RESEARCH ARTICLE

TREATMENT OF TEXTILE WASTEWATER USING VERTICAL FLOW CONSTRUCTED WETLAND WITH PLANTED ALTERNANTHERA SESSILIS AND ZEA MAYS

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Abstract

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Constructed wetland is a promising approach to remediate the industrial effluent. The detoxification of industrial effluent in a constructed wetland system may be enhanced by macrophytes with beneficial bacteria that are able to degrade contaminants present in textile effluent. Vertical Flow Constructed wetland (VFCW) systems have been used as a cost effective alternative to conventional methods of wastewater treatment. The system has engineered and monitored was set-up with limited resources in terms of manpower and materials, and also easy to maintain and to manage. It is observed that these adsorbents are active in removal of dye and harmful pathogenic bacteria. From this study, the promising attributes of Alternanthera sessilis and Zea mays includes its tolerance to dye and dye absorption along with good root development, low maintenance and ready availability in contaminated regions. The significant decrease in color, turbidity, temperature, pH, Electrical Conductivity (EC), Total Solid (TS), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Alkalinity, Chloride, Hardness, Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) are taken as indicators of effectiveness of phytoremediation.

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Introduction:-

The textile industrial sector is one of the most important and largest industrial sectors in India. Among various industries, textile industry ranks first in usage of dyes for adding colors to the fibers such as cotton; animal fibers such as wool and silk; and a wide range of synthetic materials such as nylon, polyester, and acrylics (Sachin et al., 2010). Textile industries consume a large volume of water and chemicals for making various textile goods and as a result, large volume of effluent discharged on land with or without treatments. Many approaches have been taken to reduce water consumption by recycling the effluent comes from the textile industries. The raw materials particularly dyes used in the textile industry determine the volume of water required for production as well as wastewater generated (Irina-Isabella Savin and Romen Butnaru, 2008). The wastewater generated from the various processing units are desizing, scouring, bleaching, mercerizing, dyeing, printing, and packing required huge amount of organic chemicals of a complex structure (Bisschops and Spanjers, 2003). The main parameters identified in the textile industry are pH, electrical conductivity (EC), chloride, sulphate, phenols, total dissolved solids (TDS), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) and other solution substances. Therefore, wastewaters from the textile industry have to be treated before being discharged to the environment (Vera et al., 2005).

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Improper disposal of waste causes direct contamination of ground water and surface water both. This wastewater has serious negative impact not only on land area but also on the aquatic ecological system. Due to usage of dyes and chemicals textile effluents are dark in colour, thus increasing the turbidity of the receiving water body. Metal pollution has harmful effect on biological systems and does not undergo biodegradation. Ions of Heavy metals (Cd and Cr), which are frequently present in the wastewaters can cause renal dysfunction as well as chronicle alterations in nervous system and gastrointestinal tract (Santosh Kumar Prajapatai et al., 2012).

For the removal of textile dyes from the environment, the selection of an appropriate plant with certain desirable characteristics is one of the most important preliminary steps in phytoremediation research. Though several plants have shown the ability to remediate contaminated soils; non edible plants are generally selected to be applied onto dye contaminated sites. Most of the studies on phytoremdiation of textile dyes demonstrate their removal through either degradation of the dye or the adsorption and/or accumulation of the dye. All of these technologies involve relatively high capital expenditure and manpower as well as long-term operating costs. Therefore, efforts are underway to develop more cost-effective approaches to treat large volumes of contaminated natural resources such as soil, ground water, and wetlands (Prithabai, 2008). Currently, phytoremediation is used for treating many classes of contaminants including petroleum hydrocarbons, chlorinated solvents, pesticides, explosives, heavy metals and radionuclides, and landfill leachates. In India, terrestrial plants like Helianthus annuus, Phragmiteskarka, Daturainnoxia, Brassica juncea, Alternanthera sessilis, and Zea mays have been used to treat different metals contaminating effluent soil and sludge from various types of industries (Prithabai 2008). In view of the foregoing literature, it is programmed to make an attempt to study the nature of phytoremediation technique in the soils of study area by using the terrestrial plant.

Constructed wetlands (CWs) have traditionally been used to treat municipal wastewaters but during last two decades the application of this technology has significantly expanded to treatment of various industrial effluents. The early constructed wetlands applied to industrial wastewaters included those for wastewaters from petrochemical, abattoir, meat processing, dairy and pulp and paper industries. During the 1990s constructed wetlands were also used to treat effluents from textile and wine industries or water from recirculating fish and shrimp aquacultures. The most recent applications include those for brewery or tannery wastewaters as well as olive mills effluents (Wu et al., 2015).

Wastewater treatment in wetland systems is the result of physical, chemical and biological processes in the soil and water environment with the usage of wetland plants (macrophytes). Unlike conventional biological reactors, wetland systems do not produce secondary sludge. They are also characterized by resistance to uneven and variable flow of sewage. The operational costs of these facilities are very low mainly because of minor energy supply requirements. For the treatment of industrial wastewaters both subsurface and surface flow CWs have been used. Within subsurface flow constructed wetlands both horizontal and vertical flow systems have been designed. Also, the use of various hybrid constructed wetlands for industrial effluent treatment has been reported recently (Jawecki et al., 2017; Skrzypiec et al., 2017; Stefanakis et al., 2014; Vymazal, 2014). In this paper the applications of constructed wetlands for treating various industrial effluents are summarized. The purpose of the paper is to review the characteristics of industrial wastewater and possible operational problems occurring in constructed wetlands treating analyzed effluents.

