



Eco-management of Wastewater by ZESTP

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ARTICLE INFORMATION

Received: 12 Jan 2018
Revised: 17 Feb 2018
Accepted: 21 Feb 2018
Published online: 06 March 2018

Keywords:

ZESTP, Ecomanagement, Wastewater,
Phytoremediation.

DOI: <https://doi.org/10.15415/jce.2018.42007>

ABSTRACT

In present study, an evaluation of ZESTP (Zero Energy Sewage Treatment Plant) has been described as an alternative solution of sewage water treatment. This system has become widely famous because of having great absorption efficiency of nutrients, simple construction and maintenance, relatively less costly as well as a strong process. After treatment of sewage water, the level of dissolve oxygen was increased up to 73% due to the enhanced numbers of photosynthetic organisms. Some aquatic macrophytes such as *Eichhornia crassipes* (Mart.) Solms, *Pistia stratiotes* L. and *Hydrilla verticillata* Casp were used in ZESTP for waste water treatment based on phytoremediation. ZESTP could reduce the around 84% turbidity, 46% electrical conductivity, 43% salinity, 74% acidity, 69% free CO₂, 73% BOD, 44% COD, 70% suspended solids, 62% total hardness, 71% chloride, 59% cadmium, 51% iron, and 71% copper from the waste water. Naturally, some plants have capability are to retain and/or remove fatal chemicals which are present in sewage water. Moreover, macrophytes based ZESTP is a cost effective and an eco-friendly technique of sewage water treatment.

1. Introduction

Generally, sewage, a waste material which is mostly derived from municipalities, animal shelters, food industries, excreta of human beings, paper, soaps and detergents. It poses several human health problems and still it is needed to develop effective and affordable technological solutions for management. Gorakhpur is a district headquarters of state Uttar Pradesh (located at the *Terai* belt) of India lies between 26°75'N and 83°36'E. The city is situated in the plain of Saryu at mid Gangetic valley and the confluence of rivers *Rapti* and *Rohini* [7] Cached-Similar. The major water source of Gorakhpur city is ground water. The major water source of Gorakhpur city is ground water in which 75 powers bore well, 8 mini power well, 3694 hand pumps and 450 public stand posts are involved for groundwater extraction. Approximately, 82 MLD (Million liters per day) water produced from only ground water and not a single unit of water is produced from surface water sources. On an average, the supply of domestic water is 77.60 LPCD (Liter per capita per day) and nearly 70% of this amount of domestic water is being released in Gorakhpur city as wastewater which is around 65.84 MLD. It poses several human health problems; therefore a need has arisen to develop effective and affordable technological solutions.

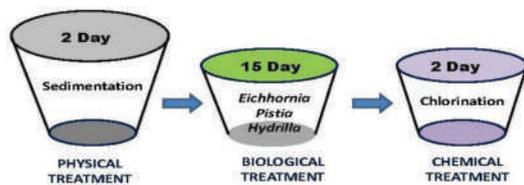
The ZESTP technology was developed to purify the water on site naturally. Moreover, it has ability to eliminate various types of fatal chemicals or contaminants from sewage water. Additionally, ZESTP technique has several advantages over the traditional wastewater purification systems because of relatively less cost of operation and maintenance, need of least energy as well as in-situ water treatment facility.

2. Material and Methods

Sewage samples were analyzed for all the water quality parameters as per the recommendations of APHA [2]. Physical water parameters like colour and odour were analyzed manually on the sampling collection sites. On the other hand, analyses of the other water parameters were carried out into the laboratory. On the basis of nature of contaminants, their resistance capacities as well as sensitivity, three aquatic macrophytes such as *Eichhornia crassipes* (Mart.) Solms, *Pistia stratiotes* L. and *Hydrilla verticillata* Casp were chosen for the study. The experiment was conducted for biological treatment and analyzed for a period of 20 days at the interval of 5 days during the treatment process. For mixed culture experiments, five aquaria of 25 L capacity were maintained.

