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Treatment And Reclamation Of Textile Mill Wastewater Using Water Hyacinth: A Techno-Economic And Eco-Friendly Approach

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ABSTRACT

Rapid population and economic growth especially in urban sectors is being experienced by most of the developing countries all over the world. As the ever-increasing population and urbanization are threatening the available water potential in many areas of the world, the treatment and disposal of wastewaters is becoming more and more crucial. Although water hyacinth (Eichhornia Crassipes) has proved to be a persistent and expensive aquatic weed problem in every part of world it has ever invaded, but at the same time, it is reported to have proved its value as a natural purifier. The objective of this study was to assess the viability of water hyacinth for treatment of industrial wastewater. The samples of industrial wastewater were treated with water hyacinth in the laboratory and it was found that water hyacinth is quite efficient in reducing the pollutional parameters such as BOD, COD, suspended solids, dissolved solids, heavy metals etc. The treated effluent is found suitable for reuse for non-potable reuses like industrial, agricultural or gardening purpose.

KEYWORDS

Aquatic weeds;
Water hyacinth;
Treatment of textile mill wastewater.

INTRODUCTION

There has been a steady increase in human population, industrialization and urbanization during the past few decades. A number of small, medium and big industries have been established in different parts of the world. This along with increase in the developmental activities has increased the demand on available water resources. These sectors not only utilize the water resources but also discharge considerable amount of wastewaters. The disposal of city waste, sewage and industrial effluents is a major problem. The cost of scientific treatment of these effluents is too high to be generally feasible in developing countries like India. As such these waters are being disposed off to both land and water bodies without any pretreatment. Direct disposal of effluents to land and water bodies has potential to contaminate air, soil as well as surface and ground waters.

Almost all water bodies have plants growing in them. Presence of plants in the water bodies is essential for the conversion of solar energy into chemical energy for the development of aquatic fauna like fish, prawns etc., and for continuous addition of oxygen to water during photosynthesis. If water plants due to over growth make such water bodies unfit and take the shape of noxious aquatic vegetation, these may be referred as aquatic weeds.

From environmental point of view, a small quantity of aquatic weeds is necessary for stabilizing organic matter present in water body naturally, but in excess quantity, due to eutrophication, they prove harmful to aquaculture and so to water ecology. Aquatic weeds have always existed, but in recent decades their effects have been magnified due to the creation of artificial water bodies such as dams and canals and polluting them with farm and city wastewater causing enrichment of natural waters by nutrients and fertilizer runoff, which promotes aquatic weeds to grow prolifically and profusely.

Aquatic weeds are the greatest problems in fishing, irrigation and efficient water supply. In earlier time, man was not concerned to manage aquatic weeds because of abundant water supply and low population but now it has almost become imperative in every city and country to save the water from the ravage of noxious weeds. Since the beginning of this century, greater efforts were made using a variety of implements, chemicals and bio-agents. Recently more attention has been paid to manage world's worst weed like water hyacinth, water fern and Hydrilla spp.

For an optimum utilization of available supplies of water therefore, the eradication of aquatic weeds has to receive immediate and greater attention. Various methods are being adopted in different organizations/departments of the world to control the aquatic weeds.

Eradication of the weeds by biological, chemical or mechanical means has proved impossible either due to the adverse side effects, cost considerations or the ability of weed-seeds to remain in dormant state for several years. The best alternative therefore would be to turn these weeds into useful resources such as fiber, feed, fertilizer, and fuel or make use of its scavenging ability to treat the wastewater, because when it is possible to utilize the aquatic weeds in some way or the other, then it is the best method of controlling the weed.

Therefore, utilization approach, rather than destruction of the plant has recently received worldwide attention. Scientific cropping of water hyacinth in various types of water bodies can result in water pollution control and at the same time provides a source of energy and food. It is observed that water hyacinth growth can be utilized as a primary treatment method for reducing BOD, COD, pH, suspended solids, total solids and trace metals found in the wastewaters. Hence, wastewaters can be reclaimed for reuse and at the same time environmental protection can be ensured.

Study area-jodhpur city

Jodhpur, known as the sun city of Rajasthan, India is situated on the marginal east part of the world famous than desert. The author has carried out a study during the year 2005-06 in jodhpur city regarding the treatment of industrial wastewaters using the water hyacinth plant. The sun city jodhpur, is poised for rapid industrialization and the following industries are developed or under development. (i) Textile, (ii) Stainless steel rolling industries (iii) Engineering, Chemical, Guar gum, Handicraft and Cement industries. Most of the above industries are located in the industrial complex under Rajasthan Industrial Development and Investment Corporation Ltd. (RIICO).

