APPLICATION OF VETIVER FOR WATER AND SOIL RESTORATION

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ABSTRACT

Vetiveria zizanioides (L) Nash. (recently reclassified as *Chrysopogon zizanioides* (L) Roberty) is a densely tufted grass found throughout the plains and lower hills of India particularly on the riverbanks and in rich marshy soil. It is a multipurpose useful plant, almost all parts of which are used in one or more ways having multivarious cultural and industrial applications. Majority of the vetiver related literatures are focused on the engineering aspects. Soil erosion in many parts of the country silently affects the production of crops. In recent years, landslides, unstable slopes and flooding destroy agricultural lands in India. If the farmers of India use vetiver regularly, then they need not worry about the production of crops as it is one of the best soil erosion controllers. The industrial growth is increasing day by day in recent years, at the same time over use and misuse of large areas of agricultural lands results in excessive storage of toxic substances in the soil. When the toxic substances from the industrial wastes affect the soil, ground water quality is also affected in the course of time. The example for this can be Tirupur, the hosiery capital of India.

The problem of discharge of toxic effluents from dyeing and bleaching units into the Noyyal, a non-perennial river that meets the Cauvery near Karur, Tamilnadu is notably increasing. The Orathupalayam dam near Tirupur contains textile wastes and the toxicity of the water and the sludge is increasing. The problem of disposal of textile wastes is likely to become serious in the days ahead because of the possibility of affecting the groundwater in Tirupur itself. The remedy for this problem lies in vetiver as it is one of the most suitable plants to be used in purifying pre-treated wastewater effluent in wasteland. Most of the countries in the world are treating the wastewater with the vetiver technology. There are evidences that vetiver when grown in the wetland can be harvested and used as a source of essential oil for non-fragrance applications, especially as pesticides.

The Vetiver plant was grown in municipal wastewater and found that it reduced selective nutrients like nitrate and phosphate to a level of 94% and 90% respectively. There was a drastic reduction in BOD and COD level in the treated wastewater. Similarly when the plant was grown in textile wastewater treated soil there was a drastic reduction in the concentration of TKN, TOC, Pb, Cd, Cu, Fe etc. Further the biomass, root length and shoot length were found increased. There is a great need for latest techniques to reduce the toxic metals at contaminated sites. Phytoextraction is an integrated multidisciplinary approach to the cleanup of contaminated soils using accumulator plants. One of the best accumulator plants is vetiver in which the roots are responsible in accumulating the toxic metals especially in the lead and zinc contaminated soils. The research work for the removal of toxic substances from the sewage/effluent water is going on and the results are encouraging that vetiver can be a best remedy for this. When the toxic metals accumulate in the culm/root of vetiver it can either be incinerated or dumped deeply in the soil. Vetiver has the greatest role in soil and water conservation. From the experimental results, it was concluded that the vetiver could be applied for remediation of domestic as well as dye contaminated wastewater and soil because of its extensive fibrous rhizosphere system. The demand for vetiver plant and its products is increasing very high at the moment; the cultivation of vetiver for the restoration of soil

and water is need of the hour.

1. INTRODUCTION

Soil erosion in many parts of the country is silently affecting the production of crops. In recent years, landslides, unstable slopes and flood destroy agricultural lands. The overuse and misuse of large areas of agricultural lands result in excessive storage of toxic substances in the soil. The toxic substances from the industrial wastes affect the soil, ground and surface water quality.

Vetiver (*Chrysopogon zizanioides* (L) Roberty) is a native grass of India and has traditionally been in use for contour protection. It is a low cost, extremely effective system that offers proven solutions for soil and water conservation, wastewater treatment, embankment stabilization, flood control, disaster and pollution mitigation and many other environment friendly applications. It is a densely tufted grass found throughout the plains and lower hills of India particularly on the riverbanks and rich in marshy soil. The effectiveness of vetiver for soil and water conservation measures not only reduces soil erosion but also provides more soil moisture conservation cropping system.

Internationally, vetiver is well known as an useful agent for erosion control because of its steady shoot and dense root system. A vetiver hedgerow for soil and water conservation is widely used by the farmers in Karnataka. The plant is a partial hydrophyte and is powerful to remove nitrogen and phosphorus from water and therefore the plant can be used for phytoremediation (Zheng *et al*., 1997) and garbage leachets (Xia *et al*., 1998), Wagner *et al*, (2003) reported that it is capable of withstanding extremely high nitrogen supply (10,000 kg N/ha/year) and P (1000 Kg P/ ha/ year). Vetiver is highly tolerant to heavy metals like arsenic, cadmium, copper, chromium, lead, mercury, nickel, selenium and zinc (Truong and Baker, 1998) and can absorb more heavy metals in comparison with bahia and is less likely to form secondary pollution or bioaccumulation as is bahia (Xia and Shu, 2001).