Materials And Methods:-
The three plastic container bed were length 44 cm, width 34 cm and 14.2 cm height, this container filled with gravel (5 cm), sand (5 cm) followed by filter media used for plants. Approximately 10 liters of raw effluent from factories was brought to the laboratory in plastic containers and the experiments were set up in plastic craits. The two plants used for the study was an emergent wetland plant Alternanthera. Sessilis and Zea mays as shown in Figure 1 a and b. The experimental plants were initially subject to stabilization in tanks containing well water for one month for acclimatization. The base of the tank was filled with gravel and sand up to three inches in height.
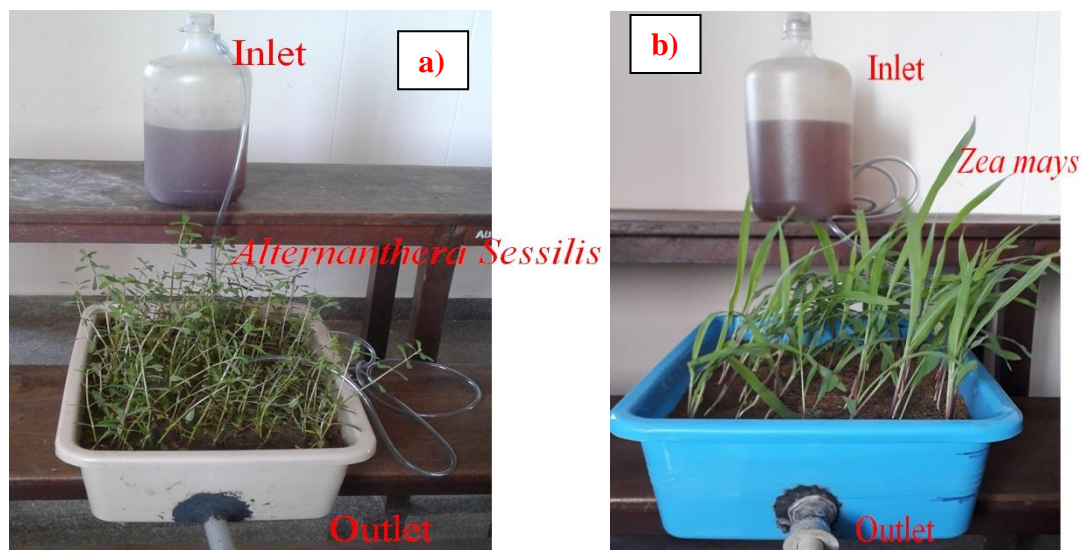
Figure 1:- A Schematic diagram of planted with a) Alternanthera sessilis b) Zea mays

Ten liters of the respective dilutions of the effluent were prepared and then transferred to plastic tubs. For each experimental set, one control was maintained with ten liters of and ten liters of raw effluent. For treatments, the plants which maintained in the stock tanks were collected, cleaned and introduced in the experimental tanks. Approximately 250g each experimental plant used for the study, each occupying half of tanks. Triplicate of each experimental setup was maintained 500ml each of water and effluent from the respectively. The wastewater was treated at different hydraulic retention time of 24 hour. The water samples were collected in a sterile 500 ml plastic bottle and stored at 4º C and physico-chemical parameters like pH, Electrical Conductivity (E.C), Turbidity, Total Dissolved Solids, (TDS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD$_5$) and Phosphate (PO$_4$) were analyzed as described by APHA (2005).

Collection of samples:
The wastewater samples were collected at the end of unit operation in dying unit at Karaikudi which contains the wastewater of process as dyeing in acid washed cans.

Analysis of samples:
The effluent samples which contain several metals and organic compounds were analyzed to measure their Temperature, pH, electrical conductivity, Total solids, Total dissolved solids, Total suspend solids, dissolved oxygen, dissolved oxygen and chemical oxygen demand (COD), Biological Oxygen Demand (BOD) using standard methods APHA (2005).

Results:-
The characteristics of textile effluent from the collected from the Karaikudi Textile effluent treatment plant in Equation tank are presented in table 1.

Table 1:- Physico-chemical characterization of textile effluents.