Almost all the water-polluting industries are in small-scale sectors. There are two main sectors that generate polluted water effluent namely textiles processing and stainless steel re-rolling. The total number of such small-scale units is approximately 300. The effluent of the textile processing industries is mainly alkaline in nature whereas the effluent of the stainless steel re-rolling units is acidic.

The textile processing industries are in small-scale sector and carry out processes like desizing, kiering, bleaching, mercerizing, dyeing and printing. During desizing and kiering, the cloth is treated with synthetic detergents, caustic soda, acids or enzymes. The cloth is further subjected to bleaching and dipping into oxidizing agent where the impurities present are oxidized and the cloth attains whiteness. The effluent water from these units consists of washings containing these chemicals and having the pH in alkaline nature. During dyeing process, the mercerized cloth is passed through a tray of dyes for color fixation. Dye cloth is further subjected to wash and the effluent consists of washed out dyes with colors. The cloth is further subjected to printing on wax tables with the help of screens and then the cloth is dried for color fixation. The cloth is finally finished by starching and other chemical treatment before folding and dispatching. Few mills have synthetic mixed with cotton process where the cloth undergoes carbonization process, where the cloth is passed through concentrated sulfuric acid solutions. The cotton fabric part of the cloth is removed and the synthetic yarn is left out with the cloth. The cloth is further subjected to alkali wash followed by drying, rolling and packing.

In Jodhpur industrial area, the number of textile units is 211 and the textile mills work in 2 shifts per day. Hence, the effluent discharged from the textile units is continuous. The effluents from textile mills are carried to the CETP site through the open drains. The treatment methodology consists of primary, secondary and tertiary treatment of the industrial effluents. The primary treatment of the effluent consists of neutralization and physico-chemical treatment with coagulant, lime and electrolyte. The secondary treatment consists of extended aeration followed by secondary clarifiers and recirculation of sludge. The tertiary treatment comprises of the pressure sand filtration and activated carbon adsorption. After the above treatment steps, the effluents are within the permissible limits for discharge into the existing open drains leading to the Jojri River.

Objective of the study

Water hyacinth(Eichhornia crassipes) is a free floating water plant with beautiful lilac violet flowers. Water hyacinth has a tremendous capacity to grow and regenerate. Even a small piece of this plant can produce a full crop within a short span of time. Crops of water hyacinth can double itself within eight to ten days. In summer especially, this weed grow to such an extent that every inch of water surface is covered with it giving thick green carpet appearance to water-bed. It has created many problems to civil life. This prompted several to undertake the utilization aspect of the weed.

The water hyacinth's unique survival capacity has made the permanent eradication of this plant very difficult. Therefore, utilization of this plant is the best means of its control. In this study, the suitability of water hyacinth for treatment of textile mill wastewater had been studied.

EXPERIMENTAL

To carry out the experimental work in the laboratory, two treatment ponds of dimensions approximately 1.0m×1.0m×0.50 m were constructed in the open space available in the environmental engineering laboratory of the department of civil engineering, M.B.M.engineering college, and jodhpur with brick masonry and their inner sides were made water proof with cement plaster. The young equal sized fresh water hyacinth plants were planted in these ponds. The volume of wastewater taken for treatment in each pond was 200 liters.

The aquatic plant water hyacinths were obtained from the 'gangalao pond' near siwanchi gate, Jodhpur.

This pond is completely filled up with water hyacinth. The fresh medium size 10-12 plants of approximate weight 0.50-0.75 kg each was collected from the pond. The composite samples of textile mill wastewater were collected for the study. The samples were collected from the common effluent treatment plant(CETP) sangaria, Jodhpur, where the industrial wastewater is sent through the industries of Jodhpur city for proper treatment. The samples of 200 liters were collected in plastic containers and were carried to the laboratory. One pond was used for samples of textile mill wastewater and another pond was used as control pond.