Tirupur, which is hosiery capital of India, discharges large quantity of wastewater from dyeing and bleaching units. On the industrial front with over 700 industries the contribution of the industrial discharges in Tirupur is significant. Most of the dyeing and bleaching units located with in the city limits discharge their effluents without any treatment either into the Noyyal River or onto the agricultural lands in the vicinity of these industries. About 75,000 m^3 of effluent is discharged per day (Rajaguru, 1997). Dyeing industries in Tirupur use numerous synthetic dyes and dye intermediate chemicals such as caustic soda, soda ash, hydrochloric acid, sulphuric acid, peroxides, hypo chlorites etc. Many of these poisonous chemicals are known to persist for long period in the environment and their concentration build-up geometrically as they are transferred to different stages of food web (Kumar, 1977). These chemicals may destroy the soil microflora and fauna in which the existence of man depends. Attempts made to remediate the contaminated soil were inconclusive. Since the vetiver grass is a versatile plant capable of growing in different conditions, it was attempted for the first time to find out its role in remediating dye-contaminated soil besides municipal wastewater. The objective of the present study is to find out the efficiency of vetiver in remediation of municipal wastewater and textile wastewater treated soil.

2. METHODOLOGY

Municipal wastewater was collected from the inlet of municipal sewage plant. Pilot study has been carried out in the laboratory, Department of Environmental Sciences, Bharathiar

University, Coimbatore, by using plastic tubs of 15 lit capacities to carry out the experiment. The physico – chemical parameters of the wastewater were analyzed. Healthy vetiver culms were selected from the vetiver nursery of the Department of Environmental Sciences and initial weight was recorded. The culms with root (10 cm) and shoot (10 cm) were floated on the wastewater in the plastic tubs by the support of bamboo sticks. Each plastic tub had two culms and their root axis was kept submerged in the wastewater. The experiment set up was kept in triplicate and tubs were kept in the open garden to get natural light.

2.1 Experiment i:

t1 – control (municipal waste water alone)
t2 – municipal waste water + vetiver float
t3 – diluted municipal water (1:1) + vetiver float

the parameters like ph, ec, bod (winkler's method, apha 1998), cod (reflex method, titration, APHA, 1998), TDS (APHA, 1998), Nitrate nitrogen (Phenol disulphonic acid, Colorimetric method, Spectrophotometric, APHA, 1998), OC (Wakley and Black, 1934), microbial population (Allen, 1953) were analyzed. The morphological parameters like root length (RL), shoot length (SL), fresh weight (FW), dry weight (DW), total chlorophyll content were estimated on 0^{th} day and on 60^{th} day.

Textile wastewater treated soil was collected from Orathupalayam area near Tirupur in Coimbatore District. The soil was used for pot culture study with the combination of vermicompost (VC). The vermicompost was collected from the vermipark in the Department of Environmental Sciences, Bharathiar University campus. The pot culture studies were carried out in the green house. The pots were filled with 5 Kg of Orathupalayam soil (OS) and vermicompost (VC) at different ratios. The culms of vetiver grass with root (10 cm) and shoot (10 cm) were selected for the pot culture study. Two healthy culms were planted in each pot. Each treatment was made in triplicate.

2.2 Experiment II:

T1 – Control (OS) + vetiver plant
T2 – OS + VC (1:0.1) + vetiver plant
T3 – OS + VC (1:0.2) + vetiver plant
T4 – OSl + VC (1:0.3) + vetiver plant
T5 – OS + VC (1:0.4) + vetiver plant
T6 – OS + VC (1:0.5) + vetiver plant

The initial physico-chemical parameters like pH, EC (Jackson, 1973), Total Kjeldhal Nitrogen (Kjeldhal method, Tandon, 1993), phosphorous (Colorimetric method, Tandon, 1993), potassium (Flame photometric method, Tandon, 1993), organic carbon (OC) (Wakley and Black, 1934) and heavy metals like cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), were analyzed using Atomic Absorption Spectroscopy (AAS) (Tandon, 1993) and iron (Fe) and manganese (Mn) were analyzed by spectrophotometric method (Jackson, 1973).