S. No	Physico-chemical parameter	Textile effluent	BIS Standard
1	Temperature (ºC)	29.5	
2	pH	10.39	7 to 8.5
3	EC (µS/cm)	6.09	-
4	TS (mg/l)	8000	-
5	TDS (mg/l)	5000	500
6	TSS (mg/l)	3000	-
7	Total Alkalinity (mg/l)	250	-
8	Chloride (mg/l)	660	200

9	Hardness (mg/l)	480	300
10	COD (mg/l)	1450	250
11	BOD (mg/l)	650	30

Temperature:

The temperature of textile effluent was observed to be 29.5 $^\circ$ C. The effluent from the planted A. sessilis and Zea mays had as mean 27.5 and 27 $^\circ$ C temperature, unplanted bed had a mean temperature of 28 $^\circ$ C during different retention time 24 hour respectively.
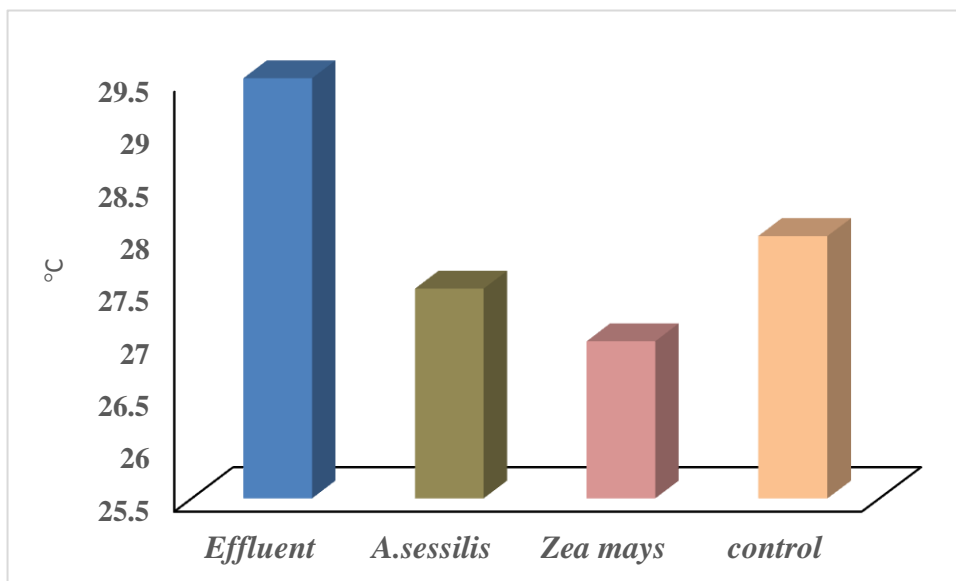

Figure 2:- Performance of phytoremediation with planted and controlin.

Temperature pH:

The pH of textile effluent was 10.39; the alkaline nature shall be due to colours, dyes, chemicals etc. The effluent from the planted A. sessilis and Zea mays had a mean pH of 8.80, and 8.12, unplanted bed had a mean pH of 9.04 during different retention time of 24 hours respectively.
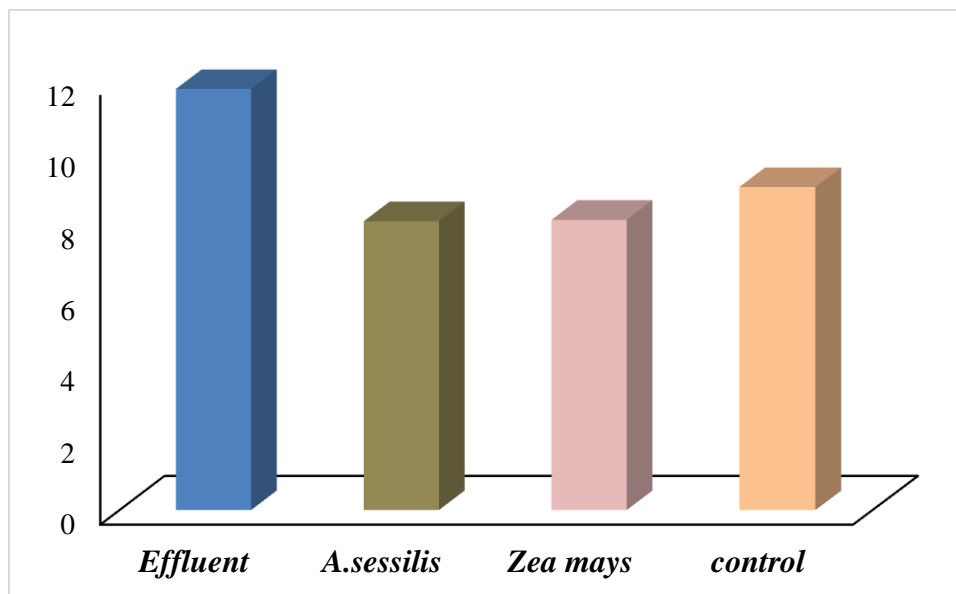

Figure 3:- Performance of phytoremediation with planted and control in pH.