Mechanism involved

There are innumerable types of aquatic weeds, which, by virtue of its inherent characteristics and survival needs, decompose many toxic chemicals present in water bodies. In aquatic macrophyte based wastewater treatment systems, the pollutants are removed by a variety of complex of biological, physical and chemical processes. The aquatic macrophytes are the most obvious biological component of the systems. However, the uptake of pollutants by the vegetation itself cannot account for the removal efficiency often observed in such systems. Godfrey et al. (1985) pointed out that bacterial transformations and physico-chemical processes including sedimentation, absorption and precipitation are also involved in the process. The macrophytes play an important role by providing surfaces and substrates for bacterial growth and by altering the physico-chemical environment in the water and in the rhizosphere.

Removal of pollutants in an aquatic treatment system depends on the nutrient assimilative capacity of the plant and the biochemical/physico-chemical processes taking place within the system. The removal of dissolved organic matter is due to aerobic, facultative anaerobic and anaerobic activities. Rate of substrate degradation depends on its biodegradability and on the availability of electron acceptors, which ultimately dictates the mode of respiration. Nitrogen removal occurs via plant uptake and nitrification/denitrification, while phosphorus removal is due to plant uptake, precipitation and microbial immobilization[9].

Laboratory procedure

The samples of textile mill wastewater from the CETP sangaria jodhpur were brought to the laboratory and they were tested for their initial concentration of pH, biochemical oxygen demand, chemical oxygen demand, suspended solids, dissolved solids, chloride content, alkalinity, nitrates, fluoride, sulfates and heavy metals.

Five to six water hyacinth plants were placed in the treatment ponds consisting the textile wastewater in such a manner that they cover approximately 70% to 80% of surface area[2]. On a regular interval, a known volume of samples was taken out from the treatment ponds for assessment purpose and simultaneously same volume of deionized distilled water (DDW) was added in the treatment ponds so as to keep the total volume of the wastewater constant throughout the detention period. The withdrawn samples were used to analyze the reduction of various parameters regularly.

To perform the experimental work, all the parameters, i.e. pH, TSS, TDS, BOD, COD, chloride content and alkalinities were analyzed in the environmental engineering laboratory of the department of civil engineering, M.B.M.engineering college jodhpur and some experiments were also performed in the public health engineering laboratory, jodhpur while tests regarding assessment of heavy metals were performed in the defence laboratory, jodhpur as per the procedures mentioned in the 'Standard methods for examination of water and wastewater', 20th Ed., American Public Health Association, AWWA, WPCE[3].

RESULTS AND DISCUSSION

The laboratory results obtained show that the water hyacinth has got the capacity to remove pollutants from wastewater. The initial characteristics and the results obtained after treatment with water hyacinth for samples of textile wastewater are presented in TABLE 1 and the percentage reduction in various characteristics of industrial wastewaters are represented in TABLE 2 and 3.

In this study, it was found that the concentration of the most of the physicochemical parameters of

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TABLE 1: Characteristics of raw/treated textile wastewater through water hyacinth

S.N.	Parameter	Unit	Textile mills wastewater	
			Initial concentration	Final concentration after water hyacinth treatment
1	Color	-	Light green	Colorless
2	Temperature	°C	24.7	21.5
3	Suspended solids	mg/l	1240	170
4	Dissolved solids	mg/l	4600	580
5	Total solids	mg/l	5840	750
6	pH	pH unit	10.3	8.1
7	Alkalinity as $CaCO_3$	mg/l	700	250
8	Acidity as $CaCO_3$	mg/l	ND	ND
9	Calcium hardness	mg/l	390	250
10	Total hardness	mg/l	610	350
11	Chlorides as Cl	mg/l	1510	120
12	Fluoride as F	mg/l	13.2	2.92
13	Nitrate as NO_3	mg/l	30	10
14	Sulfate as SO_4	mg/l	393	192
15	BOD	mg/l	460	30
16	COD	mg/l	1280	150
17	Iron as Fe	mg/l	8.74	0.57
18	Zinc as Zn	mg/l	0.07	0.05
19	Nickel as Ni	mg/l	2.5	1.5
20	Chromium as Cr	mg/l	ND	ND
21	Cadmium as Cd	mg/l	ND	ND
22	Copper as Cu	mg/l	0.29	0.09
23	Lead as Pb	mg/l	ND	ND

ND stands for 'Not detected'.

untreated effluent exceeds the tolerance limits prescribed by the B.I.S.(I.S. 2296-1982 and 2490-1974) as well as by the food and agriculture organization (FAO), USA and this indicates fairly good amount of organic and non-organic pollution.

