna siamensis.***

Better efficiency of constructed wetlands was observed during hydraulic retention time of 4 and 6 days. Efficiency of constructed wetland planted with Vetiveria zizaniodes is achieved as follows: improved pH & Electrical conductivity, Turbidity(96%), TDS(29%),TSS(65%),BOD(70%),COD(80%), Chlorides(53%),Nitrates(50%) and Phosphates(55%) and Canna siamensis removes Turbidity(90%), TDS(49%), TSS(79%), BOD(61%), COD(78%), Chlorides(38%), Nitrates(54%) and phosphates(50%). Canna species is better in removing TDS&TSS, Nitrates when compared to Vetiveria zizaniodes, all other parameters were observed to remove better by Vetiveria zizaniodes.

KEYWORDS: **Constructed wetlands, HRT, vetiver, canna, Treatment efficiency.**

I. INTRODUCTION

Water is one of the important resources which is very important to the life of mankind.one cannot assume the life of living beings including both plants and animals without water. But as population increases, need for water also getting increased in random manner. When this necessity increased beyond the limits or when there is no other option than using the available water, people starts using either partially or fully treated water according to their living standards. Out of all available resources 97% of water is present in oceans, 2% polar ice caps, the deep ground water accounts for 0.31%. This 99.31% of water is of no use to man. The remaining 0.69% which represents the fresh water resources with which man has to deal.

As human population increases, there are corresponding increases in the anthropogenic waste generated and also increase in the amount of environmental pollution which includes soil, water, air and noise pollution. The number of pollutants, its type, concentration and amount of pollutants created by resource consumption and released through industrial, residential and all toxic wastes today are affecting human health and ecosystem quality. To protect the environment from these contaminants human should find ecofriendly ways to treat contaminants and recycling of these wastes.

Mankind has been exploiting the natural resources since the beginning of civilization to ensure his comfort. Water is one of the important resources which are the essential commodities of society. Water is precious and therefore WHO refers to "all people, whatever their stage of development and their social and economic conditions, have right to have access to an adequate supply of safe drinking water" as one of primary objectives of environmental sanitation [1].

The green technology that uses plants for remediation of contaminants and restoration is known as phytoremediation. The process is a natural method, cost effective, and multiple contaminants can be removed by a single species. Constructed wetlands are built and are designed to optimize the physical, chemical and biological processes of natural wetlands in treating wastewater and are strong enough to receive shock loading resistance systems.

The wetlands are considered as a natural passive cleaning of waste water. Is a process characterizes by its simplicity of operation, low or zero-energy consumption and low waste production. These consist of shallow ponds planted with plants. The processes of decontamination are performed simultaneously by its physical, chemical and biological properties. Wetlands not only help to purify the water, but also help the conservation of flora and fauna that is dependent on wet conditions, as only biodegradable materials are used there is no pollution to the ground, helping

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the conservation of the environment[2]. Horizontal subsurface flow constructed wetlands is often used in almost all the case. In this system, wastewater flows horizontally through artificial filter bed, usually consisting of a media such as gravel or sand. Constructed wetlands also function as Eco-scan systems considering the aspects of water reuse and biomass production. [5]

The treatment of airport surface runoff, industrial waste and mine drainage, landfill site and composting system leachate and the drying of sludge are also applications of constructed wetlands. Many mechanisms are included in removing pollutants from the wastewater in the system of constructed wetlands, including nitrification, denitrification as well as physicochemical processes such as fixation and precipitation. [8] And zinc removal of upto 100%, 94% of sulphate and improvement in all other parameters. [4] Potential of hybrid constructed wetlands for various types of wastewaters are found to be better than planting with individual species and are suitable for treating domestic, industrial wastewaters and also the landfill leachate.[7]

The aquatic natural treatment system involves impounding wastewater in ponds or lagoons for sufficient period so that pollutants and pathogens in wastewater are removed through natural biological degradation processes. [9]

These natural systems are often referred to as examples of green technology because of the use of plants. However, `green' is a widely used and often misleading label attached to any product or system which claims to reduce the impact on the environment. The factors which need to be considered when assessing how `green' a waste water treatment system have been listed by Brix (1998):