Effect of Electrical Conductivity:
The Electrical Conductivity (E.C) of textile effluent was observed to be 6.09µS/cm. The effluent from the planted A. sessilis and Zea mays had as mean E.C. of 2.89 and 3.06 µS/cmunplanted bed had a mean E.C. of 5.32 µS/cm. during different retention time 24 hours respectively.
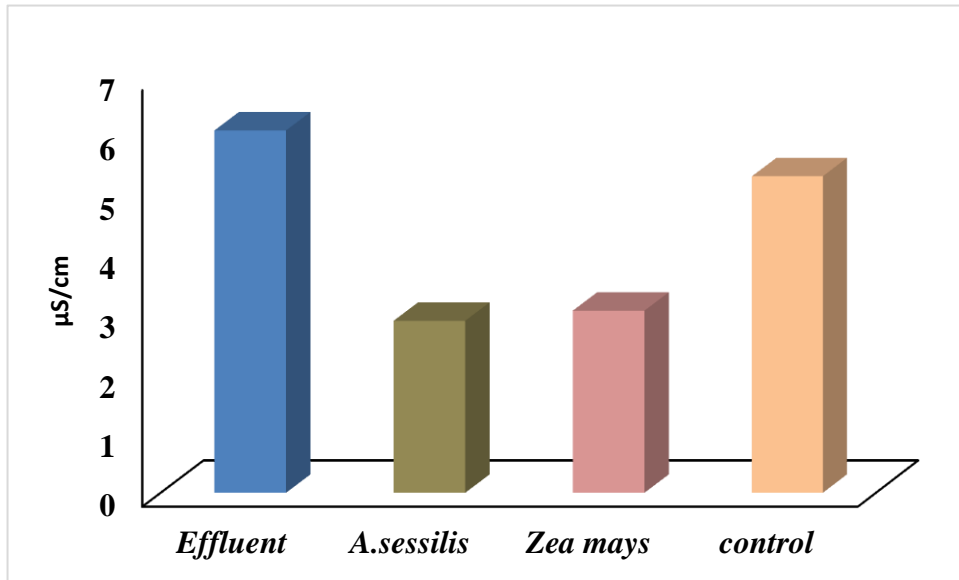

Figure 4:- Performance of phytoremediation with planted and control in Electrical Conductivity.

Effect of Total Solids
Total Solids of textile effluent was observed to be 8000 mg/l. The A. Sessilis and Zea mays planted had mean TS of 2500 and 2800 mg/l, unplanted bed had mean TS of 5000 mg/l during 24 Hydrualic retention time (HRT) hour respectively.
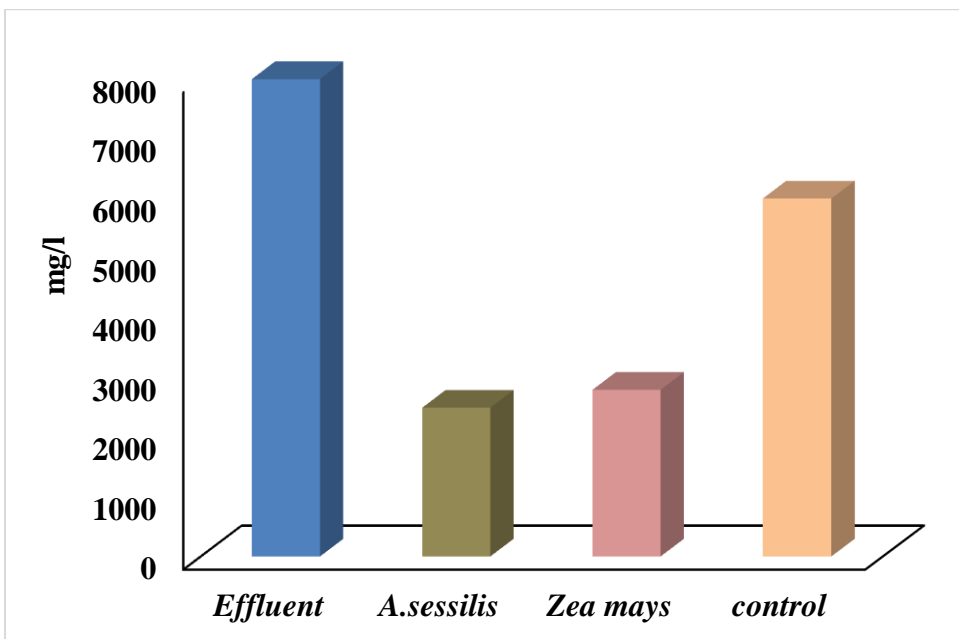

Figure 5:- Performance of phytoremediation with planted and control in Total Solids Effect of Total Dissolved Solids.

