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Removal of Pollutants from Sewage through Constructed Wetland using *Pennisetum purpureium*

V. P. DHULAP[1]
Department of Environmental Science
Solapur University, Solapur (MH)
India
S. S. PATIL
Department of Environmental Science
Dr.B.A.M.University, Aurangabad (MH)
India

Abstract:

Constructed wetlands are human induced systems that impersonate the functions of natural wetlands which are applied for sewage treatment. A study is carried out to investigate feasibility and optimization in pollution concentration through Angular Horizontal Subsurface Flow Constructed Wetland in the sewage treatment using Pennisetum purpureium Schumach. The plant species are implanted and propagates in the bed of constructed wetland. The sampling and analysis through physico-chemical and biological parameters viz. pH, EC, TSS, TDS, TS, BOD, COD, NO_3, PO_4 and SO_4 were carried out at both inflow and outflow in the pilot plant. The sewage samples with different concentrations such as 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% were tested before and after treatment. Results revealed that pH range was changed from 6.72 to 7.22, maximum reduction of E.C was reduced by 34.61% at 80% sewage concentration, TSS was reduced by 55.17%, TDS was reduced by 56.18%, TS was reduced by 55.48%, BOD was reduced by 76.65%, COD was reduced by 77.51%, NO_3 was reduced by 74.62%, PO_4 was reduced by 57.81% and SO_4 was reduced by 51.06% respectively provided after 96 hrs (4 days) Hydraulic Retention Time. The color and odour were removed and observed samples of treated water were very clear and odorless. The overall results indicated that, maximum pollutants removal were obtained in sewage with Pennisetum purpureium by root zone bed technology in constructed wetland at 80% to 90% sewage

[1] Corresponding author: vpdhulap@gmail.com

concentration. This model removes maximum pollutants and useful for reducing surface and subsurface water pollution load.

Key words: Sewage Treatment, *Pennisetum purpureium*, Angular Horizontal Subsurface Flow, Constructed Wetland, Root zone Technology

Introduction:

The constructed wetlands are basically manmade or human induced wastewater treatment systems consisting of shallow ponds or channels. They have been planted with aquatic macrophytes or plants which rely upon natural microbial, biological, physical and chemical process to treat wastewater. In natural looking constructed wetlands are pre-treated the wastewater by filtration, settling and bacterial decomposition. These constructed wetland systems have been used internationally with good results (David et al. 2002). The Constructed wetlands are designed to mimic natural wetland systems, utilizing wetland plants, soils and associated microorganisms to remove contaminants from wastewater (EPA 1993). The first experiment conducted by K. Siedel in Germany in early 1950's at the Max Planck Institute in Plon, aimed at the possibility of treatment by wetland vegetation. She carried out numerous experiments on the use of wetland vegetation for treatment of various types of wastewater like, dairy wastewater and livestock wastewater. In early 1960's scientists carried out different trials to grow macrophytes in wastewater and sludge of different origin and tried to improve the performance of rural and decentralized wastewater treatment which was either septic tanks or ponds systems with inefficient treatment. Siedel named hydrobotanical method for this early system (Vymazal 2005). In 1970's and 1980's, constructed wetlands were nearly limited built to treat domestic or municipal sewage. In 1990's, the constructed wetlands have been used for all kinds of wastewater including landfill leachate, runoff from urban, highway, airport and agricultural areas, food processing such as winery, cheese and milk production, industrial effluents of chemicals, paper mill and oil refineries, agriculture farms, mine drainage or sludge dewatering (Farooqi et al. 2008).

Constructed wetlands treatment systems are based on ecological systems found in natural wetlands. These wetlands are generally characterized by the presence of three basic parameters such as soils, hydrology and vegetation. Constructed wetlands can treat and remove the contaminants from the wastewater such as solids, organic compounds and inorganic constituents etc. Although the same wetlands can achieve multiple goals of contaminant removal, but the mechanisms are different.

