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WASTE WATER TREATMENT EFFICIENCY OF VETIVER GRASS IN CONSTRUCTED WETLANDS

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Abstract: Pollution with industrial waste waters is common for a developing country. Waste water treatment is the only practice to reduce the pollution of soil and water by these effluents. Constructed wetland technology is one of the emerging and acceptable technologies because it can effectively remove all most all types of pollutants from waste waters without harming the environment. The main aim of the study was to find out the effectiveness of vetiver grass (Vetiveria zizanioides L. Nash) in the treatment of waste waters in constructed wetlands. The vetiver plants (Vetiveria zizanioides L.Nash) (ODV-3) were planted in the constructed wetland (Test group and control group). After 90 days, the test groups were divided into three (T1, T2, T3) and were treated with waste water from automobile service station (W1), spray painting workshop (W2) and sewage (W3) respectively and were allowed to grow for further 15 days. The total experimental period was for 105 days. At the end of the experiment (on the 15th day of waste water treatment), the treated water from the tanks was collected and tested to find out the physico- chemical changes. The results of the study show that more than 50% percentage removal of pollutants especially nutrients after 15 days treatment of waste waters in constructed wetlands was observed and it showed the efficiency of the vetiver variety for improving the water quality. The result shows that after the experimental period the important biometric parameters like number of leaves and total wet biomass were increased compared to that of control plants in the entire test groups and highest values were observed in T3 groups (plants treated with sewage water). Comparatively lesser plant height, root length, number of leaves and biomass content were recorded in the test plant group treated with service station effluent (T1), and these changes indicate the waste water induced stress on plants. The physico-chemical characteristics of the waste water analysed show that the effluent collected from automobile service station was heavily polluted. Even though that waste water is highly polluted, the plants survived in the harsh environment and it indicated the high tolerance of vetiver grass against the waste water induced stress. So from the present study it was evident that vetiver grass is an ideal candidate for waste water treatment using constructed wetland technology.

Key words: Constructed wetland, Waste water, Biometric parameters, Physico-chemical characteristics, Pollutant.

INTRODUCTION

One of the greatest problems that the world is facing today is that of environmental pollution, increasing with every passing year and causing grave and irreparable damage to the earth. The mechanization of society, the urbanization, industrialization, introduction of motorized vehicles, and the explosion of the human population have caused an exponential growth in the increase of waste by-products. Domestic sewage, industrial wastes, fertilizers, detergents, silt, gases and other waste products is being dumped into the components of biosphere have changed the quality of our environment to a great extent. Due to this fast urbanization with industrial and commercial development, in its wake has posed a major problem of safe disposal of these effluents in different parts of the country. Pollution of soil and water with waste waters of different characteristics is a common practice. Treatment is necessary to correct wastewater characteristics in such a way that the use or final disposal of the treated effluents can take place in accordance with the rules set by the relevant legislative bodies without causing an adverse impact on the receiving bodies of air, water or soil. The treatment of these waste waters rich in nutrients and other toxic chemicals has mainly been done using conventional wastewater treatment systems such as activated sludge and biological nutrient removal technologies or otherwise by several chemical methods. These technologies are very expensive and dependent on electrical energy and skilled personnel or impossible to carry out, as the volume of contaminated material is very large (Salomons *et al*., 1995). These problems can counter balanced by the new emerging field of waste management, the bioremediation. Vegetative methods (phytoremediation) are thought to be most practical and economical than the use of microbes for bioremediation because of the easily availability and practicability.

The constructed wetland systems have proved to be an adequate technology for the treatment of a wide variety of waste water in urban, suburban and rural areas of many developed countries (ITRC, 2003). Natural wetlands act as a bio filter, removing sediments and pollutants such as heavy metals from the water, and constructed wetlands can be designed to emulate these features. Constructed wetland technology (CW) is one of the emerging and acceptable technologies because it can effectively remove all most all types of pollutants from waste waters without harming the environment. The concept of CWs is to further enhance the natural treatment process by harnessing energy and source materials from the natural environment. The objective is to promote an effective, cost efficient, low-maintenance water treatment process that can be replicated at different locations within the impact areas. The use of indigenous natural materials further enhances the efficiency of the system as well as reducing capital and operating costs. Energy within the CW is harnessed from the sun (photosynthesis), topographical relief (hydraulic gradient), and microbial metabolism.

Vegetation is important for all phytoremediation applications, either in soil or in wetlands. The plant accepted as safe for phytoremediation and assisted works; it should have certain qualities or characteristics. It is necessary to use plants that tolerate high levels of toxic pollutants (Troung *et al*., 1995).