Initial reading of all the variables was also recorded for the comparison of results. In each aquarium 25 L waste water was poured and roots of all selected macrophytes were washed thoroughly in tap water before the placing plants in aquarium. Best results were obtained in case of 15th day of treatment, therefore, only the reading of 15 days is expressed here. In the light of above experiment ZESTP model (Figure 1b) was developed which have shown 2270 liter purifying capacity in peri-urban part of Gorakhpur city (Jangal bahadur Ali block Chargaawa). Zero Energy Sewage Treatment Plant (ZESTP) is a three chambered Sewage Treatment Plant made up of brick, cement, plastic pipe, barrel pump and iron net which works without using energy. It is able to treat sewage water using aquatic plants.

ZESTP works in following three steps (figure 1a):



a.



Figure 1a: Flow diagram of ZESTP. **b:** Zere Energy Sewage Treatment Plant (ZESTP), **c:** Barrel Pump, **d:** *Eichhornia crassipes* (Mart.) Solms., **e:** *Pistia stratiotes* L., **f:** *Hydrilla verticillata* Casp., **g:** Sewage sample before Treatment, **h:** Sewage sample after Treatment.

Step I: Collection of sewage directly in the first tank and stay for two days.

Step II: Transfer the stagnant sewage water (except precipitate) from 1st chamber to second tank of ZESTP with the help of barrel pump (figure 1c), then implant aquatic macrophytes (Two plants of each *Eichhornia*, *Pistia* and *Hydrilla* per square feet) for 15 days.

Step III: After 15 days, transfer the second tank water into third tank with the help of barrel pump followed by chlorination (5gm/100 L) and leave water for two days before irrigation or other application of treated sewage.

In general, *Eichhornia crassipes* (Mart.) Solms is known as water hyacinth (Figure 1d) belongs to family Pontederiaceae. It is a perennial, free floating; consisting of horizontal and spongy stem having large aerial leaves, cluster of brown or pinkish adventitious root with root pockets, growing by the means of offset. *Eichhornia crassipes* is monocotyledonous and cosmopolitan in distribution.

Pistia stratiotes L. commonly known as water lettuce (Figure 1e) belong to monocotyledonous of family Araceae. Plants are small, free floating, perennial aquatic herbs of gregarious nature with sessile and spatulate leaves. They arise in close spirals and form cup shaped rosette in the region of nodes. Roots bear root pocket.

Hydrilla verticillata Casp is a submerged plant belonging to family Hydrocharitaceae of monocot. It is free floating and herbaceous in nature. *Hydrilla verticillata* (Figure 1f) release high amount of oxygen directly into the water.

Treatment Capacity

One cubic foot (1x1x1) area have = 28.317 L water
= 28 L and 317 mL

Total area covered by ZESTP - = 15 x 4 feet
= 60 square feet

Total requirement of aquatic macrophytes:

= 60 x 2 macrophytes each
= 120 macrophytes
(*Eichhornia*, *Pistia* and *Hydrilla*)

Size of one tank:

= 4 Length x 5 Breadth x 4 Depth
= 80 cubic foot
= 80 x 28.371
= 2269.68 L water

Therefore, after complete operation of ZESTP can purify nearly 2270 L sewage water in every 15 days.

Table 1: Result of Biological Treatment (initial and after 15 days), * Increase Percentage **Standard by CPCB [6].

S. No.	Parameter	Before Treatment	After Treatment (Mix Culture)	Reduction (%)	
		mg/L	mg/L	—	Standard** mg/L
1	Colour	Blackish	Light yellowish	—	—
2	Odour	Sewer like	Light smell	—	—
3	Temperature	38.5 °C	28.8 °C	—	—
4	pH	7.86	7.12	—	5.5–9.0
5	Turbidity	76	12	84.21	—
6	Electrical conductivity	512	278	45.70	—
7	Salinity	234	134	42.73	—
8	Total solid (TS)	1270	817	35.66	600
9	Total Dissolve solid (TDS)	815	678	16.80	600
10	Total Suspended solid (TSS)	455	139	69.45	<100
11	Acidity	145	37.8	73.93	—
12	Alkalinity	NIL	NIL	NIL	—
13	Free CO ₂	145	44.5	69.31	—
14	Total Hardness	660	248	62.42	—
15	Chloride	130.4	38.2	70.70	—
16	DO*	2.4	8.8	72.72*	4–6
17	BOD	185	50	72.97	<100
18	COD	210	118	43.80	<150
19	Cadmium	0.457	0.187	59.08	—
20	Iron	2.00	0.985	50.75	—
21	Copper	0.905	0.211	76.69	—