The morphological parameters like root length (RL), shoot length (SL), fresh weight (FW), dry weight (DW), total chlorophyll content were recorded on initial day and on final day (60^{th} day). Microbial population (Allen, 1953) was estimated in rhizosphere and non-rhizosphere soil on initial and 60^{th} day.

3. RESULTS

3.1 Experiment I

pH is one of the factor influencing the availability of the nutrients to the plants. pH affects the solubility of $PO_4 - P$. pH was 7.9 ± 0.1 initially and the final was 7.2 ± 0.1 in T2 where as in T3 it was 7.6 ± 0.2 and 7.3 ± 0.1 and in T1 (control) it was 7.9 ± 0.1 and 7.7 ± 0.2 respectively. Roots absorb ions by a mechanism, which is pH dependent. In the present study pH was higher in the initial stage but the values were nearly neutral on the final day. pH of T2 and T3 were lower than T1 (control). It was observed that EC was decreased from initial to the final day. It was 1.36 ± 0.01 dSm^{-1} on 0^{th} and 0.9 ± 0.02 dSm^{-1} on 60^{th} day in T2.

The average dissolved oxygen (DO) concentration of effluent was decreased in other two treatments except T1 (control). In T2 it was 6.9 ± 0.1 mg/l on 0^{th} day and 5.2 ± 0.2mg/l on 60^{th} day. In T3 the DO level was decreased from 6.1 ± 0.1 to 5.7 ± 0.3 mg/l as the municipal wastewater was diluted. The average BOD concentration was ranging from 64 ± 1 to 29.6 ± 2 mg/l in T2. BOD was lower on 60^{th} day in all the treatments. The removal efficiency of vetiver in T2 and T3 were significant than T1 (Table 1).

Table 1: Physico-chemical parameters of Municipal wastewater treated with *C.zizanioides*

Parameters	Treatment					
	T1		T2		T3	
	Initial	Final	Initial	Final	Initial	Final
pH	7.9 ± 0.1	7.7 ± 0.2	7.9 ± 0.1	7.2 ± 0.1	7.6 ± 0.2	7.3 ± 0.1
EC	1.36 ± 0.01	1.24 ± 0.01	1.36 ± 0.01	0.9 ± 0.02	1.33 ± 0.01	1.03 ± 0.01
DO (mg/l)	6.9 ± 0.1	6.7 ± 0.3	6.9 ± 0.1	5.2 ± 0.2	6.1 ± 0.1	5.7 ± 0.3
BOD (mg/l)	64.0 ± 1	58.2 ± 3	64.0 ± 1	29.6 ± 2	45.3 ± 1	25.4 ± 3
COD (mg/l)	160 ± 2	120 ±1	160 ±2	42.1± 1	104 ± 1	47.8 ± 1
Nitrate Nitrogen (mg/l)	0.81± 0.1	0.68 ± 0.2	0.81 ± 0.1	0.04 ± 0.01	0.59 ± 0.2	0.05 ± 0.02
Phosphate (mg/l)	54 ± 1	47.5 ± 2	54 ± 1	5.4 ± 1	35 ± 2	4.55 ± 1
OC (%)	12.33 ± 1	9.9 ± 1	12.33 ± 2	5.3 ± 0.5	8.32 ± 2	4.9 ± 0.5
TDS (mg/l)	189 ± 2	174 ± 1	189 ± 2	140 ± 1	101 ± 2	79 ± 1

The wastewater contains phosphorous which may be removed through sedimentation and precipitation. The hydroponics technique used in this study showed that higher percentage of PO_4 removal efficiencies was 90 % and 87% in T2 and T3. Removal of PO_4 from the wastewater by vetiver in T2 was higher than T3 and T1. On the final day, the morphological parameters like root length (RL), shoot length (SL), fresh weight (FW), dry weight (DW) and total chlorophyll content in T2 were 75 ± 1cm, 64 ± 2 cm, 166 ± 1 g, 20.63 ± 1g and 1.22 ± 0.03 mg/g (**Table 2**). There was a significant increase in the dry weight in T2 than T3 as the root and shoot might have utilized all the nutrients present in municipal wastewater. It was observed that the plant could grow well in both T2 and T3.

