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Performance of Floating Constructed Wetland Reactors with Cyperus esculentus L. macrophyte at different Concentrations of Sewage.

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ABSTRACT

The wastewater is contaminated with many impurities, referred as gray water due to mixing of fecal waste therefore it is necessary to treat the wastewater. The present investigation was aimed to develop a Floating Constructed Wetland Reactor system using Cyperus esculentus L.macrophyte for in situ on-site domestic sewage treatment. The sewage in its different concentrations was treated in batch systems designed with 120 saplings of Cyperus esculentus L. macrophyte planed in 5 rows and 6 columns with 4 saplings at each point planed in crates with inter bed of thermocol sheets, stone crushed aggregates. The results in terms of reduction in terms of TSS, TDS, TS, BOD, COD and nutrient contents indicate that the design fabricated is perfectly workable and capable to work at any of the concentrations and reduce the pollution load upto 80% within 35 days at 20% and 40% concentrations.

Keywords:-Phytoremediation, Cyperus esculentus L., macrophytes, domestic, municipal sewage, wastewater treatment; floating constructed wetland, pollution reduction, contaminant removal efficiency.

1.INTRODUCTION

Indian citizens and inhabitants are suffering from water scarcity and water pollution problems. About 67% of city sewage from Indian cities is left untreated into the water bodies and pollutes the water sources which otherwise can meet the water needs including drinking water. Gray water makes the problem worst. Many of the conventional Effluent Treatment Plants do not serve the purpose of treatment due to technical faults and lack of proper planning. The pollution caused by discharge of untreated sewage affects the lives of local people causing several health problems. Indian government is taking a lot of efforts to cure the problem, but lacks in technical difficulties, incorrect planning, variable quantities of sewage loads, lack of sustainability, lack of sufficient electrical supply, unavailability of land to set up treatment units at decentralized location and financial insufficiency for managing treatment units.

To meet these challenges, there is an urgent need to develop a suitable solution which will be sustainable, ecofriendly, cost effective, technically simple, based on locally available resources, suitable for in-stream or in situ treatment of sewage, non-electricity consuming and operationally simple and easy to implement in a decentralized manner as per needs in different parts of city without acquiring the additional land.

In the present investigation, efforts have been made to provide a solution to the problem by developing alternative technology that meets the above requirements. The floating constructed wetland system reactor was designed using commonly and locally available materials and the macrophytic bed of Cyperus esculentus L. as treatment plant. The sewage treatment was facilitated with this plant using root-zone method and tested for its field applicability under batch mode of operation. The advanced model of phytoremediation technology for in-stream application for the treatment of domestic and municipal sewage has been successfully developed and tested for its applicability at different concentrations of sewage as the concentration is variable that affects the process efficacy in the treatment process.

2.METHODOLOGY

A.Experimental Design and Layout:

Floating constructed wetland reactor models were designed and developed using plastic crates with the beds consisting of thermocol sheets, stone crushed aggregates and river sand layers one after another in which the locally available

plant of Cyperus esculentus L. was planted, acclimatized for sewage for a month and the used for treatment studies at various concentrations of sewage in a batch mode of operation. The holding tank made up of iron sheet was used as batch effluent holder in which the floating constructed wetland reactor system was floated.

The design prepared and layout of macrophyte planting is as shown in Fig.1 and 2. The experiments were planned to assess the suitability of newly designed floating constructed wetland reactor and pollution reduction efficacy of Cyperus esculentus L.macrophyte at different concentrations of sewage under the same operational conditions in same surrounding environmental conditions in terms of physic-chemical characteristics and compared with a set of control with dilution water operated simultaneously without sewage.