3. Results and Discussion

3a. Colour, Odour and Temperature

The colour of sewage water was light black (figure 1g) due to the decomposition of organic pollutants, formation of humic acid which gives dirty colour after getting dissolved as similar observations were also reported by Singh *et al.* [17]. Temperature fluctuation was observed during the change of environmental conditions. Stink was observed from the water due to decomposition of organic matter over the study site [1]. The colour of sewage water was

changed to light yellowish (figure 1h) from dark blackish by biological treatment. Moreover, after treatment odour and temperature were reduced favorably (Table 1).

3b. pH

pH is an important parameter which indicates the water quality and treatment efficiency. pH of water always fluctuates due to microbial degradation as well as different aquatic chemical reactions. It was found that the selected vegetation of water hyacinth significantly reduced the pH of wastewater. pH of treated effluent was found near to

neutral, though it was decreased in small percentage than inlet. Such reduction in pH with the help of water hyacinth was also reported by Wolverton and McDonald [18]. Initial pH was 7.86 before treatment and it got reduced up to 7.12 by using macrophyte *Eichhornia*, *Pistia*, *Hydrilla* in mixed culture experiment, respectively. The mixed culture of macrophytes was able to reduce pH which gives only the intensity of acidic or basic character and not the total acidity or alkalinity.

3c. Turbidity and Conductivity

During the month of June, both temperature as well as Brownian movement was observed elevated. Moreover, total suspended solids concentration in water was also enhanced which suggests about its involvement in increasing the level of turbidity because colloidal suspended particles could not settle down easily and found responsible for turbid appearance. Capacity of passing electric current through any liquid can be determined by estimating the conductivity of solution. For example, inorganic and organic materials shows better and poor conductance, respectively. The initial readings of turbidity and conductivity were recorded as 76 mg/l and 512 mS/cm, respectively. Heavy reductions in Turbidity and Conductivity were observed as 84.21% and 45.70%, respectively by the use of aquatic macrophytes during the treatment (Table 1).

3d. TS, TDS and TSS

The residue left after evaporation of unfiltered weight of water is known as total solids (TS), whereas residue left after evaporation of the filtrate water sample is known as total dissolved solid (TDS). Increase in the level of turbidity and decrease in the light penetration capacity may due to the presence of suspended solids. Moreover, this can contribute in the enhanced level of pollution as well by adding pollutants from their sediments. Reduction in suspended solids is helpful to decrease the turbidity as well as BOD load of water. Through stems, the *Eichhornia crassipes* (Mart.) Solms indicates about the presence aerobic conditions in their root systems which may favors the growth of aerobic bacterial colonies. Karthikeyan and Singh [9] studied that high concentrations of total solids and total dissolved solids cause problems to the soil health because of least aeration and also favors high BOD levels. Additionally, it will affects the occurrence of trace elements. Mixed culture of aquatic macrophytes has reduced the concentration of TS (35.66%), TDS (16.80%) and TSS (69.45%) in sewage water, as given in Table 1 and Fig. 1. Because, the *Eichhornia* provides suitable environment of microbial growth, also retards the flow of water by capturing suspended solids.

3e. Free CO₂ and Chloride

Accumulation of free Carbon dioxide in water takes place due to microbial activity and respiration of organism; this imparts acidity to the water by the formation of carbonic acid. Free CO₂ and chloride were decreased up to 44.5 mg/l (69.31%) and 38.2 mg/l (70.70%) from 145 mg/l and 130.4 mg/l, respectively as also shown in Table 1.

3f. Acidity, Alkalinity and Hardness

Acidity is the capacity of water which can neutralize a strong base. It is an aggregate property of water due to several specific substances but chiefly it is due to the CO₂ dissociating from carbonic acid. Alkalinity is a quantitative capacity of neutralizing strong acid to a designated pH. Table 1 shows reducing potential of mixed culture of plants, in respect of acidity (73.93%) and hardness (62.42%). Acidity which is 145 mg/l before treatment reduced to 44.5 mg/l after treatment in the mixed culture of *Eichhornia*, *Pistia* and *Hydrilla*. Hardness of water is generally the results of dissolution of the salts of calcium and magnesium compounds present in water.