The use of plants or macrophytes acts as role of bio-filters in the wastewater treatment technologies (Dhote and Dixit 2007). Today, the conventional wastewater treatment process is inconvenient in the form of its operation and maintenance costs. Problems of conventional high-technology wastewater treatment system are in many situations not a suitable solution in developing countries because it is not sustainable to install wastewater treatment facilities which require guaranteed power supply, replaceable spare parts and a skilled labor for operation and maintenance (Konnerup et al. 2009). In developed as well as in developing countries, the goal is elimination of all pollutants like pathogens, nutrients, organic and inorganic chemicals. Whereas the primary treatments aimed for protection of the public health through control of pathogens to prevent transmission of water borne diseases (Kivaisi 2001). For this purpose constructed wastewater systems are suitable since they can be efficient in removal of BOD_5, pathogens and nutrients (Konnerup et al. 2009). Therefore, efforts are made for the use of natural process, which can be used as an eco-friendly and effective source for treatment. Despite the recognition of constructed wetlands technology as an excellent alternative for conventional wastewater treatment systems, not much work has been done to determine its applicability in this study area.

The phytoremediation or root zone bed technology both are the bioremediation processes that uses various types of plants to remove, transfer, stabilize and destroy contaminants in the waste water. It employees natural or genetically modified plants, often together with their associated rhizospheric microorganisms. It stimulates plant growth and removes contaminates from the wastewater. Plants can extract heavy metals, natural aromatic and hydrocarbon compounds and man-made chemicals such as pesticides, herbicides, fungicides and antibiotics including heavy metals. This approach is relatively cheap, efficient and environment friendly with the use of variety of mechanisms. The plants can sequester heavy metals in their cell walls, chelate them in inactive forms using secreted organic compounds or complex them, store in their tissues after transporting them into specialized cells and cell compartments and in vacuoles, safe from the sensitive cell cytoplasm where most metabolic processes occur or make chelating cysteine-rich peptides or small proteins such as phytochelatins and metallothioneins those can be stored safely in vacuoles (Newman et al. 1998., Chavan et al 2012a. and Chavan et al. 2012b).

Constructed wetlands have proved to be an effective low cost treatment system which utilizes the interactions of emergent plants and microorganisms in the removal of wastewater pollutants (Shen and Yin, 1995 and Koottatep et al. 2001). But there is exists a research gap between the literature information and localized need for adaptive aquatic weeds for the phytoremediation. The efforts have been made to fill up this gap with practical efforts in the present work. The investigations are also carried out to determine the potentiality of Pennisetum purpureum plant for reducing the water pollution in the study region. The studies are aimed to investigate the phytotreatabilty potential of Pennisetum purpureum. Considering the abundant growth and availability of Pennisetum purpureum in Solapur region, this plant was selected for the study. This plant is locally adaptive, abundant, fast growing and easily available which made it easy to select for the present investigation. The specific objectives were to design, construct and conduct operational testing of Angular Horizontal Subsurface Flow treatment through constructed wetland over a period of six month with the use of Pennisetum purpureum plant for treatment of sewage. The research work also evaluates the effectiveness of Pennisetum purpureum emergent plant in the treatment of sewage (Oluseyi and Abimbola 2011).

Materials and Methods:

1. Collection of sewage sample: Treatment of sewage through constructed wetland, grab samples were collected from Shelgi nala near Pune naka which is near to National Highway No. 9 in Solapur city. These samples were treated using *Pennisetum purpureum* by Phytoremediation (root zone) technique after their pre-treatment characterization **(Figure 1).**

2. Collection of macrophytes or plants: The strengths of this grass are leafier and making it to prefer as high quality feed for cattle's. Plant having high production potential and it is readily eaten by all grazing animals. It is distributed worldwide, mostly grows or adapted in the tropics. This grass grows in partly shaded areas, generally on clayey soil. In the constructed wetland technology young and healthy plants were collected from vicinity of Solapur city. The selected plant *Pennisetum purpureum* belongs to Kingdom–plantae and Family-Poaceae. The plant produce short, creeping rhizomes 15 to 25 cm long with fine roots at the nodes and culms that are from 2 to 8 m in height, up to 2.5 cm in diameter at the base, and have a solid center. Older culms may branch several times. Leaf blades are 50 to 90 cm long and 1 to 3 cm wide, flat and have a white midrib. Leaves of new, vigorous growth have wide, robust leaves; older culms have finer, narrow leaves. Leaf margins are rough (fine-toothed). The inflorescence is a compact, erect, bristly tawny or purplish spike 8 to 30 cm long and 1.5 to 3 cm wide. Spikelets are arranged around a hairy axis, and fall at maturity. The culms are tufted, erect and 100-400 cm tall. The leaves are linear, sometimes broadly so and 27-75 x 1-3 cm. The smooth to hairy leaf sheaths are 9-16 cm long. Division or Phylum is Magnoliophyta, Class-Monocots, Order-poales, the inflorescence is an erect, bristly, terminal spike, 15-30 cm long and golden yellow-brown. The central stalk is smooth to inconspicuously ridged and densely hairy. The spikelets are in clusters of 1-3, surrounded by involucres of bristles 1.9 cm long and with 2 florets. The lower floret is male or sterile, the upper bisexual. The genus is *Pennisetum,* species is *purpureum*. It is commonly known as Elephant grass or Napier Grass.