- Treatment performance in relation to effluent standards;
- Robustness of process;
- Emissions of various pollutants to environment;
- Waste production (e.g. sludge);
- recycling or reuse potential;
- Energy consumption, including source of energy used;
- Use of chemicals;
- Area use;
- Environmental nuisance;

Brix suggests that an environmental life-cycle assessment approach, which quantifies energy and resource inputs and outputs at all stages of the life cycle, could be applied to constructed wetland systems. However, he emphasizes that it is very difficult to quantify some of the parameters included in the assessment and that the impacts and benefits will have to be weighted for each system [3]. Phytoreduction of pollutants from environment serves as an excellent example of the process of plant facilitated phytoremediation and its role in removing environmental stress. [12]

The study aimed at meeting the following objectives:

- To construct the artificial horizontal flow constructed wetland using vetiver and canna grass.
- To determine the efficiency of constructed wetland by measuring input and output parameters.
- To compare the efficiencies of wetland systems to treat specific pollutional parameter.

II. MATERIALS AND METHODS

A. Domestic wastewater

Domestic wastewater is selected as an influent for the constructed wetland. Sewage was collected at regular intervals from the channel flowing near U.B.D.T engineering college, Davangere. If this sewage is allowed to enter the natural sources it affects the water body and also aquatic life. Therefore wetland can be used as a solution to treat the domestic sewage before entering water bodies.

Domestic sewage comprised of many components. A partial list of main components of what it may contain includes the following:

- Water (more than 95%) added often to carry a waste downstream the wastewater drain.
- Pathogens such as bacteria, virus, fungi and other parasitic worms.
- Organic particles due to the discharge of faecal matter, hairs, paper, plant waste, food waste etc.
- soluble organic materials such as pharmaceuticals, drugs, urea, soluble proteins, and fruit sugar etc.
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- soluble organic materials such as pharmaceuticals, drugs, urea, soluble proteins, and fruit sugar etc.
- Toxic materials due to pesticides, poisons, herbicides, hospital discharges etc.
- Emulsions such as paints, adhesives, emulsified oils, hair colorants etc.
- Inorganic particles such as sand, grit, metal particles, ceramics etc.
- Gases liberated may contain hydrogen sulphide, carbon dioxide, methane etc.

B. Acrolithic Sheet (for construction of wetland pond)

Poly methyl methacrylate (PMMA) is one of the transparent thermoplastic often used as a light weight or shatter – resistant alternative to glass. PMMA is an economical when extreme strength is not necessary. It is due its moderate properties, easy handling and processing, low cost and temperature resistance. Non modified PMMA becomes brittle when it is loaded, and is more sensitive to scratching than conventional inorganic glass, but modified PMMA can achieve high scratch and impact resistance.

For experiments artificial Wetland tank was constructed using acrolithic sheet which is 5mm thick in diameter. The dimensions of the tank are 0.7m X 0.45m X 0.3m. It is

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believed that it gives high resistance to heat and gives good strength to hold both the media and waste water feed into it.

C. Filter bed or Media

Course aggregates or gravel can be used for analysis. But for convenience coarse aggregates are used. The aggregate size being 20mm retained and must be free from dust and dirt. In addition to this, inlet and outlet piping arrangements aggregates of larger size i.e. greater than 40mm are placed in order to avoid clogging problem. The reason for choosing crushed stones as media for wetland is to avoid the clogging problem which usually occurs when sand or other media with smaller voids are used. The two processes that usually occur in the wetland media are mechanical straining and physical adsorption.

D. Inlet and outlet arrangements

Domestic wastewater is allowed to flow into the wetland through a pipe in a controlled manner. Constant flow rate is maintained through its feeding. Once the tank is filled it is allowed to given retention time of about 2, 4 and 6 days. The outlet is made at the same level as of inlet pipe and is checked for different characteristics.