3g. Dissolve Oxygen (DO)

The amount of oxygen dissolved in water is known as DO. The main sources of DO in water are photosynthesis and/or atmospheric diffusion. It is an important water quality parameter. Low concentration of DO indicates higher pollution load in the wastewater which affect the treatment efficiency. In the constructed wetlands, all the inlet samples collected were devoid of DO. Macrophytes play a very important role in increasing DO levels through the process of photosynthesis. Such increased DO levels favors the aerobic microflora in the wastewater involved in degradation activity [4]. The increased DO helps to reduce BOD load of wastewater. It was also indicated by reduction of BOD and COD in the wastewater and also increases the mass weight of the vegetation. DO have a significant role in the treatment of wastewater as it can directly affect the removal of various types of pollutants [8]. For the treatment of wastewater, a constructed wetland system was developed which had improved levels of DO due to the application of *Eichhornia crassipes* [19]. A tremendous increase in dissolve oxygen by mixed culture was recorded. Initially, DO was 2.4 mg/l, which increased to 8.8 mg/l through aquaculture of mixed culture respectively. An increase of ~73% dissolved oxygen concentration was observed level increased due to photosynthetic activity (Table 1).

3h. Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

Oxygen requirement of microorganism for the decomposition of biodegradable materisl present in water is

known as BOD. Biochemical Oxygen Demand (BOD) was used to check the organic load in the water body. Biological oxygen demand can be used to indicate the amount of organic matter in the water. High BOD levels reflects that more oxygen will be consumed as organic matter decays leading to low dissolved oxygen levels. Similar reduction in BOD has been reported by using bio filter for treatment of wastewater [14]. The reduction in BOD occurred due to aerobic, anoxic and anaerobic microbial processes in the constructed wetland system. Water hyacinths have the ability of removing pollutants from water by absorbing their tissues for providing a suitable growth environment to the microorganisms for pollutants transformation as well as their removals [18]. Whereas, the oxygen concentration required to oxidize the biodegradable as well non-biodegradable materials present in water using strong oxidizing agent is known as COD. The initial reading of COD and BOD was recorded to be 210 and 185 mg/L respectively (Figure 2), which show tremendous reduction by the use of aquatic macrophytes recorded after treatment. Choudhary [5] showed 87.17% reduction in COD with *Eichhornia crassipes* (Mart.) Solms. Such reduction is helpful in increasing the DO level in the wastewater. Roy *et al.* [15] also worked on the various types of aquatic macrophytes as well as algae (*Nostoc*, *E. crassipes* and *P. stratiotes*) and observed very effective to reduce the level of COD (-69%) in water. In present study, the level of COD was reduced as 72.97% in BOD and 43.80% in COD as well.

3i. Heavy metals

The concentration of toxic heavy metals such as Cd (0.457ppm), Fe (2.00ppm) and Cu (0.905ppm) were observed significantly higher in sewage water while Pb and Cr were found nil. These heavy metals concentrations were reduced (59.08% for Cd, 50.75% for Fe and 76.68% for Cu) after biological treatment (Table 1). Enhance level of heavy metal in the aquatic environment causes several health problems in living creatures. Mohanty *et al.* [13] were carried out an experiment on aquatic submerged plant i.e. *E. crassipes* which was found very well in the removal of chromium from water. Around 73% to 89% removal of 10 mg/L initial concentration was observed with 0.05 to 0.2 g/100 mL biosorbent dosage range indicating that the biomass of *E. crassipes* is efficient biosorbent for the removal of chromium from waste water. Combined application of *E. crassipes* and *L. minor* was found better in the removal of heavy metals from water [12] and this can be applicable for the treatment of waste water at large scale. Mishra and Tripathi [11] used *E. crassipes* for the accumulation of Cr and Zn from water up to 3.542 and 2.412 mg/g at 10 mg/L initial metal concentration with an exposure of 11 days.

Using ZESTP, 84% of Cr and 94% of Zn were removed successfully (Table 2).

Table 2: Removal efficiency of aquatic macrophytes.