TDS was measured in Filtration and Evaporation (103°C) method. The total dissolved solid removal byA. Sessilis and Zea mayswas good in almost all concentration as shown in figure 4.The Total Dissolved Solids (TDS) of textile effluent was observed to be 5000 mg/l. The effluent from the planted A. sessilis and Zea mays had a mean TDS of 2000 and 2100 mg/l, unplanted bed had a mean TDS of 3200 mg/l during Hydrualic retention time (HRT) 24 hour respectively.
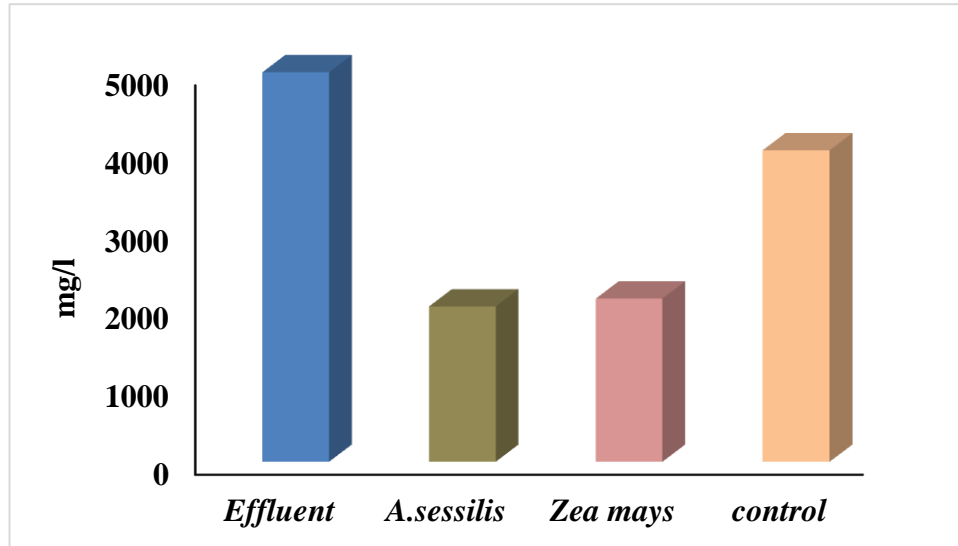

Figure 6:- Performance of phytoremediation with planted and control in Total Dissolved Solids Effect of Total Suspended Solids.

The Total suspended solids of textile effluent were observed to be 3000 mg/l. The effluent from the planted A. sessilis and Zea mays had a mean TSS of 500 and 700 mg/l, unplanted bed had mean TSS of 500 mg/l during Hydrualic retention time (HRT) 24 hour respectively.
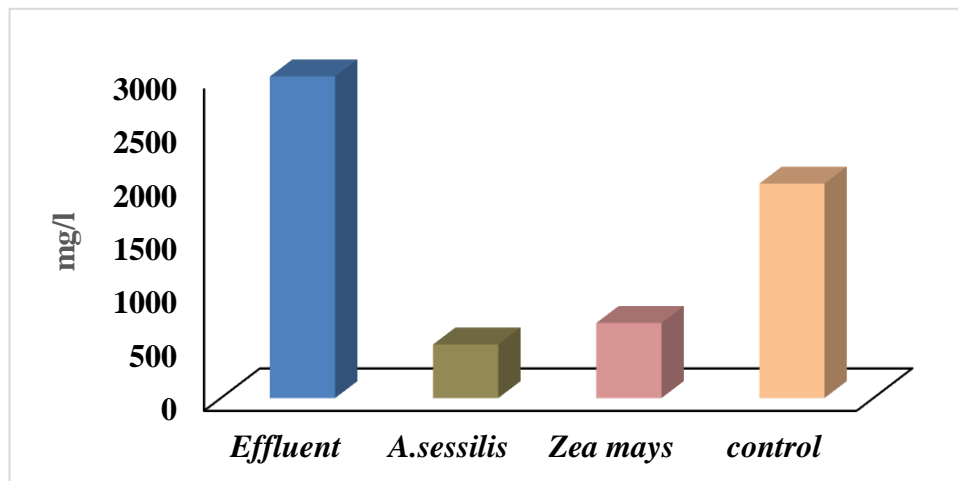

Figure 7:- Performance of phytoremediation with planted and control in TSS.

Effect of Chloride:
The Chloride of textile effluent was observed to be 660 mg/l. The effluent from the planted A. sessilis and Zea mays had a mean chloride of 260and 300 mg/l and unplanted bed had a mean chloride of 450 mg/l during Hydrualic retention time (HRT) 24 hour respectively.
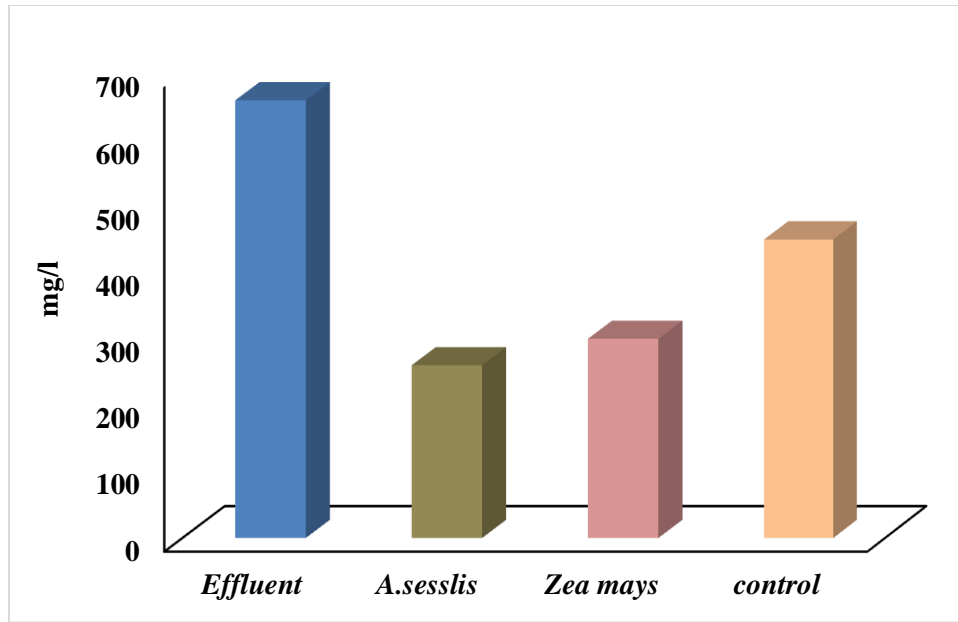
Figure 8:- Performance of phytoremediation with planted and control in Chloride.