Vetiver grass is a versatile hardy plant having stuff and erect stems, deep, extensive, fast growing and penetrating root systems and are highly tolerant to adverse climatic conditions [frost, heat, wave, temperature (5-550C), drought, flood and inundation], edaphic conditions, and highly tolerant to elevated levels of heavy metals, herbicides, pesticides, and high efficiency in absorbing dissolved nitrogen, phosphorous, sulphate, As, Cd, Cu, Pb, Hg, Ni, Se and Zn (Zhen *et al*., 1997).

MATERIALS AND METHODS

Plant Materials

The vetiver plants (*Vetiveria zizanioides* L.Nash) (ODV-3) were obtained from the Herbal Garden- Aromatic and Medicinal Plants Research Station (Kerala Agricultural University), Odakkali, Ernakulam, Kerala. It is a selection variety developed from the Aromatic and Medicinal Plants Research Station (Kerala Agricultural University), Odakkali, Eranakulam, Kerala. The vetiver plants were removed from the propagating soil and surface sterilized with distilled water to remove any adhering soil. Then the tops and roots of the vetiver sprouts were pruned to 10 cm and 5 cm respectively.

Waste waters used for the experimental study

The waste waters were collected from three selected stations in Thiruvananthapuram city and were used for phytoremediation studies in constructed wetlands using vetiver plants. These include wastewaters collected from an Automobile Service station at Kaniyapuram (W1); Automobile spray painting workshop at Kazhakkuttom (W2) and the raw sewage from the Valiyathura sewage farm (W3) in Thiruvananthapuram district, Kerala.

Methodology

The various physico-chemical attributes of waste water samples were analyzed by following the procedure of APHA (2005) and Trivedy and Goel (1998). All the chemicals used for the estimations were of analytical grade.

Experimental Design

The wetlands were constructed according to UN-HABITAT (2008) in plastic tanks having 50 litres capacity with drainage facility by filling the base with gravel (20-40mm) up to 8 cm height. The next layer was filled with gravel (5-10mm) to a height of 3 cm. Then the thick sand was used to fill the next layer to a height of 25 cm and again the gravel (5-10 mm.) was used to fill the top layer of 3 cm height. The tap water was poured into the tanks so that the water column was 10cm above the soil bed and kept for 1 week for acclimatization. Then drained out all the water from the tanks and six clumps of vetiver grass, (*Vetiveria zizanioides* L. Nash, ODV-3) were planted in each tank and were maintained in the controlled condition for growth. All the plants were watered daily with sufficient amounts of tap water for growth and acclimatization. After one month growth, the tanks were loaded with tap water until the water level was 10 cm higher than the soil surface to create a constructed wetland (CW) system.

The vetiver plants were allowed to grow under controlled conditions for three months then the test plants were divided into three groups (T1, T2, T3) and were treated with waste water collected from automobile service station, spray painting workshop and sewage respectively. The test groups and control group plants were allowed to grow for further 15 days. The total experimental period was for 105 days. Replicates of the experimental groups were also maintained. The wastewater treatment period was for 15 days.

At the end of the experimental period (on the 15th day of waste water treatment), the treated water from the tanks were collected in sampling bottles and the physico-chemical parameters were analyzed. The entire study group plants were uprooted and the morphological changes (plant height, number of leaves, leaf area, and root length) were noted.

RESULTS AND DISCUSSION

Water and Waste water Characteristics before treatment

The results of the chemical characteristics of tap water and waste waters are given in Table. 1 and it show that the various chemical parameters of tap water used in the control wetland are within the permissible limit of Indian Environmental Standards and Environment Protection Act (Raman and Devotte, 2006; EPA, 2002).

In different waste waters analysed majority of the water quality parameters i.e. TDS, COD, TN, NH4-N, SO42-, Ca, Mg, Fe etc. are above the permissible standard limits for safe disposal to inland water bodies/ land as per the Indian Environmental Standards (Raman and Devotte, 2006) and EPA (2002). All the other parameters analysed were within the standard permissible level but the continuous discharge of these effluents can cause serious effects on land or receiving water body. So the waste waters should be treated to remove undesirable amounts of pollutants before it is disposed into the inland surface waters or to land.

Changes in the waste water characteristics after treatment

The results of the analysis of various chemical characteristics of water and waste waters after the experimental period were given in Table 2.