TABLE I. CHARACTERISTICS OF CONSTRUCTED WETLAND POND

Operational parameters	Characteristics
Type of wetland (flow type00)	Subsurface horizontal flow wetland
Filter media	Course aggregates(20mm retained)
Bed dimensions	0.7m*0.3m
Bed depth	0.45m
Subsurface area	0.21 m^2
Plant species	*Vetiver zizaniodies* and *canna siamensis*
Type of waste water	Domestic sewage
Mode of operation	Batch type
Hydraulic retention time	2 days, 4 days, 6 days
Flow rate	40 liters/day

E. Wetland vegetation

Two artificial constructed wetland tanks which are of similar size, depth are filled with the media. The vegetation used which serves two purpose, removal of nitrogen and phosphorous are providing oxygen at the root zone for decomposition of organic matter. The entire set up will be placed on roof and waste water will be fed into the system at regular interval of time. The wetland vegetation was planted in the cell 15 days before the waste water was fed into it. Two different types of vegetation used for two wetlands. The species are vetiveria zizaniodes and canna siamensis.

Vetiveria zizanioides, commonly known as vetiver is a perennial grass of the Poaceae family, native to India. In western and northern India, it is popularly known as khus. The stems are tall and the leaves are long, thin, and rather rigid; the flowers are brownish-purple. Though it originates in India, vetiver is widely cultivated in the tropical regions of the world. Vetiver is a fast growing, tall (1–2 m), high biomass, xerophytic as well as hydrophytic grass with a long (3–4 m) and massive root system, which is tolerant to a wide range of climatic conditions. Vetiver showed promise in removing various environmental contaminants from both aqueous media and soil. The vetiver species is suitable to check phytoremediation potential for tetracycline [10] and to treat wastewater from textile industries [11]

Vetiver is having high efficiency in absorbing dissolved nitrogen, phosphorous, sulphate and heavy metals such as As, cd etc. [6]

Canna siamensis finds its habitat mostly in margins of marshes, swamps, ponds, and wet ditches. Flowers pure yellow, sepals are narrowly elliptic-triangular, apex very gradually narrowing to acute. Inflorescences racemes, simple or occasionally branched, bearing flowered cincinni, more than 10 flowers per inflorescence; Flowering occurs almost in summer season. It is one of the strong species which shows very good efficiency to treat the wastewater in constructed wetland system. It is easily available in almost all the climates and easily adopted to the wetland media. This species is aesthetically good in its appearance and it is used to plant in gardens, parks for beauty purpose.

F. Methodology

Design of the constructed wetland ponds

To carry out the performance of the wetland, to determine the pollutional parameters, a bench scale study will be done by constructing the wetland pond of following dimensions. The wetland pond was constructed of acrylic sheet of 5mm thickness. The design parameters are as follows;

Total volume=L X B X D

$$=0.7 \times 0.3 \times 0.45==0.0945m^3$$

Nearly 40% of volume, waste water can be hold in the wetland cell. =0.0945 x 0.4 =0.0378 m^3/day

=38litres/day

Theoretically the flow rate was found to be 38 liters/day which is based on the design of wetland.

Experimental flow rate analysis

Following procedure is adopted to determine the experimental flow rate.

Designed pond is filled entirely with crushed stone aggregates of size 20 mm diameter in size. To determine the volume of water that fills into the void spaces and also the total volume of water that the tank can retain at a time. Further without aggregates only fill the tank entirely with water. The water is measured with measuring jar or litre. Therefore experimentally the flow rate was found to be 40 litres/day. For 1 day hydraulic retention time the wastewater to feed was 40 litres/day. For 2 days HRT it is 20 litres/day, similarly for 4 and 6 days it is 10litres/day and6.5 litres/day.

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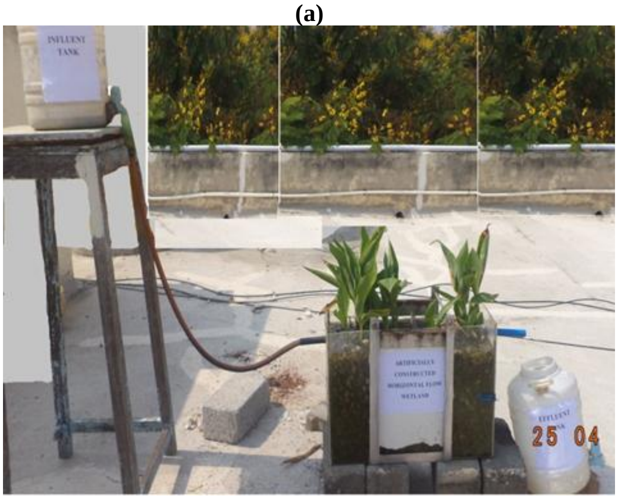
Set up of an artificially constructed wetland system

The tanks of capacity to hold 40 litres /day were designed and it is planted with the vegetation viz. *Vetiveria zizaniodes* and *Canna siamensis*. Proper inlet and outlet arrangements are made. The figure 1 shows artificially constructed wetland. Batch type of operation was adopted to feed the raw sewage.