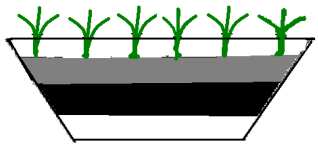


Fig. 1: Conceptual Design of Floating Constructed Wetland Reactor

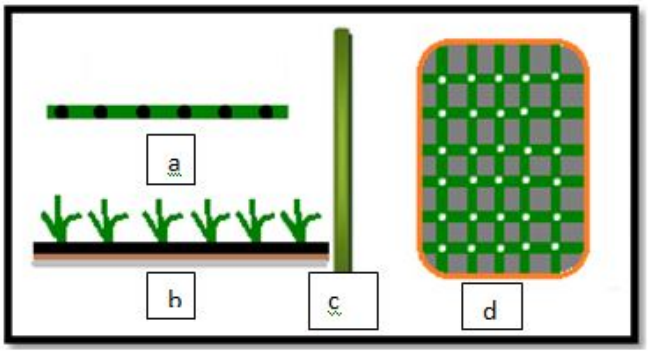
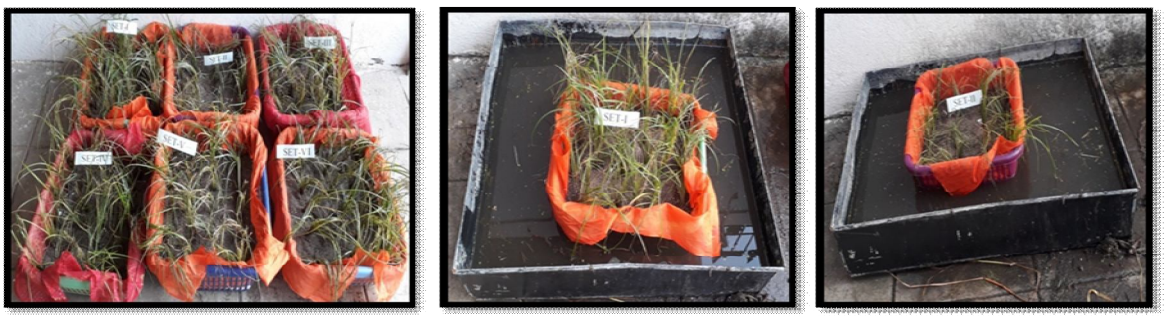


Fig. 2: Design views of planting points of Cyperus esculentus L. in floater bed of constructed wetland; a-points of planting, b-planting of saplings, c-symbolic column for planting and d- basal view from top indicating planting points.

B. **Macrophyte selection and planting**

The locally available macrophyte plant used in experiment was identified as Cyperous esculenta. Macrophyte Cyperus esculentus L. is also known as Tiger nut or tigernut an edible perennial grass-like plant native to the Old World. It is to produces sweet nut-like tubers known as "earth almonds" [6]. Tiger nut is also known by various other names as chufa (in Spanish), earth nut, yellow nut sedge, groundnut, rush nut, and edible galingale [14] and Nagarmotha in Marathi local language. The fully and almost uniformly grown saplings of Cyperus esculentus L. were collected from local water logged agricultural fields located in the vicinity of Itkhada-Kanchanwadi area of Aurangabad. The shoot and root of seedlings were washed and allowed to air dry for 15 minutes prior to planting. Each seedling were tagged after placing the cloth over the thermocol sheets at the bottom for each crate and then transplanted in suitable (05) rows and (06) columns at 30 equidistance points with the clump of 4 plants per junction points and adjacent lines amounting to 120 plants supported with crushed aggregates followed by sand layer over it as the inert beds of each set (Fig.3 A). The system developed experimental set ups of constructed wetland reactor systems with Cyperus Cyperus esculentus L. and floated in shallow basin type rectangular sewage holding tank are shown in Fig.3 B and C.



(A) (B) (C)

Fig. 3: A. Experimental set ups with Cyperus esculentus L.planted in floating constructed wetland reactor systems. B. Test Reactor set up. C. Floating view.

C.Experimental Procedures

The floating constructed wetland reactor setups with Cyperus esculentus L.were floated for batch studies in the holding tank containing municipal sewage in different concentrations along with the control using tap water were arranged simultaneously after characterizing the holding contents for initial characterization in terms of pollution parameters. The characteristic studied included physiochemical parameters like pH, EC, TSS, TDS, TS, BOD, COD, Nitrates, phosphates, sulphates and chlorides using standard methods [1]. The adequate samples were taken at the interval of 7 days and anlysed for intermediate stage of treatment and the experiment was continued for 35 days for final analysis. The results obtained before phytoremediation were noted as initial values while the results obtained after phytoremediation are indicated by final values for the data analysis.