Total Dissolved Solids (TDS) are the amount of solids which are dissolved in water. It was found that after the experimental period the TDS of

Table 1. Chemical characteristics of tap water and waste water

Parameters	Tap Water	W1	W2	W3
TDS (mg L^{-1})	57	62406	4460	3669
BOD (mg L^{-1})	BDL	11.62	14.82	86.75
COD (mg L^{-1})	BDL	740	963	2340
NO_3-N (mg L^{-1})	BDL	0.68	0.82	1.57
NO_2-N (mg L^{-1})	BDL	0.02	0.07	0.48
TN (mg L^{-1})	BDL	14.6	16.7	44.06
NH_4-N (mg L^{-1})	BDL	6.4	6.3	31.41
Total Phosphorus (mg L^{-1})	BDL	4.44	3.27	7.48
Inorganic Phosphorus (mg L^{-1})	BDL	2.47	2.13	4.27
Silicate (mg L^{-1})	6.5	25.8	16.4	21.7
Chloride (mg L^{-1})	56.6	184.9	1235.4	142.6
Sulphate (mg L^{-1})	68.7	172.6	72.3	134.6
Ca (as $CaCO_3$) (mg L^{-1})	36	121.6	1082.16	214.7
Mg (as $CaCO_3$) (mg L^{-1})	24	75.5	77.94	95.3
Na (mg L^{-1})	5.9	437.5	115.6	125.44
K (mg L^{-1})	0.7	79.8	85.4	95.6
Iron (mg L^{-1})	0.62	10.6	1.2	3.7

Table 2. Chemical characteristics of tap water and waste water after treatment

Parameters	Tap Water	W1	W2	W3
TDS (mg L^{-1})	59.9	2195.58	1025.8	770.49
BOD (mg L^{-1})	0.91	2.62	3.05	16.44
COD (mg L^{-1})	2.12	189.29	224.76	469.17
NO_3-N (mg L^{-1})	BDL	0.16	0.18	0.32
NO_2-N (mg L^{-1})	BDL	BDL	BDL	0.11
TN (mg L^{-1})	0.13	6.48	7.88	19.96
NH_4-N (mg L^{-1})	BDL	2.95	4.41	14.32
Total Phosphorus (mg L^{-1})	0.021	1.29	0.91	1.91
Inorganic Phosphorus (mg L^{-1})	BDL	0.83	0.75	1.39
Silicate (mg L^{-1})	0.36	13.76	9.14	11.79
Chloride (mg L^{-1})	2.64	87.21	559.14	65.77
Sulphate (mg L^{-1})	BDL	59.63	25.44	42.11
Ca (as $CaCO_3$) (mg L^{-1})	1.62	44.69	391.2	81.48
Mg (as $CaCO_3$) (mg L^{-1})	1.21	26.79	27.89	31.69
Na (mg L^{-1})	BDL	164.33	43.95	45.98
K (mg L^{-1})	BDL	31.22	32.34	35.6
Iron (mg L^{-1})	0.91	3.11	0.36	1.13

BDL-Below Detectable Level

the waste waters were reduced and the percentage reduction was recorded as 96.48 %, 77.00 %, and 79.00 % in service station effluent, spray painting spent wash and raw sewage respectively. This removal may be accomplished through a complicated set of internal processes including production of transportable solids by biota, vegetation, low water velocity, filtration and substrate (Reed *et al.*, 1995) and processes like straining, sedimentation, impaction and interception. In addition, other removal mechanisms such as adhesion, chemical and physical adsorption, and flocculation, depending on characteristics of the particles and media are also accelerating the removal efficiency in the constructed wetlands (Koottatep *et al.*, 2010).

Biological Oxygen Demand (BOD) is an indicator of pollution in water. It is clear from the result that the BOD content of the waste waters were higher before the treatments were given. But after the treatment it was reduced by 77.45%, 79.42% and 81.05% in the service station effluent, spray painting spent wash and raw sewage respectively. It may be by the action of aerobic bacteria attached to the media and to the plant roots (Shivhare and Roy, 2013). Chemical Oxygen Demand (COD) determines the amount of DO used for the chemical oxidation of wastes in water. High COD indicates that high degree of pollution load in water. The COD of the waste waters was reduced considerably after treatment in constructed wetland. The percentage reduction was recorded as 74.42%, 76.66% and 79.95% in the service station effluent, spray painting spent wash and raw sewage respectively. From the results it is observed that, constructed wetland technology is a very effective method of treating waste waters containing higher COD. According to Zirschky (1986) and Vipat et al. (2008) BOD and COD associated with settleable solids in waste water is removed by sedimentation while that in colloids and soluble form is removed as a metabolic activity of microorganisms and physical and chemical interaction within the root zone/substrate.

Nitrates are one of the important limiting nutrients. Presence of nitrate indicates organic pollution in water. From the tables it could be noted that, the NO3-N concentration waste waters were reduced to a notable extent by the treatment with vetiver grass and the reduction was recorded as 76.47%, 78.05% and 79.62% for the respective waste waters. In the case of nitrite-nitrogen (NO2-N) it was also proved that, the NO2-N content was also condensed by 100%, 100% and 77.08% in the service station effluent, spray painting spent wash and raw sewage respectively. By comparing the values of total nitrogen (TN) in the waste waters such as service station effluent, spray painting spent wash and raw sewage indicated that the treatment in the wetland with the vetiver grass is very efficient in removing the TN content from the waste waters. The result shows that the TN contents were reduced by 55.62%, 52.81% and 54.70% for the respective waste waters.