This plant is growing on poorly drained clay soils through the gamut of soil types to excessively drain sandy soils. Growth is best on rich, moist, well-drained medium-textured soils. This plant growing in rainfall at excess of 1500 mm per year and temperatures for optimum growth should be from 25 to 40° C (Skerman and Riveros 1990). Grass also grows in light shade but it does not survive under a closed tree canopy. In turn, it was suppress most of grasses, herbs, and tree seedlings. A cold kills the above-ground parts, but the soil also froze and kills the rhizomes (Center for New Crops and Plant Products 2002).

In the reproduction, flowering takes place mainly in the fall and winter (Long and Lakela 1971). Because of asynchrony of male and female flower parts, the plant relies on crosspollination by wind. Elephant grass is an inconsistent seed producer and rarely develops seeds in some habitats. When seeds are produced, they are often of low viability (Holm ey al. 1977).

3. Design and fabrication of constructed wetland: The experiment was performed in the Department of Environmental Science, Solapur University Solapur (M.S) India. In experimental designing and fabrication of constructed wetlands there are three sets of buckets with different sizes and dimensions were used **(Figure 2)**. The vertical buckets as holding tank (Inlet) were used to hold the sewage. The water storing capacity of tank was 30 liters each. The rectangular tub with test plant bed was used as experimental setup for preparing root zone bed. Size of plant bed was 62 cm length and height 35 cm having suitable outlet. Vertical 'T' shape pipe was placed above the tub in an inverted position for equal distribution of sewage which was connected with the rubber pipe at the inlet of holding tank for each set. The length of plastic pipe was 40 cm and the holes for equal distribution of sewage were provided at the distance of 5 cm and equal flow was adjusted manually through them. Clean plastic cans were used for the collection of treated water and for flowing out from the root zone bed through the outlets (Chavan et al 2012a). Inlet bucket, Root zone tub and outlet cans were connected to each other with taps by tubes and plastic water pipes. The constructed wetland or root zone bed set was prepared in three layers which were prepared with pebbles, sand and garden sieved soil (Chavan et al 2012b). The big size pebbles of 20 kg weight making bottom layer of 10 cm height followed by sharp and medium sized sand 15 kg were added to form a middle layer of 10 cm height and small size and sieved soil of 6 kg forming upper layer of 10 cm height were used for construction of bed. The pebbles and sand materials were neatly washed with tap water and then arranged in different layers. Selective healthy, small, young, locally available grass saplings of

Pennisetum purpureum were transplanted and which were arranged in rows and columns and covered by layer of small pebbles, sand and sieved soil (Chavan et al, 2012c).

The rectangular tub with plant bed was provided 10^0 slopes and kept in the slanting position **(Figure 3)**. Flow rates (Inlet and outlet) were adjusted by using bucket and timer. For the present investigation ten different concentrations of sewage samples were used for the treatment. Inlet flow and outlet flow of wastewater were adjusted to maintain Hydraulic Retention Time (HRT) of 4 days (96 hrs). Initially, grass in bed was acclimatized for two weeks with suitable dilutions of each time. As the time passed, the concentrations were increased such as 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% of sewage through plant treatment (Chavan et al 2012d). Test samples before and after treatment were analyzed for selective parameters like pH, EC, TSS, TDS, TS, COD, BOD, NO_3, PO_4 and SO_4 using standard method (APHA, 2005., Trivedy and Goel, 1986). All theses parameters were analyzed in the departmental laboratory on same day of before and after treatment. Finally, pollution reduction efficiency and treatment efficiency of the test plant were calculated.