(a)



(b)

Fig. 1: Experimental set up of horizontal flow constructed wetland planted with (a) *Vetiveria zizaniodes* and (b) *Canna siamensis.*

Sampling Procedure

The raw waste water samples will be collected from sewage channels. The main aim of the work is to determine the performance of the constructed wetland in reducing the pollutional parameters to meet BIS standards for their disposal. The sample collection type will be grab samples collected at regular interval of time. The samples should be used within 24hours after its collection the parameters will be analysed both at inlet and outlet of constructed wetland.

III. EXPERIMENTAL RESULTS

Experiments are conducted by using vetiver and canna in constructed wetland system for certain period of retention time (i.e. 2, 4 & 6 days). Constant flow rate is maintained for the flow of influent into the tank and is allowed to stand in the pond so that vegetation in the wetland absorbs the nutrients present in the raw domestic sewage. In addition to this many other processes occur in the wetlands such as sedimentation, degradation, adsorption, photolysis, plant uptake [1] etc. The effluent is taken from the outlet and is checked for different pollutional parameters.

1. P^H and Electrical Conductivity

Sewage is always acidic in nature. But after treatment it becomes alkaline. Mostly raw sewage is having pH in the range of 6-7.2. After treatment it will be in the range of 7.1-8.5. Therefore it shows an improvement in changing the concentration of hydrogen ions. Similarly Electrical conductivity also increases after passed through constructed wetland system.

2. Turbidity

Turbid particles such as sand particles, grit, clay etc. settle to the bottom of the tank due to sedimentation. Some of other lighter turbid particles attached to the media. Hence, constructed wetlands showed higher efficiency in treating more turbid water. Variations of turbidity with the change of HRT are shown in the fig 2.

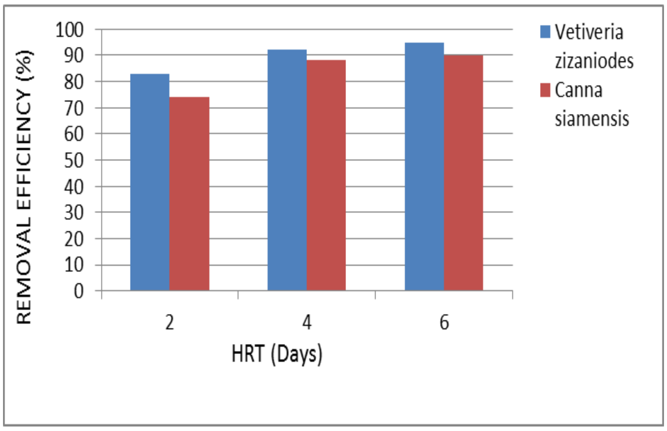
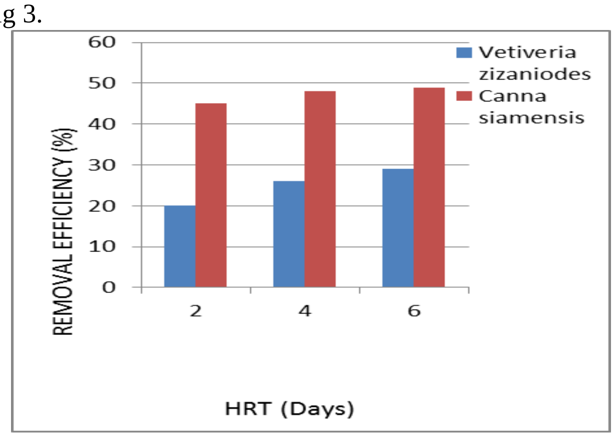


Fig.2: Turbidity removal efficiencies with HRT in Constructed wetland systems.