It was also clear from the results that, the ammonia- nitrogen content in the waste waters also reduced considerably due to the vetiver wetland technology by 53.91%, 30.00% and 54.41% in the service station effluent, spray painting spent wash and raw sewage respectively. Shivhare and Roy (2013) reported that about 35% of total ammonia oxidized gets converted into nitrites and the oxidized ammonia is either getting converted into nitrogen gas or consumed by plant uptake or by volatilization through aeration but volatilization requires high pH (>11) and high DO in the system. Hence plant uptake is the major mechanism of ammonia removal in the system. The nitrogen undergoes several transformations in wetlands, including ammonification, nitrification, denitrification, volatilization, adsorption and plant and bacteria uptakes and these mechanisms are considered as the key process for nitrogen removal from wetlands. Billore et al. (2002) reported that plant absorption is the dominant mechanism of nitrogen removal.

Other important nutrients like inorganic phosphorus and total phosphorus were also found to be decreased due to the treatment with vetiver wetland technology and the percentage reduction was recorded for inorganic phosphorus as 66.40%, 64.79% and 67.45% and for total phosphorus the reduction was found by 70.95%, 72.17% and 74.47% in the service station effluent, spray painting spent wash and raw sewage respectively. Studies by Hoffman *et al.* (2011) and Boonsong and Chansiri (2008) reported that phosphorus removal can be achieved in constructed wetlands by burial adsorption and precipitation, sedimentation, exchange process between soil and overlying water column and a small amount is also taken up by plant growth.

The concentration of silicates and sulphate was also found to be reduced to a notable extent and was recorded as 46.67%, 44.27% and 45.67% and 65.45%, 64.81% and 68.71 respectively. The study also revealed that the waste waters containing chlorides, calcium and magnesium can also be treated effectively using constructed wetland technology with vetiver plants. The chloride contents in the waste waters were reduced by 52.83%, 54.74% and 53.88%, the Ca contents were reduced by 63.25%, 63.85% and 62.05% and the Mg contents were reduced by 64.52%, 64.22% and 66.75% in the service station effluent, spray painting spent wash and raw sewage respectively. As in the case of other nutrients the sodium and potassium contents in the waste waters were also reduced to a good extent. The percentage reduction of sodium was recorded as 62.44%, 61.98% and 63.33% and potassium in the waste waters were reduced by 60.88%, 62.13% and 62.76% in the service station effluent, spray painting spent wash and raw sewage respectively.

It is clear from the result that the Iron content in the waste waters is effectively removed by vetiver plants. After the treatment period the iron content in the waste waters were reduced by 70.66%, 70.00% and 69.46% in the service station effluent, spray painting spent wash and raw sewage respectively. It was also evident from the study that metal contents were also can be removed by constructed wetland technology using vetiver grass.

Changes in the Biometric parameters of Vetiver plants

Characteristics of waste waters may differ with their source of generation. So the response of the plants grown in waste water contaminated soil may also differ. The morphological characteristics such as plant height, root length, number of leaves and total wet biomass of the plants are given in Table No.3. From the results it is clear that the different waste waters influenced the growth of the plants. The comparison with control plants, the test group plants showed variations in their biometric parameters. The

Table 3. Changes in the plant morphology and biomass

Groups	Plant Height (cm)	Root Length (cm)	No. of Leaves	Total Biomass (g)
C	180.6	190.2	26	428.5
T1	168.6	174.3	28	428.8
T2	180.9	192.3	28	437.6
T3	182.3	192.4	28	440.6

plants treated with service station effluent (T1) showed comparatively lesser growth than the others. It is evident from the height, root length, lesser number of leaves and low biomass content. It may be due to the waste water flood induced stress and various pollutants in the service station effluent such as heavy metals - Cd, Zn, Cu, Cr and Pb (Singh, 2005).

The waste water from spray painting workshop showed moderate growth and biomass production. But the sewage treated vetiver plants showed higher growth and biomass production when we compare them with the control plants. It may be resulted due to the sewage water application. The sewage waters were rich in nutrients like N, P and K, because of the presence of organic matter (Boonsong and Chansiri, 2008). He also reported that, the intake of these nutrients by highly tolerant plants resulting in fast growth even in metal contaminated sites.

CONCLUSIONS

The results show that vetiver can tolerate crude service station effluent and have an unusual ability to take up nutrients and other pollutants from treatment medium. In view of their fast growth, high biomass, high nutrient uptake ability and adequate tolerance nature, vetiver appears to have great potential for remediation purposes. So the Vetiveria zizanioides (L.) Nash. (ODV-3) are good candidate for phytoremediation of waste waters using constructed wetland technology however the vetiver plants are struggled in the stressful environment created by the effluent to establish their successful survival.

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