3.Result

In order to verify the practicality and remediation effect of such a phytoremediation technique in field environments under batch mode, newly designed floating beds cultured with Cyperus esculentus L.were used to treat sewage at different concentrations. The pre-treatment analysis of sewage indicated that the sewage was highly polluted in terms of solids, BOD, COD and nutrient contents (Table 1). The results obtained after the phytoremediation treatment with newly fabricated floating constructed wetland indicated that pH was improved from alkaline to slight alkaline level, EC was decreased and the solid contents were considerably reduced, both in terms of Total Suspended Solids and Total Dissolved Solids thereby contributed the reduction in Total Solids ultimately (Table 2).

Table 1: Initial Characteristics of sewage in the treatment with different concentrations before the treatment with Cyperus esculentus L.

Pre-treatment Details of all Experimental Set Ups	**Treatment Set with initial Characteristics of sewage at different concentrations**					
Parameters	**Reference set (T_0) with 0% Conc. of sewage (Tap water)**	**Treatment (T_1) with 20% Conc. of sewage**	**Treatment (T_2) with 40% Conc. of sewage**	**Treatment (T_3) with 60% Conc. of sewage**	**Treatment (T_4) with 80% Conc. of sewage**	**Treatment (T_5) with 100% Conc. of sewage**
pH	7.1	7.3	7.3	7.4	7.4	7.5
EC (µS/cm)	796	826	834	843	852	968
TSS (mg/L)	12	108	214	322	425	532
TDS (mg/L)	16	73	146	220	291	364
TS (mg/L)	28	181	360	542	716	896
BOD (mg/L)	1.2	36	68.8	104	138.2	172
COD (mg/L)	12.3	77	155.6	227.3	303.4	378
NO_3(mg/L)	0.11	0.043	0.087	0.130	0.175	0.22
PO_4(mg/L)	0.01	1.26	2.46	3.78	5.04	6.13
SO_4(mg/L)	4.4	15.44	31.06	47.04	61.95	77.4
Cl (mg/L)	1.0	37.2	74.4	111.6	148.8	186

Table 2: Final Characteristics of sewage in the treatment with different concentrations before the treatment with Cyperus esculentus L..

Pre-treatment Details of all Experimental Set Ups	**Treatment Set with final Characteristics of sewage at different concentrations**					
Parameters	**Reference set (T_0) with 0% Conc. of sewage (Tap water)**	**Treatment (T_1) with 20% Conc. of sewage**	**Treatment (T_2) with 40% Conc. of sewage**	**Treatment (T_3) with 60% Conc. of sewage**	**Treatment (T_4) with 80% Conc. of sewage**	**Treatment (T_5) with 100% Conc. of sewage**
pH	7.1	7.1	7.1	7.2	7.1	7.1
EC (µS/cm)	753	779	796	766	796	963
TSS (mg/L)	9	23	52	96	200	281

TDS (mg/L)	12	15	30	66	85	203
TS (mg/L)	21	38	82	162	285	484
BOD (mg/L)	1.0	26.0	14.6	40.5	55.2	77.0
COD (mg/L)	7.0	14.5	34.5	92.6	133	207
NO_3(mg/L)	0.05	0.008	0.027	0.053	0.079	0.130
PO_4(mg/L)	0.005	0.252	0.74	1.60	2.00	3.63
SO_4(mg/L)	1.2	9.0	9.30	13.22	28.5	46.44
Cl (mg/L)	0.8	14.9	33.6	64.7	111.7	152.5

The treatment efficiency in terms of different parameters after the treatment of 35 days reflected that the technique is capable to reduce the pollution at any of the sewage concentrations. The reduction in terms of various physic-chemical parameters was highest in the sets of 20% and 40% sewage concentration, which is attributed to less pollution stress on the macrophyte growth and further the reduction rate was slightly reduced for higher concentrations of sewage. There was no mortality of Cyperus esculentus L noticed during the entire treatment process indicating the high tolerance of this macrophyte for sewage pollution. The analyses of results obtained in terms of treatment efficiency in each set are summarized in Fig. 3. There was considerable reduction in BOD, COD and nutrient contents indicating that this design with Cyperus esculentus Lis capable to control eutrophication with its in-situ or in-stream application and is suitable for ecological restoration of polluted water bodies.