Table 2: Morphological parameters of *C.zizanioides* grown in different treatments (Municipal waste water)

S.No	**Parameters**	**T1**	**T2**		**T3**	
			Initial	**Final**	**Initial**	**Final**
1.	Root length (cm)	Without plant	10 ± 0.5	75 ± 1	10 ± 0.5	70 ± 2
2.	Shoot length (cm)		10 ± 0.6	64 ± 2	10 ± 0.6	59 ± 1
3.	Fresh weight (g)		8.8 ± 0.2	166 ± 1	8.8 ± 0.2	162 ± 3
4.	Dry weight (g)		-	20.63 ± 1	-	18.52 ± 2
5.	Total chlorophyll (mg/g)		0.81± 0.01	1.22 ± 0.03	0.81± 0.01	1.30 ± 0.02

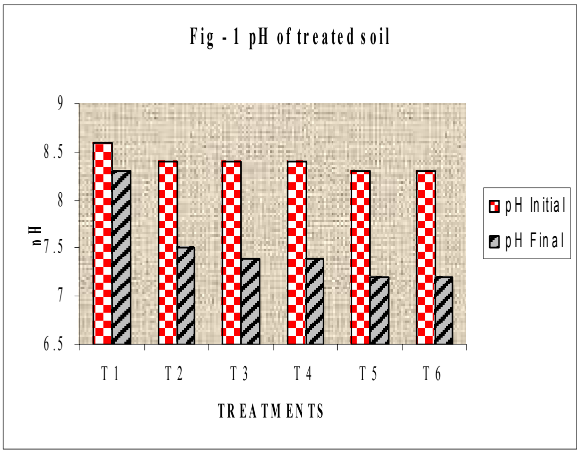
The microbial populations were enumerated and the results are recorded in Table 3**.** The rhizosphere (R) organisms were found to be more populated than the non-rhizosphere (NR) organisms. Microbial populations of the roots of both the treatments (T2 and T3) were estimated. The final readings of T2 showed that bacteria, fungi and actinomycetes were 210.0 cfu x 10^5/g, 34 cfu x 10^4/g and 26 cfu x 10^4/g respectively in the rhizosphere. It was obvious that the rhizosphere organisms were highly populated in T2.

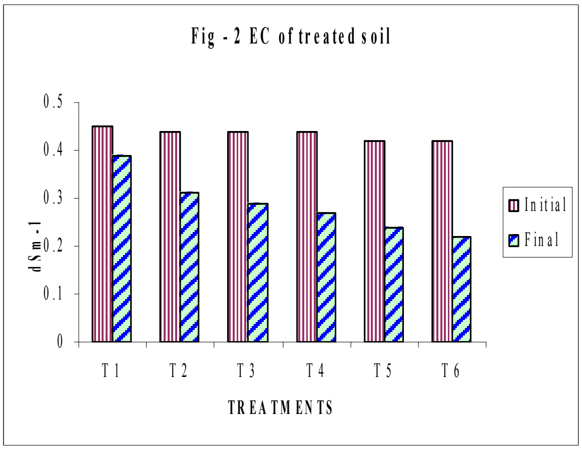
Table 3: Microbial population of municipal wastewater in different treatments.

Treatments	**Bacteria (cfu x 10^5/g)**				**Fungi (cfu x 10^4/g)**				**Actinomycetes (cfu x 10^4/g)**			
	Rhizosphere		**Non Rhizosphere**		**Rhizosphere**		**Non Rhizosphere**		**Rhizosphere**		**Non Rhizosphere**	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
T1	**-**	**-**	**126**	**138**	**-**	**-**	**12**	**16**	**-**	**-**	**8**	**12**
T2	**131**	**210**	**126**	**166**	**11**	**34**	**12**	**26**	**9.5**	**26**	**8**	**23**
T3	**129**	**196**	**112**	**145**	**9**	**27**	**8**	**19**	**7.5**	**14**	**5.5**	**18**