Figure 1: Sewage Sampling

Figure 2: Design of AHSSCW

Figure 3: Growth of plants used for Sewage treatment

Figure 4: Growth of plants used for Sewage treatment

Results and Discussion:

Concentrations in %	pH		EC (µMohs/Cm)		TSS (mg /L)		TDS (mg /L)		TS (mg /L)		BOD (mg /L)		COD (mg /L)		NO_3 (mg /L)		PO_4 (mg /L)		SO_4 (mg /L)	
	B	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**
10	7.81	7.61	0.96	0.79	117	99	612	457	729	556	4.92	3.36	14.8	8.8	5.4	3.1	3.60	2.31	28	19.16
20	7.94	7.30	1.12	0.89	144	107	678	478	822	585	5.94	3.82	17.4	9.4	6.0	3.2	5.12	3.16	39	26.02
30	7.64	7.20	1.24	0.96	157	109	807	520	964	629	6.84	4.26	19.3	9.9	9.5	4.5	8.66	5.16	53	33.08
40	7.52	7.21	1.36	1.00	160	111	857	521	1017	632	7.27	4.28	21.8	10.1	11.7	5.1	9.86	5.53	66	38.09
50	7.47	7.12	1.47	1.04	169	116	958	544	1127	660	10.92	5.61	24.4	10.4	13.2	5.2	12.41	6.71	78	41.0
60	7.18	7.20	1.59	1.09	239	127	999	547	1238	674	12.31	5.92	27.7	10.8	17.0	6.0	14.66	7.31	84	43.0
70	6.91	7.30	1.71	1.15	258	128	1129	550	1387	678	22.08	8.32	36.9	11.0	19.6	6.2	16.83	7.46	89	44.0
80	6.87	7.26	1.82	1.19	290	130	1251	556	1541	686	37.04	8.73	51.6	11.6	21.4	6.3	17.92	7.56	94	46.0
90	6.84	7.24	1.94	1.33	345	203	1326	581	1671	784	46.02	13.63	92.8	26.1	24.6	6.4	18.81	8.62	97	48.0
100	6.72	7.22	2.56	1.84	394	229	1364	661	1758	890	51.44	18.76	118	39.8	26.8	6.8	21.60	10.18	107	56.0

Table 1: Pennisetum purpureum used in the CW

PARAMETERS	SEWAGE CONCENTRATIONS									
	10%	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
E.C %	17.70	20.53	22.58	26.47	29.25	31.44	32.74	34.61	31.44	28.12
TSS %	15.38	25.69	30.57	30.62	31.36	46.86	50.38	55.17	41.15	41.87
TDS %	25.32	29.49	35.56	39.20	43.21	45.24	51.28	55.55	56.18	51.53
TS %	23.73	28.83	35.68	37.85	41.43	45.55	51.11	55.48	53.08	49.37
BOD %	31.70	35.69	37.71	41.12	48.62	51.90	62.31	76.65	70.49	63.53
COD %	40.54	45.97	48.70	53.66	57.37	61.01	70.18	77.51	71.87	66.27

NO_3 %	42.59	46.66	52.63	56.41	60.60	64.70	68.36	70.56	73.98	74.62
PO_4 %	35.83	38.28	40.41	43.91	45.93	50.13	55.67	57.81	54.17	52.87
SO_4%	31.57	33.28	36.22	41.06	47.43	48.80	50.56	51.06	50.51	47.66

Table 2: Percentage wise reduction in various parameters using *Pennisetum purpureum*

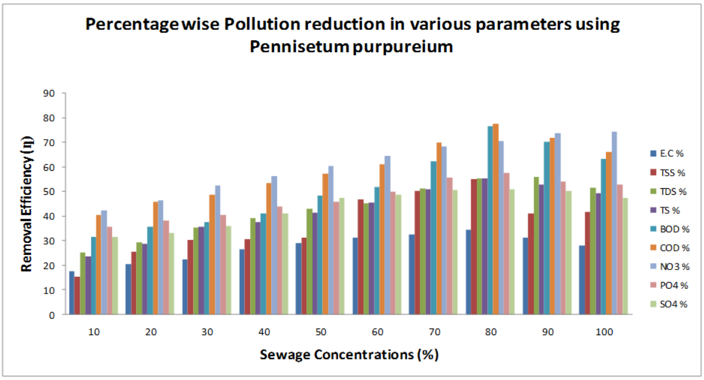

Figure 5: Percentage wise Pollution reduction efficiency in various parameters using Pennisetum purpureum.