Aquatic Macrophyte	Heavy Metal Removal Capacity (%)	References
	Fe (95%), Cu (96%), Cd (82%), Cr (81%), Zn (92%)	Mishra and Tripathi [11]
<i>Pistia stratiotes</i>	Cd (83.24%), Ni (32.77%), Cu (94.48%), Zn (26.08%), Pb (54.77%)	Miretzky <i>et al.</i> [10]
	Cr (VI) (73-89%)	Mohanty <i>et al.</i> [13]
<i>Eichhornia crassipes</i>	Fe (90.1%), Cu (95%), Cd (85%), Cr (84%), Zn (95%)	Mishra and Tripathi [11]
	Fe (89%)	Singh and Rai [16]
	Fe (92.39%), Cu (90.12%), As (65.30%),	Banerjee, <i>et al.</i> [3]
<i>Mixed Culture</i>	Cu (76.69%), Cd (59.08%), Fe (50.75%)	ZESTP (Present study)

Miretzky *et al.* [10] simultaneously removed Cd, Ni, Cu, Zn, and Pb from water using *S. intermedia*, *L. minor* and *P. stratiotes*. The species *L. minor* biomass was found best as it could remove 84.52%, whereas *P. stratiotes* was found least performer in the same work. Interestingly, Pb and Cd were efficiently removed by all the above macrophytes. Heavy metals such as Pb and Cd removals using *S. intermedia*, *L. minor* and *P. stratiotes* were observed a potential and less costly method of industrial waste water treatment.

4. Conclusion

The colour of waste water was changed light yellowish from dark blackish by biological treatment. After treatment, odour became light smell and temperature reduced as well. pH which was 7.86 before treatment but reduced up to 7.12 (9.41%) by using these macrophytes. Mixed culture of aquatic plant reduces the concentration of TS (35.66), TDS (16.80%) and TSS (69.45%) in waste water. Free CO₂ and chloride were 145 mg/l and 130.4 mg/l respectively before treatment and those were reduced after treatment 44.5 mg/l (69.31%) and 38.2 mg/l (70.70%) by mixed culture. Initially, DO was 2.4 mg/l which was increased up to 8.8 mg/l (72.42%) through mixed culture. COD and BOD were 210 mg/l and 185 mg/l before treatments which had shown tremendous reductions as 43.80% COD and

72.97% BOD after treatment. Aquatic macrophytes have shown rapid growth rate, absorb large quantity of nutrients which would provide practical and economical method for tertiary treatment. As an outcome of the complete remedial experiments, mixed culture of the selected aquatic macrophytes for 15 days is suggested for the best performance. The concentration of toxic metals such as Cd (0.457mg/l), Fe (2.00 mg/l) and Cu (0.905 mg/l) were significantly higher in sewage water while Pb and Cr were nil. These heavy metals concentrations were reduced (Cd- 59.08%, Fe- 50.75% and Cu- 76.68%) after biological treatment. ZESTP is an on-site and established technique of wastewater treatment systems which depends on the application of macrophytes. Additionally, it is less costly, requires less energy with respect to traditional waste water purification units. Also, it could be an attractive and cost effective option over the existing technologies for the removal of metal ions. Phytoremediation is being significantly used for the removal of contaminated wastewater using natural ability of macrophytes to remove toxic chemicals/pollutants from wastewater. Therefore, ZESTP can be introduced for the removal of contaminants using these above studied macrophytes because of its eco-friendly nature.

4a. Precautions to be taken for the management of ZESTP

- Need of well cleaning of ZESTP at regular intervals.
- Removal of old plants after 15 days and implant new one.
- Wash the aquatic plant with tap water before implantation.
- Always cover iron net above the tank.
- Use barrel pump for the transfer of water from one tank to another.

4b. Advantages of ZESTP treated sewage water

- In irrigation of agricultural crops and vegetables.
- For aquaculture of fish.
- Save energy.
- Reduce the exploitation of ground water.
- Optimum utilization of municipal sewage water.

5. Acknowledgement

The authors are grateful to Department of Botany, M.G.P.G. College, Gorakhpur and Prof. Prabhat Kumar Singh, Department of Civil Engineering, I.I.T. (B.H.U.) Varanasi for providing facilities to analyze heavy metals in the water samples.

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