3. Total dissolved and Suspended solids

Solids in the wastewater are removed more efficiently on increasing retention time, i.e. wastewater given retention time of 6 days gets filtered more than that of 2 days shown in fig 3.



(a)

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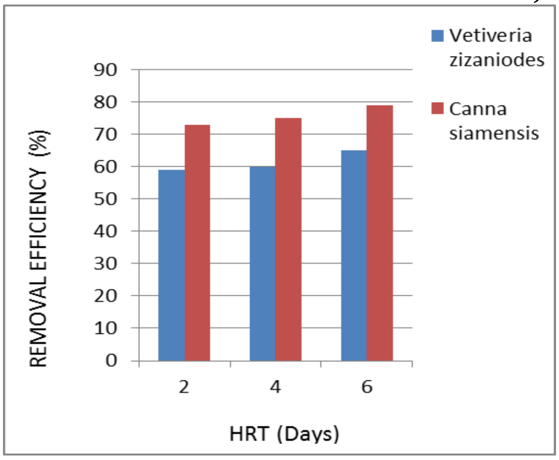
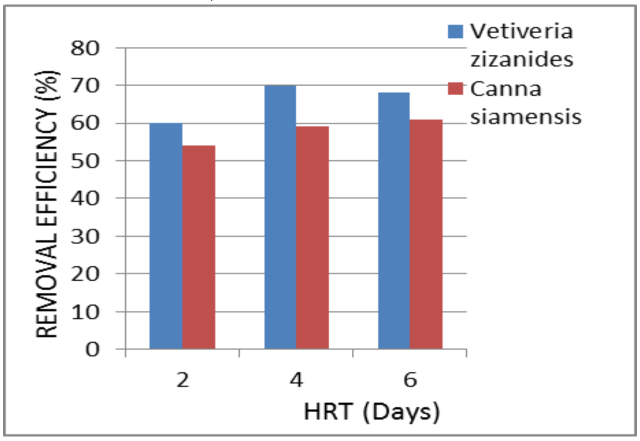


(b)

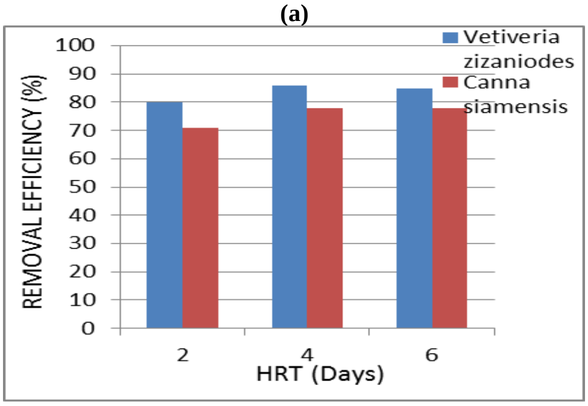
Fig. 3: TDS (a) and TSS (b) removal efficiencies with HRT in Constructed wetland systems.

4. Biochemical oxygen demand and Chemical oxygen demand

The rate of removal of BOD with time varies as shown in the figure. Higher removal efficiencies are observed during 4 days and 6 days. Average removal efficiency of vetiver and canna species is shown in the graphs fig 4(a) and 4(b). BOD shows 60%, 70%, and 68% respectively with *Vetiveria zizaniodes* whereas 54%, 59%, 61% respectively with *Canna siamensis.* COD shows 80%, 86% and 85% with *Vetiveria zizaniodes* and 72%, 78% and 78% with *Canna siamensis.*



(a)

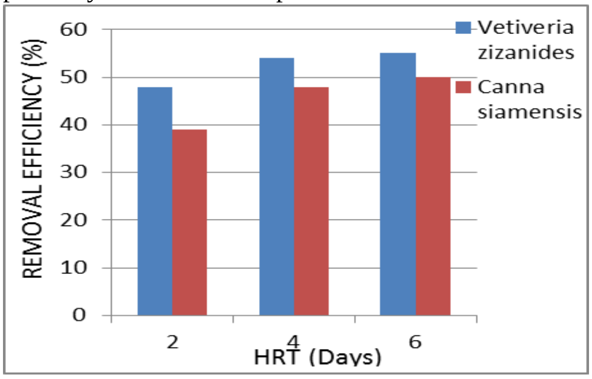


(b)