According to FAO, the general characteristics of treated industrial effluent used for irrigation or discharge to the municipal sewers and to the sea are mentioned in the following TABLE 4[10]

According to the Indian Standards(I.S. 2296-1982 and 2490-1974), the effluent standards acceptable for agricultural and gardening use should have the following limits(D.K.Saxena, 1991): Dissolved oxygen=6-9mg/l, BOD=12-20mg/l, Total solids=30-200mg/l and Suspended solids=30mg/l.

As the effluent of industrial wastewater treated by water hyacinth treatment showed more or less the same concentration as per the B.I.S. and FAO, the effluent is suitable to use for agricultural/industrial or gardening purpose safely and economically and that also with this low cost method.

Water is an important resource and aquatic weed affect it adversely by blocking canals and pumps in irrigation projects; interfering with hydroelectricity production, wasting water in evapotranspiration; hindering boat-traffic, increasing water borne diseases; interfering with fishing and fish culture and clogging rivers and canals with resultant flood.

But at the same time the water hyacinths are among the most productive plants in the world. They possess an excellent ability for assimilating nutrients and creating favorable conditions for microbial decomposition of organic matter. This ability of weeds should be utilized for rehabilitation process

TABLE 2: Percentage reduction in various characteristics of textile mill wastewater during water hyacinth treatment

Days of treatment	SS	DS	TS	Alka-linity	Calcium hardness	Total hardness	Cl	F	NO_3	SO_4	BOD	COD
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	11.29	7.61	8.39	7.71	2.05	3.28	7.28	4.55	4.00	3.31	5.26	4.02
2	20.97	15.43	16.61	12.29	4.10	5.74	13.25	15.15	8.67	5.85	10.53	9.04
3	31.45	25.00	26.37	17.71	7.18	7.87	23.18	26.14	15.00	11.96	15.79	15.43
4	38.71	34.57	35.45	21.71	9.23	10.82	29.14	33.18	22.67	18.32	23.68	23.86
5	50.00	40.43	42.47	26.29	10.77	13.11	38.15	46.21	25.33	23.16	28.95	33.85
7	52.90	47.17	48.39	30.29	12.82	16.07	41.72	49.70	30.00	27.74	35.53	44.48
8	58.06	54.13	54.97	35.43	14.87	18.03	47.02	54.39	35.33	31.81	42.11	50.13
9	62.90	60.96	61.37	40.29	16.92	21.31	52.32	58.64	43.33	35.11	50.00	57.33
10	67.90	67.39	67.50	46.57	20.51	24.26	56.56	62.42	46.67	38.42	59.21	62.30
11	73.39	72.17	72.43	50.71	23.08	26.89	60.93	65.61	50.00	40.97	67.11	67.59
13	77.10	76.96	76.99	55.71	26.15	29.51	66.23	67.80	53.33	44.02	76.32	72.14
14	80.65	84.13	83.39	58.29	28.21	32.46	73.51	70.83	56.67	45.55	81.58	78.23
15	83.87	85.65	85.27	59.14	30.26	35.41	79.47	72.73	60.00	47.07	89.47	81.08
16	85.48	87.17	86.82	64.00	33.33	39.02	85.43	74.62	61.67	48.60	93.42	84.50
17	86.29	87.39	87.16	64.29	34.87	40.33	89.67	76.52	63.33	49.62	96.05	87.14
18	86.29	87.39	87.16	64.29	35.90	42.62	91.39	77.88	66.67	50.64	96.05	88.24
19	86.29	87.39	87.16	64.29	35.90	42.62	92.05	77.88	66.67	51.15	96.05	88.24

SS=Suspended Solids, DS=Dissolved Solids, TS=Total Solids, Cl=Chloride, F=Fluoride

TABLE 3: Percentage reduction in concentrations of heavy metals from textile mill wastewater through water hyacinth treatment