Effect of Total Hardness:
The Hardness of textile effluent was observed to be 480 mg/l. The effluent from the planted A. sessilis and Zea mays had a mean hardness 200 and 290 mg/l, unplanted bed had a mean chloride of 380 mg/l during Hydrualic retention time (HRT) 24 hour as respectively.
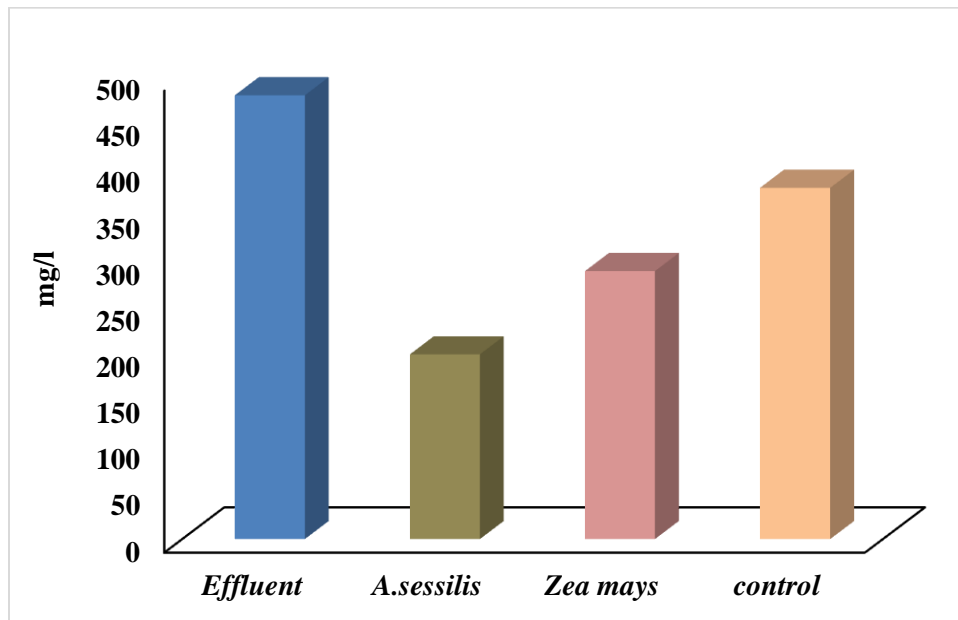

Figure 9:- Performance of phytoremediation with planted and control in Hardness.

Effect of Total Alkalinity:
The Total Alkalinity of textile effluent was observed to be 250 mg/l. The effluent from the absorbent A. sessilis and Zea mays had a mean Total Alkalinity of 80 and 120 mg/l, control had a mean Total Alkalinity of 380 mg/l during Hydrualic retention time (HRT) 24 hour respectively.
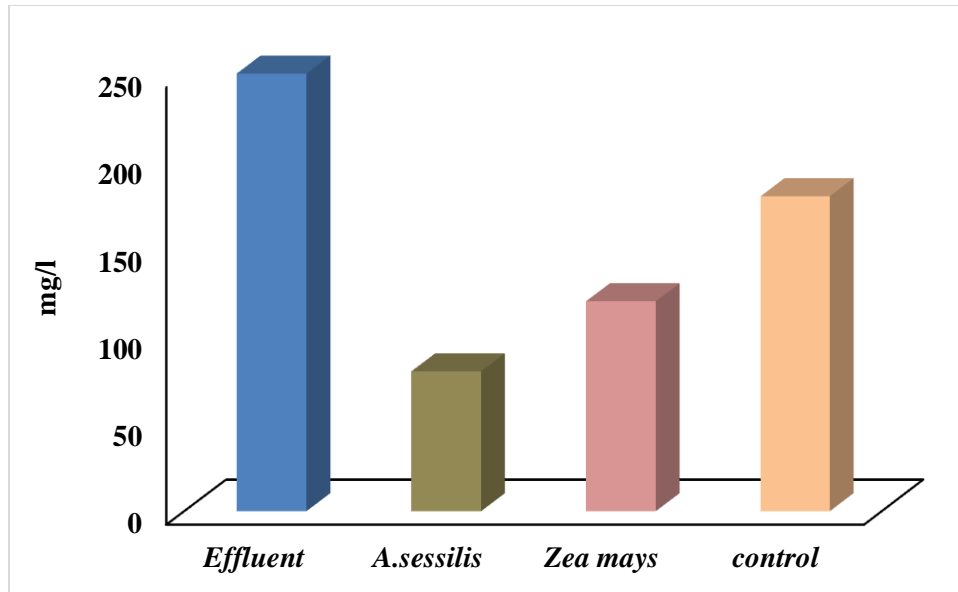
Figure 10:- Performance of phytoremediation with planted and control in Total Alkalinity.