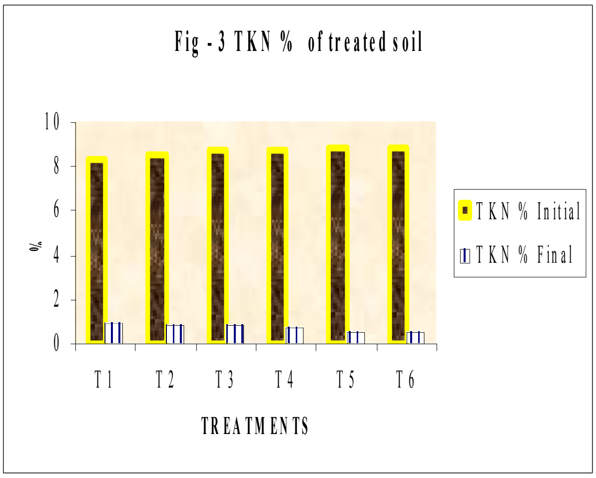
3.2 Experiment II

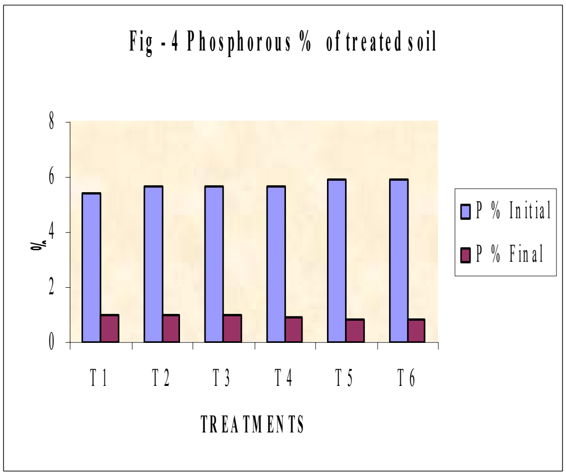
Vetiver plant can tolerate wide range of pH, EC, Total Kjeldhal Nitrogen (TKN), phosphorous, potassium and total organic carbon (TOC). Initial pH was found to be 8.6 and final was 8.3 in T1 (control). But in all other treatments the pH was found to be reduced than T1 on the final day (Fig 1). There was a reduction in EC in all the treatments (Fig 2). EC was 0.22 dSm^{-1} in T6 and it was 0.39 dSm^{-1} in T1.



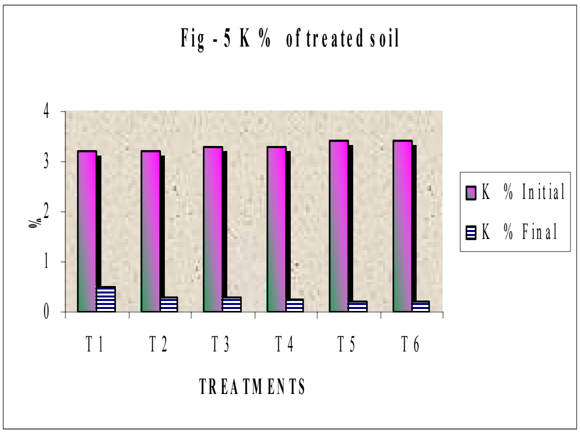


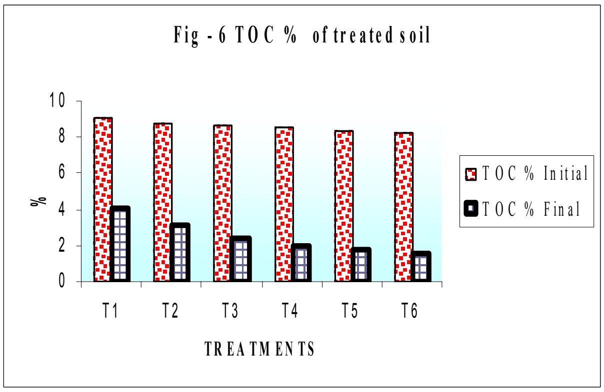
Initial value of TKN was 8.85% in T6 and it was reduced to 0.53% on the final day (Fig 3). In the same way phosphorous was also found to be higher in T6 (5.9%) initially (Fig 4).





On the final day, concentrations were reduced from 5.9% to 0.81%. The percentage of potassium was drastically reduced from 3.4% to 0.18% in T1 (Fig 5). In T6, the percentage of potassium was reduced from 3.4% to 0.2%. The TOC on 60th day was 1.6% in T6 (Fig 6).





It was reduced from 8.3% to 1.8% in T5, whereas in T3 and T4 it was from 8.6% to 2.4% and 8.5% to 2.0%. Metals like Pb, Cd, Cu, Fe, Zn, Mn, were also reduced on 60th day in all the treatments. The metal uptake by the plant was prominent in T6 (Table 4).