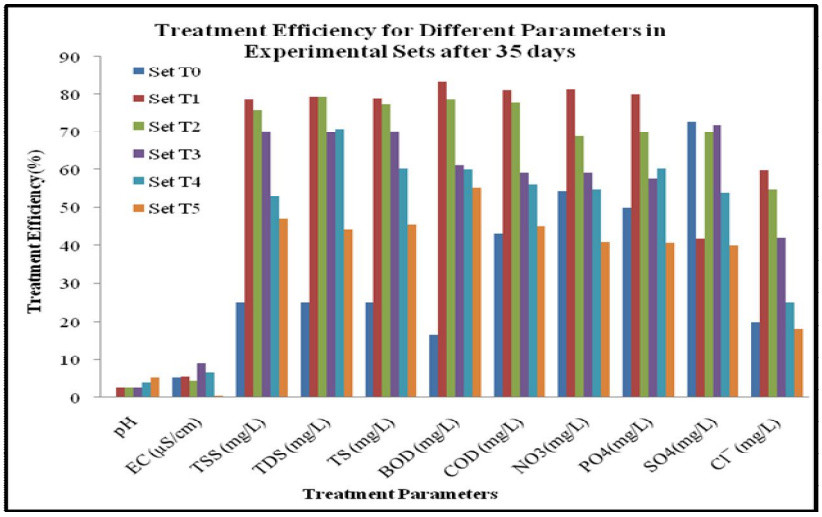


Fig. 4: Treatment Efficiency in Different Experimental Sets after 35 days of sewage treatment at different concentrations using Cyperus esculentus L in floating constructed wetland reactor systems.

4.Discussion

A.Justification for Design and macrophyte selection:

Phytoremediation reactor set with floating constructed wetland reactor designed and constructed with PVC plastic crate reactors were capable to work rationally and thus provided a well working environment for macrophyte Cyperus esculenta L. planted to treat the sewage was perfectly workable. The practical use of designed system to study the remediation effect of phytoremediation technique in field environments using floating beds cultured with Cyperus esculenta were successful.

Determination of its tolerance to high concentration of sewage and withstanding potential were subject matter of present study which indicated that Cyperus esculentus L.is capable to tolerate higher concentrations of sewage and is capable to reduce the pollution load at all concentrations of sewage in terms of different sewage parameters. Therefore, the selection of this plant for the sewage treatment in the form of floating constructed wetland system is fully justified.

B.Pollution reduction efficiencies:

Aquatic pollution is a significant problem globally, primarily due to the discharge of large amounts of untreated or partially treated sewage, industrial effluents or wastewaters derived from various sources [2], [3], [4] & [20]. The traditional physical and chemical treatment methods for pollution remediation are generally cost intensive, non-sustainable and also in some times having the potential to induce secondary pollution [13]. In recent years,

phytoremediation has been demonstrated as an effective method to cure the water pollution problems by reducing the content of organic matter, nutrients and heavy metals in polluted waters with sustainable process and hence this technique is commonly regarded as a green technology [9], [10] & [20]. Presently employed design and method of phytoremediation is a novel bioremediation technology in which plants are utilized to remove or degrade complex environmental pollutants as done by the others [7], [13] & [17] but in an innovative way suitable for in-stream application using native macrophyte Cyperus esculentus L.

Floating wetlands have been mainly used for water quality improvement their usage has been documented for the treatment of airport run-off sewage [15], acid mine drainage waters [16], piggery effluent [12] and poultry processing waters [18]. Because of their resilience, floating treatment wetlands are little affected by fluctuations of the water level which makes the system highly applicable in situations where the water level can significantly change causing stress to plants rooted in sediments. Smith and Kalin [16] as well as Hogg and Wein [11] listed some of the advantages of floating wetlands which are applicable to the present work.

5.Conclusion

Floating constructed wetland reactor systems developed with Cyperus esculentus L are convenient and suitable in the treatment of domestic effluent and combined sewer overflows at any of the sewage concentrations. The bench scale experiments studied are successful to meet the current needs. This technique is also cost effective, ecofriendly and is easily acceptable.

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