Days of Treatment	Iron as Fe	Zinc as Zn	Nickel as Ni	Chromium as Cr	Cadmium as Cd	Copper as Cu	Lead as Pb
0	0.00	0.00	0.00	ND	ND	0.00	ND
1	4.85	1.43	2.00	ND	ND	4.83	ND
2	9.70	2.86	4.00	ND	ND	9.66	ND
3	14.55	4.29	6.00	ND	ND	14.48	ND
4	19.41	5.72	8.00	ND	ND	19.31	ND
5	24.26	7.15	10.00	ND	ND	24.14	ND
7	29.11	8.57	12.00	ND	ND	28.97	ND
8	33.96	10.00	14.00	ND	ND	33.80	ND
9	38.81	11.43	16.00	ND	ND	38.62	ND
10	43.66	12.86	18.00	ND	ND	43.45	ND
11	48.51	14.29	20.00	ND	ND	48.28	ND
13	54.94	16.33	22.86	ND	ND	51.24	ND
14	61.36	18.37	25.71	ND	ND	54.19	ND
15	67.78	20.41	28.57	ND	ND	57.15	ND
16	74.21	22.45	31.43	ND	ND	60.10	ND
17	80.63	24.49	34.29	ND	ND	63.06	ND
18	87.05	26.53	37.14	ND	ND	66.01	ND
19	93.48	28.57	40.00	ND	ND	68.97	ND

TABLE 4: Permissible limits of treated industrial wastewater for different purposes

Parameter	Unit	Permissible limits for		
		Irrigation	Discharge into municipal sewers	Discharge into sea
COD	mg/L	-	700-1000	200
BOD	mg/L	-	500	-
TSS	mg/L	-	300	30
Chloride	mg/L	140-350	-	-
Hardness	mg/L	90-500	-	-
Copper	mg/L	0.20	1.00	0.10
Cadmium	mg/L	0.01	0.10	0.005
Iron	mg/L	5.00	-	2.00
Zinc	mg/L	2.00	2.00	2.00
Nickel	mg/L	0.20	2.00	0.02

of natural streams, lakes and wetlands and in wastewater treatment since they have several potential advantages compared to conventional treatment systems. These are:

(1) The cost of operation is low.
(2) The requirement of energy is low.
(3) They can be established at the wastewater production site.
(4) They are more flexible and less susceptible to shock loading.
(5) They are suitable for small villages, single farms, camping sites, small industries etc.
(6) The biomass produced can be utilized as energy, as compost or as animal fodder.

It is found that the water hyacinth(Eichhornia crassipes) appears to be one of the most promising aquatic plants for the treatment of textile wastewater and has received the most attention in this respect.

CONCLUSIONS

Based on the results, from the experimental study, the following conclusions appear to be justified.

(1) The cost of treatment is very low, in most cases negligible. This technology is traditional, rudimentary, and easy to implement, ideal for rural areas.
(2) Water hyacinth treatment proves to be an economical aid to reuse the effluent for agricultural and gardening purpose, i.e., non-potable reuses.
(3) The water hyacinth is found quite efficient in reducing the polluting parameters such as BOD, COD, suspended solids, dissolved solids, chlorides and heavy metals etc.
(4) The percentage reductions in the pollutional parameters are as follows: suspended solids (86.29%), dissolved solids(87.39%), total solids(87.16%), alkalinity(64.29%), calcium hardness(35.90%), total hardness(42.62%), chloride (92.05%), fluoride(77.88%), nitrate(66.67%), sulfate(51.15%), BOD(96.05%) and COD (88.24%). Also the heavy metals are reduced to a large extent.
(5) After water hyacinth treatment, the level of pollutants is decreased nearer to the acceptable limits suggested by the Indian Standards. Hence, the treated effluent may be used for agricultural or gardening purpose.
(6) Water-hyacinth-based and other wetland systems produce plant biomass that can be used as a fertilizer, animal feed supplement or source of methane.
(7) It is observed that since water hyacinth requires a lot of space, so this method is usually suited for rural areas where land is available in plenty.
(8) Heavy metals absorbed by the plants in aquatic treatment systems are not returned to the water.
(9) There have been many researches to control the aquatic weed problem by method of utilization, as it seems to be the best and most effective method from economic point of view. So, in future, utilization method would be adopted predominantly than any other method for management of aquatic weeds. And in near future, thrust shall be given to the following aspects:
    - Detail study on survey and identification of location specific problem
    - Identification of different aquatic weeds for human use
    - Use of weed biomass in crop fields for nutrient recycling
    - Possible ways for utilization
    - Development of waterlogged areas for other purposes
    - Investigation of other native plants and plant

materials to be used as coagulants for removal of color and turbidity and control of pH

(10) And last but not the least, although control of water hyacinth is a problem, it provides a means of wastewater treatment which is sound both economically and ecologically and the harvested plant material is a good source for production of biogas with high percentage of methane and the resulting fermented slurry as fertilizer. Thus, water hyacinth must surely be recognized as a plant of the future.

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