Effect of Biological Oxygen Demand:
The Biological Oxygen Demand (BOD_5) of textile effluent was observed to be 320 mg/l. The effluent from the planted A. sessilis and Zea mays had a mean BOD_5 of 60 and 120 mg/l, unplanted bed had a mean BOD_5 of 260 mg/l during different retention time 24 hours respectively.

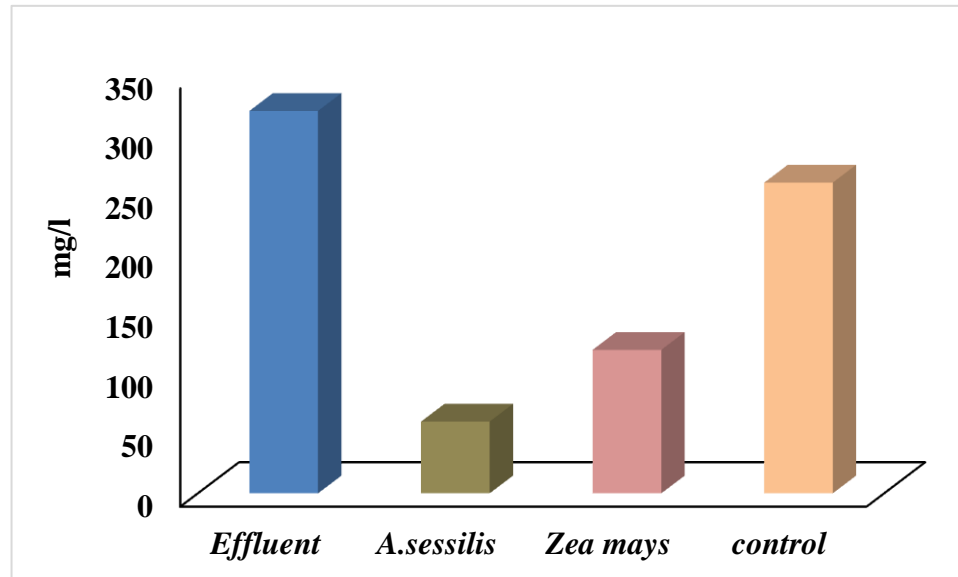**Figure 11:-** Performance of phytoremediation with planted and control in BOD_5 Effect of Chemical Oxygen Demand.

The Chemical Oxygen Demand (COD) of textile effluent was observed to be 1640 mg/l. The effluent from the planted A. sessilis and Zea mays had as mean COD of 450and 600 mg/l, unplanted bed had a mean COD of 1200 mg/l during Hydrualic retention time (HRT) 24 hour respectively.
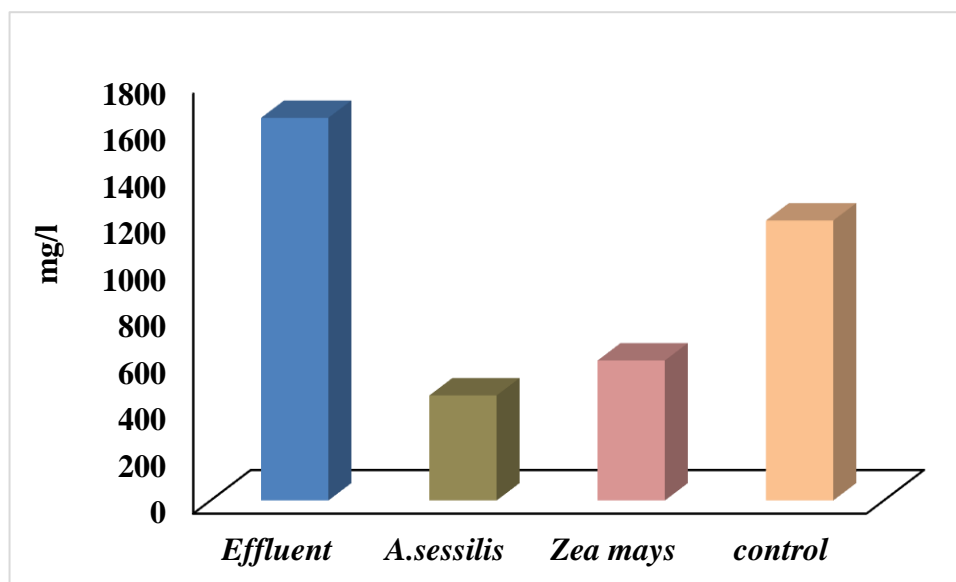
Figure 12:- Performance of phytoremediation with planted and control in COD.

Table 2:- The removal efficiencies of textile effluent treated by VFCWs with planted Alternanthera sessilis and Zea mays.