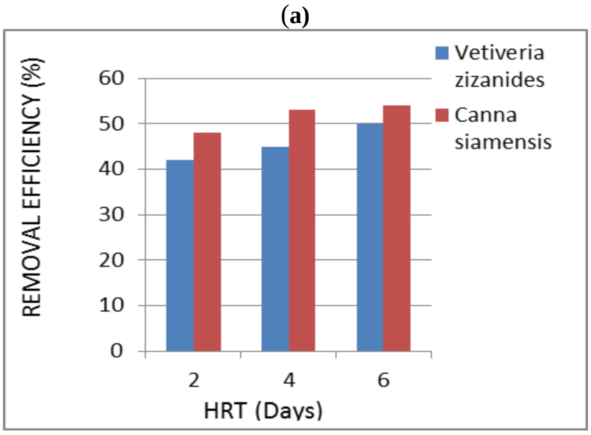
Fig. 4: BOD (a) and COD (b) removal efficiencies with HRT in Constructed wetland systems.

5. Nitrates and Phosphates

Constructed wetland systems showed good efficiency in removing nitrates. The plant *Vetiveria zizaniodes* species providing retention time of 2, 4 and 6 days shows 42%, 44.5% and 50% respectively and *Canna siamensis* shows 48%, 53%, and 54% respectively. Similarly phosphates removal efficiency for HRT of 2, 4 and 6 days 48%, 54% and 55% with *Vetiveria zizaniodes* and 39%, 48% and 50% respectively for the wetland planted with *Canna siamensis*.



(a)



(b)

Fig. 5: Nitrates (a) and Phosphates (b) removal efficiencies with HRT in Constructed wetland systems.

Total average removal of all the parameters with constructed wetland systems are plotted in the fig 6. From this graph it is proved that constructed wetland systems are efficient in their working and they can be used instead of conventional wastewater treatment to treat above said parameters.

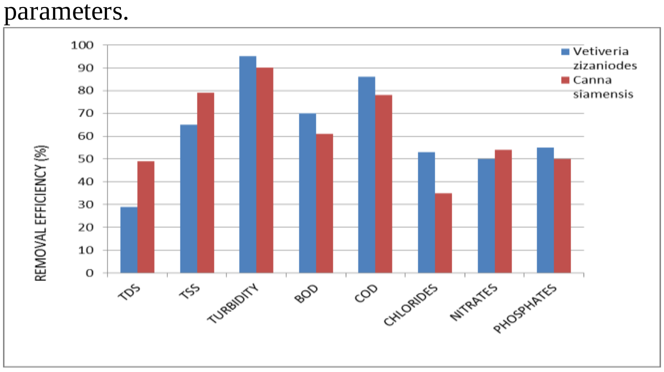


Fig.6: Average removal efficiencies of all parameters in Constructed wetland systems

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IV. CONCLUSION

Constructed wetlands are an emerging and acceptable phyto technology because of its eco-friendly concept which helps to recycle and reuse the wastewater. Since 70-80% of consumed water becomes sewage, the need to recycle and reuse this water to reduce scarcity of water. Billions of people in the world have insufficient drinking water. So if we use recycled water treated by constructed wetlands for toilet flushing, gardening and irrigation one can reduce water demand. Therefore constructed wetlands are considered as one of the best management practices which help to conserve water. In this study, two species are used to treat domestic wastewater viz. *Canna siamensis* and *Vetiveria zizaniodes.* They proved to give better efficiency than conventional wastewater treatment. In addition to that it is economical and also an environmental friendly technique which is robust in its nature. It is suitable to small scale municipal wastewaters, institutional sewage and also for industrial effluent.

V. SCOPE FOR FUTURE WORK

Constructed wetlands planted with mixed culture of different species will give better performance than with single species. CW's are cheaper than conventional wastewater treatment with low initial and maintenance cost. In addition to this, they can be used to treat industrial, institutional, agricultural wastes. It can also be extended to treat landfill leachate, toxic wastes etc.

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