Table 4: Heavy metal contents of Orathupalayam soil in different treatments

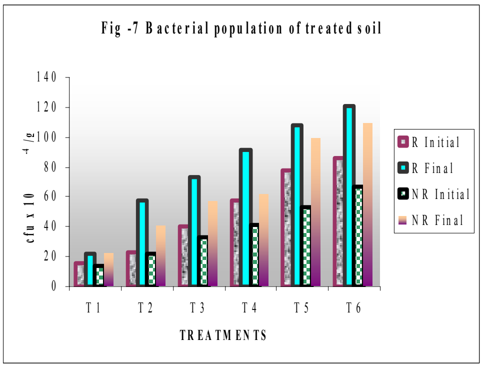
Treatment	Pb (ppm)		Cd (ppm)		Cu (ppm)		Zn (ppm)		Fe (ppm)		Mn (ppm)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
T1	**1.57 ± 0.01**	**0.55 ±0.02**	**0.244 ± 0.01**	**0.044 ±0.02**	**0.78 ±0.02**	**0.07 ±0.01**	**1.10 ±0.02**	**0.63 ± 0.01**	**6.66 ±0.02**	**3.01 ±0.02**	**2.64 ± 0.01**	**0.44 ±0.02**
T2	**1.55 ±0.02**	**0.53 ±0.01**	**0.339 ±0.02**	**0.041 ±0.01**	**0.76 ±0.01**	**0.05 ±0.02**	**1.08 ±0.01**	**0.45 ±0.01**	**6.62 ±0.02**	**2.84 ±0.02**	**2.34 ±0.01**	**0.40 ±0.02**
T3	**1.49± 0.01**	**0.48± 0.02**	**0.233 ±0.01**	**0.039± 0.02**	**0.74± 0.02**	**0.04± 0.02**	**1.05± 0.02**	**0.33± 0.01**	**6.55± 0.02**	**2.62± 0.01**	**2.32± 0.02**	**0.32± 0.01**
T4	**1.42± 0.02**	**0.40± 0.02**	**0.231 ±0.01**	**0.035± 0.01**	**0.73± 0.02**	**0.04± 0.01**	**1.04± 0.02**	**0.32± 0.01**	**6.49± 0.02**	**2.35± 0.02**	**2.29± 0.02**	**0.25± 0.02**
T5	**1.36± 0.02**	**0.32± 0.01**	**0.229± 0.02**	**0.032± 0.02**	**0.69± 0.01**	**0.03± 0.02**	**1.03± 0.01**	**0.29± 0.02**	**6.38± 0.02**	**2.28± 0.01**	**2.27± 0.02**	**0.14± 0.01**
T6	**1.30± 0.01**	**0.28± 0.02**	**0.221± 0.01**	**0.029± 0.02**	**0.69± 0.02**	**0.01± 0.02**	**1.02± 0.02**	**0.28± 0.01**	**6.21± 0.02**	**2.21± 0.02**	**2.19± 0.02**	**0.12± 0.02**

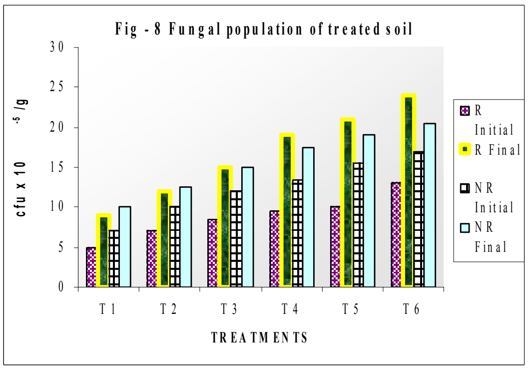
The growth parameters of vetiver of root length, shoot length, fresh weight, dry weight and total chlorophyll content were recorded on 0th day and 60th day. There was an increase in all the growth parameters in T6. There was an increase in root and shoot length until harvest in all the treatments. However, the growth of vetiver was prominently greater in T6 and T5. The fresh weight (FW) of the plant in T6 (273.1 ± 0.1 g) on the final day was higher than in T1 (180.0 ± 0.1 g). Surprisingly, the dry weight was increased. It was 19.2 ± 0.1 g in T1 and 35.3 ± 0.2 in T6 (Table 5).

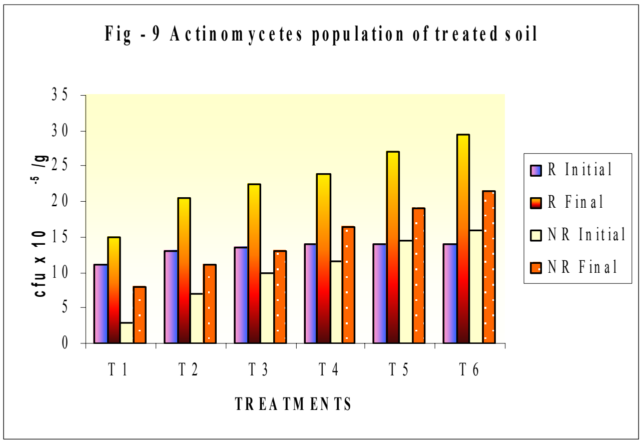
Table 5: Morphological parameters of vetiver grown in different treatment (Orathupalayam soil)