Parameter	A. sessilis	Zea mays	control
pH	8	7.5	7
EC	52	50	12
TS	69	65	37
TDS	60	58	30
TSS	83	76	40
Chloride	60	54	31
Total Hardness	53	39	20
Total Alkalinity	68	52	25
BOD	81	62	19
COD	72	63	27

The removal efficiencies of textile effluent treated by vertical flow constructed wet lands with the plant A. sessilis. This plant is treated with the following parameters. In pH range is 8 and the Electrical Conductivity (EC) of A. Sessilis is 52. The Total Solid (TS) range of A. Sessilis is 69.Total Dissolved solid (TDS) and Total Suspended Solid (TSS) parameter also tested with this plant. They are 60 and 83 respectively. In chloride test of A. Sessilis is 60. The Total Hardness and Total Alkalinity of A. Sessilis are 53 and 68 respectively. Biological Oxygen Demand (BOD) of A. Sessilis is 81 and Chemical Oxygen Demand (COD) of A. Sessilis is 72 (Table.2).

The removal efficiencies of textile effluent treated by vertical flow constructed wet lands with the plant Zea mays. This plant is treated with the following parameters. In pH range is 7.5 and the Electrical Conductivity (EC) of Zea mays is 50. The Total Solid (TS) range of Zea mays is 65.Total Dissolved solid (TDS) and Total Suspended Solid (TSS) parameter also tested with this plant. They are 58 and 76 respectively. In chloride test of Zea mays is 54. The Total Hardness and Total Alkalinity of Zea mays are 39 and 52 respectively. Biological Oxygen Demand (BOD) of Zea mays is 62 and Chemical Oxygen Demand (COD) of Zea mays is 63 (Table.2).

Discussion:-

All of the traditional physiochemical methods to remove heavy metals and pollutants from soil and water have high operational costs and uses of large amount of chemicals and nutrients creating the problem of effluent or sludge treatment. These methods can be advantageous for rapid removal in small areas. The emerging technology called 'Phytoremediation' uses plants to remove pollutants from the environment and is preferred over traditional methods because it offers site restoration, partial decontamination, and maintenance of biological activity and physical

structure whilst being potentially cheap, visually unobtrusive and with a possibility of bio-recovery of metals (Aubert and Schwitzguebel, 2004). Because of these advantages phytoremediation is considered as a 'green', sustainable pollution removal process. Advances in science and technology have created growth of industries leading to the unprecedented disturbances in ecological cycles.

The observed pH reduction is due to CO_2 production from decomposing plant litter and other wastewater components trapped in their root mat (Vilaseca ET AL., 2010) and nitrification of ammonia (IWA, 2000). Electrical Conductivity was reduced due to evapotranspiration and/ or movement of substrate by plant roots accumulated for this effect (Hoda, 2010). The decrease in conductivity despite significant water losses is explained by uptake of micro and macro elements and ions by plants and bacteria, and their removal through adsorption to plant roots, litter and settles able suspended particles (Ghodake et al., 2009). The TDS reduced due to the processes of sedimentation, filtration bacterial decomposition and adsorption. The TSS reduced due to the processes of sedimentation, filtration bacterial decomposition and adsorption. Moosvi et al., (2005) who found that longer retention time would reduce COD. The removal of COD is attributed to microbial degradation of substrate to the plants roots (Togo et al, 2008). BOD_5 removal between planted and unplanted wetlands may be due to microbial degradation of organics coupled with root zone oxygen input (Klemola et al., 2007).

Treatment performance conditions for contaminant removal in wetlands may be based on the contaminant concentration in the wetland outflow or on the total or per cent mass removal of the contaminant. It is important that the selected measures accurately reflect the actual performance of the wetland relative to the objectives and intended uses of the wetland treatment system. In the present study, an attempt has been made to have a comparative assessment of the efficiency of aquatic plants like Alternanthera sessilis and Zea mays.The effluent samples collected from the treatment set were analyzed periodically with a view tofind out the changes in its physico-chemical properties brought by the growth of the respective weeds. The physico-chemical properties of effluent samples analyzed include the changes in pH, temperature, conductivity, total solids, and chloride, Total Hardness, TDS TSS, Total Alkalinity, BOD and COD. The percentage change (increase/decrease) in the physico-chemical characteristics of control and effluent samples treated with aquatic macrophytes in retention time of 24 hours were also calculated.

Conclusion:-

India has a large network of textile industries of varying capacity and textile effluent is one of the main contributors of water pollution and it adversely affects fauna and flora. Though some effective various methods such as physical, chemical, and biological methods are available to remove the textile dye effluents. But, all the method is not significantly used in textile industry because of various difficulties such as time, cost, raw material unavailability etc. Phytoremdiation technology can be effective approach for remediating contaminated sites of such textile dyeing effluents. Phytoremediation is the most economical, eco-friendly, easy to do to degrade the contaminates completely/partially present in effluent. The different plants are found with naturally inhabited metabolic pathways to utilize different dyes and some of the genetically engineered plants are also produced in order to effectively degrade the dyes and to sustain different environmental conditions. Several researchers have done extensive studies in phytoremediation area in order to understand the removal of chemicals during treatment of textile effluents. In future mainly focuses on exact mechanism of industrial effluent treatment by using symbiotic relationships between the plants (Alternanthera sessilis and Zea mays) and microbes.

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