The pollution reduction efficiency through Angular Horizontal Subsurface Constructed Wetland unit was examined by wastewater quality parameters such as pH, EC,TSS,TDS,TS,BOD_5,COD, NO_3, PO_4 and SO_4 respectively, in the inlet and outlet of wastewater at HRT of 4 (96 hrs) days. The treated and untreated of sewage samples with different dilutions viz. 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% were tested. The results in the set of *Pennisetum purpureium* reveal that the maximum pollution reduction efficiency was observed in 80% and 90% sewage concentrations. The characteristics of the wastewater studied from inflow and outflow of constructed wetland are presented in the **Table 1.** The pollution reduction efficiencies of constructed wetland are shown in the **Table 2 Figure 5.**

The color and odor were removed and hence treated samples were observed clear and odorless. The average wastewater pH values obtained in the plant bed for the inlet and outlet of Angular- HSSF- CW were 6.72 to 7.22. This increase of pH value may be due to formation of some acidic components in the bioremediation process. In our earlier study, a similar trend in pH value was observed at same rate of HRT (Chavan et al 2012c). Other authors also have reported the decreasing trend in pH in the lake water by using various aquatic macrophytes (Dhote 2009 and Choudhary 2011a) and also noticed the average color removal from pulp and paper mill wastewater through HSSF-CW. It was by 97% and the change in pH at decreasing mode while some of them reported the change in pH in decreasing mode in his field scale study of domestic wastewater using *Phragmites karka* (Choudhary 2011b).

The maximum EC reduced was by 34.61%, TSS was reduced by 55.17%, TDS was reduced by 56.18%, TS was reduced by 55.48%, BOD was reduced by 76.65%, and COD was reduced by 77.51%. The COD removal is believed to occur rapidly through settling and entrapment of particulate organic matter in the void spaces of the substrate (Vipat 2008). The substrate is the main supporting material for plants and microbial growth. Fine gravel promotes higher growth of plants and therefore increases the quantity of contaminant removal (Garcia, 2005). The microorganisms attached to the root zone of the plants play a very important role in the degradation of organic matter. They play crucial role in the conversion of organic carbon to carbon dioxide. In this process, the oxygen is supplied by the roots of the plants. Soluble organic matter may also be removed by number of separation processes including absorption and adsorption. The degree of sorption and its rate are dependent on the characteristics of both organic and the solid surface (Vymazal 1998). The maximum NO_3 was reduced by 74.62%, PO_4 was reduced by 57.81% and SO_4 was reduced by 51.06% respectively in present study. These pollutants were reduced due to reed bed of *Pennisetum purpureium*. In addition to this, phyto-volatilization is also an important phenomenon for the removal of pollutants from the constructed wetland.

Some wetland plants also take up pollutants directly through the root transport system and transfer them to the atmosphere via their transpiration system (EPA, 2000, Hong et al, 2001 and Ma X et al 2003). These pollutants were reduced in the root zone bed due to plant uptake, trickling process and biofilm of aerobic and anaerobic microorganisms. The efficiency of each parameter indicates that the use of *Pennisetum purpureium* is helpful for better treatment of sewage at almost study of all sewage concentrations. As a result, the treatment efficiency is higher at 80% concentration of sewage, in experimental test set of *Pennisetum purpureium* which has also seems in plants through huge growth and flowering in the plant **(Figure 4)**.

Conclusion:

Angular Horizontal Subsurface Flow Constructed wetland through phytoremediation is an effective green technology for the treatment of sewage. The proper selection of locally adaptive aquatic plant is more trust worthy and insured technology for better treatment of sewage in local environment. The efficiency of each parameter in the set indicated that the use of *Pennisetum purpureium* is helpful for better treatment of sewage at almost all concentrations. The maximum pollution reduction obtained up to 80% concentration. It is concluded that *Pennisetum purpureium* is capable and suitable plant for the treatment of sewage. This plant is a mostly adaptive in western region of India. It has considerable capacity of pollution reduction and generating treated water which is useful for some common uses like gardening, washing, irrigation and general uses like toilet flushing, cooling, floor washing and cleaning applications in both, households and industries.

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