Treatments	RL (cm)		SL (cm)		FW (g)		DW (g)		Total chlorophyll (mg/g)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
T1	10 ± 0.4	18.2 ± 0.2	10 ± 0.1	43.0 ± 0.2	6.2 ± 0.1	180 ± 0.1	-	19.2 ± 0.1	0.123 ± 0.1	0.197 ± 0.1
T2	10 ± 0.2	42.0 ± 0.2	10 ± 0.2	51.1 ± 0.1	6.2 ± 0.2	195.2 ± 0.1	-	20.1 ± 0.1	0.216 ± 0.2	0.297 ± 0.1
T3	10 ± 0.1	48.2 ± 0.1	10 ± 0.4	55.2 ± 0.1	6.2 ± 0.1	210.3 ± 0.1	-	20.9 ± 0.1	0.262 ± 0.1	0.410 ± 0.1
T4	10 ± 0.2	51.3 ± 0.2	10 ± 0.3	58.1 ± 0.2	6.2 ± 0.1	252.5 ± 0.2	-	28.1 ± 0.1	0.257 ± 0.2	0.624 ± 0.2
T5	10 ± 0.1	69.4 ± 0.1	10 ± 0.1	59.7 ± 0.1	6.2 ± 0.1	260.0 ± 0.2	-	32.7 ± 0.2	0.272 ± 0.3	0.871 ± 0.2
T6	10 ± 0.3	75.2 ± 0.1	10 ± 0.4	65.3 ± 0.2	6.2 ± 0.2	273.1 ± 0.1	-	35.3 ± 0.2	0.269 ± 0.1	0.981 ± 0.2

The microbial population was enumerated in all the other treatments (T1- T6). Bacterial, fungal and actinomycetes populations in rhizosphere were found to be more than the non – rhizosphere of all the treatments. It was recorded that bacteria was 22 cfu x 10^5/g, fungi was 9 cfu x 10^4/g and actinomycetes was 15 cfu x 10^4/g on the 60^{th} day rhizosphere soil in T1. There was a gradual increase of microbial populations in rhizosphere soil T1 to T6. But it was noted that microbial population were lesser in non – rhizosphere of all the treatments when compared to the rhizosphere (Fig 7 – 9).







4. DISCUSSION

Vetiver is native to India, its environmental application for soil and water conservation is traditionally practiced for longer time. Systematic efforts to develop the vetiver grass technology for mitigation of soil erosion and water conservation were first initiated in India; however it was not practiced seriously. Several countries on the other hand, taking cues from the Indian initiative extensively implemented environmental applications of this grass (Lavania, 2004). Currently two main methods for treating contaminated water namely, 'engineering' and 'biological' are being used. The biological method consists of land irrigation, wetland and hydroponics system (Chomchalow, 2003).

As vetiver is both a xerophyte and a hydrophyte, it can withstand drought and flood. So this plant was used in the present study to treat municipal wastewater and textile wastewater treated soil. The physico-chemical parameters showed that there was a reduction in pH and EC in the vetiver treated wastewater and soil. Generally the effluent pH was higher but after the vetiver was planted the pH was found to be lower than the control. EC was found to be decreased on the final day of the experiment. This type of the reduction in pH and EC was supported by Truong *et al*. (2002).

In the present study, the dissolved oxygen (DO) levels were found to be decreased from the initial day to the final day. Dissolved oxygen is one of the most important parameters in water quality assessment and reflects the physical and biological processes prevailing in the water. Its presence is essential to maintain the higher forms of biological life in water and the effects of a waste discharge in a water body are largely determined by the oxygen balance of the system. The concentration of oxygen will also reflect whether the processes undergoing are aerobic or anaerobic.

The average BOD removal efficiency was higher on 60th day. Generally BOD could be removed by settling the particulate of BOD and utilization of degradable carbon compound during metabolic process. Higher BOD removal efficiencies were due to the higher organic decomposition rate by the vetiver plant, resulted in CO_2 and acid production, which finally lower the effluent pH.

Nitrate, which is highly soluble, is one of the major pollutants in ground and surface water. It cannot be easily removed by physical and chemical methods. But the biological treatment of wastewater is found to be successful. In the present study, it is proved that the removal of nitrate nitrogen was 90 – 94% and phosphate 87% to 90%. Summerfelt *et al*. (1999) used vetiver grass in a study for the removal and stabilization of aquaculture sludge, and found that vetiver removed 96 – 98% of total suspended solids (TSS), 72 – 91% of total COD, 30 – 81% of dissolved COD and 82 – 93% of dissolved phosphate, TKN and total phosphorous.

The growth parameters showed prominent increase in T2 and T3. There was a significant increase in the dry weight in T2 than T3 as the root and shoot might have utilized all the nutrients available in the municipal wastewater. It was observed that the plant could grow well in both T2 and T3. Reduction of nitrate nitrogen, phosphate and TOC on 60^{th} day showed that these factors promoted the growth of the plant.

The microbial populations in the wastewater treatment on 60^{th} day were found to be maximum in T2 and T3 than T1. The organic matter in the wastewater increased the microbial load and the vetiver root harboured more microorganisms.

Vetiver can grow in all types of soil regardless of pH or salinity. It tolerates wide range of pH, salinity, sodicity, acidity and heavy metals such as arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn) (Xia and Shu, 2001). In the present study, pH and EC decreased in all the treatments. This may be due to the higher organic decomposition rate resulted in CO_2 and acid production, which finally lowered the pH of the effluent. A decrease in the soil pH indicated the acidifying effect of organic acid produced upon decomposition and EC as the mineralization of free ions present in the compost and soil.

It was commonly known that vetiver could absorb higher nitrogen, phosphate and potassium. The NPK levels in the textile wastewater treated soil when amended with vermicompost were increased than those of control soil. It was found that vetiver could grow well in the treatments of T2 – T6. Wagner *et al*. (2003) reported that *C.zizanioides* is capable of withstanding extremely high nitrogen supply and phosphorous. In general, amendments such as application of organic manure or inorganic fertilizer are necessary for establishment of plants on contaminated or metal accumulated soil (Yang *et al*., 2003).

According to Karmegam (1997) the application of organic manures increased the NPK contents of the soil. Sharma *et al*. (1988) observed that farmyard manure registered higher organic carbon and available phosphorous content in the soil. All the above findings substantiate our present study very well.

The present study demonstrated that vermicompost when added to textile wastewater contaminated soil, greatly enhanced the growth of *C.zizanioides*. The increase of growth parameters like root length, shoot length and chlorophyll content was noticed. Growth stimulation was more pronounced with vermicompost supplement. The application of VC enhanced root initiation, root elongation, root biomass and rooting percentage. Vermicompost loosen the contaminated soil and make the soil texture suitable for the root growth.

The results showed that *C.zizanioides* has better growth performance in textile wastewater contaminated soil (RL, SL, FW, DW and total chlorophyll content) even though the heavy metals like Pb, Cd, Zn, Cu etc were accumulated in roots and shoots. Vermicompost acted like adsorbent for heavy metals and reduced the toxicity and supplied the required nutrients to the plants.

As vetiver has been found to be highly tolerant to extreme soil condition including heavy metal contamination, the experiment was conducted to check the reduction level of all contaminants of textile wastewater treated soil on the plant's ability to tolerate toxic levels of manganese (Mn), zinc (Zn), copper (Cu) and lead (Pb) and on the ability to accumulate these heavy metals in roots and shoots. Truong and Baker (1988) have proved the similar results. It might be concluded that heavy metals in soil even at the higher level to plant growth have no negative effect on vetiver growth (Roongtanakiat and Chairoj, 2001).

Microbial population was found to be higher in T2-T6 than T1. This may be due to the VC treatment. The earthworm casts contain maximum microbial population (Kale, *et al*., 1991). The organic humus content of the soil in T2 –T6 enriched the microbes. Most of the microorganisms appeared in the areas of rhizosphere of the vetiver root. The activity of microbial population was higher in rhizosphere of vetiver grass than non – rhizosphere. Moreover soil microbes and their activities have the important role in transformation on plant nutrients to available form and also have many metabolisms related to soil fertility improvement. Microorganisms often invade the surface tissue of roots, where they may cause a number plant link for nutrient transport between the plant and the soil, while the roots excrete soluble organic carbon compound, "polysaccharide" for soil microbial metabolism and adaptation. The soil microorganisms associated with vetiver root are nitrogen fixing bacteria, phosphate-solubilizing microbes, mycorrhizal fungi and cellulolytic microorganisms (Siripin, 2000). The substances in the exudates of vetiver root served as nutrients and energy sources for the growth of microorganisms in the rhizosphere (Russel, 1982; Lynch, 1990).

Application of the vetiver system for wastewater treatment and contaminated soils is a new and innovative phytoremedial technology and vetiver system was potential to meet all the criteria.

5. ACKNOWLEDGEMENT

The authors are thankful to the University and the Department of Environmental Sciences for providing necessary laboratory facilities.

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