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USE OF WATER HYACINTH [*EICHHORNIA CRASSIPES* (MART) SOLMS] IN TREATMENT SYSTEMS FOR TEXTILE MILL EFFLUENTS - A CASE STUDY

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Abstract: The performance of a wastewater treatment system containing water hyacinth at Veyangoda Textile Mill (VTM) in Sri Lanka was monitored for a period of one year for pollution parameters such as pH, Total Solids (TS), Suspended Solids (SS), Dissolved Solids (DS), Volatile Solids (VS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen (TN), Nitrate (NO_3^-), Phosphate (PO_4^{3-}), Chloride (Cl^-), Sodium (Na^+) and Potassium (K^+) contents. Statistical analysis of the results revealed a highly significant removal of TS (59.4%). Substantial reductions in VS 72.6% and DS 60% were observed. The reduction in mean of SS was 46.6%. A reduction of 75% in BOD was observed in the system while COD reduction was 81.4% during the period it was monitored. Results showed a 83.5% reduction in TN. With regard to PO_4^{3-} a reduction of 52.9% was observed. An increase in nitrate ion concentration was observed, suggesting nitrification of organic nitrogen in the medium during the long retention time of thirty days. The mean reduction in chloride ion was 36.0%. Similarly, highly significant reductions in Na^+ and K^+ (40.2% and 64.4% respectively) were also observed in VTM ponding system.

Key Words: pollution, wastewater, Water hyacinth, Textile mill effluent

INTRODUCTION

Textile processing wastewater contains oil and biodegradable organic compounds, which may cause anaerobic conditions in receiving surface waters resulting in die-off of fish and other aquatic organisms and emission of foul odours. Indiscriminate discharge of wastewater from textile processing industries in Sri Lanka has created environmental problems with regard to both ground and surface water pollution. Wastewater from textile processing contains various components that are harmful for the aquatic environment and are toxic to animals and also humans in case of ingestion or physical contact.

Veyangoda Textile Mill (VTM) which is one of the largest textile processing factories in the country, uses water hyacinth [*Eichhornia crassipes* (mart) Solms] in its ponding system for treatment of wastewater. Water hyacinth has been reported by a large number of workers as capable of purifying various types of industrial effluents because of its remarkable ability to absorb toxic and polluting substances .[4,7,8,9,10,18,19] Widyanto[15] in a preliminary study on the effect of textile

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mill pollutants on the growth of water hyacinth suggests that if water hyacinth is under proper control it may be utilized as a bio-agent to purify wastewater of a textile factory before reuse.

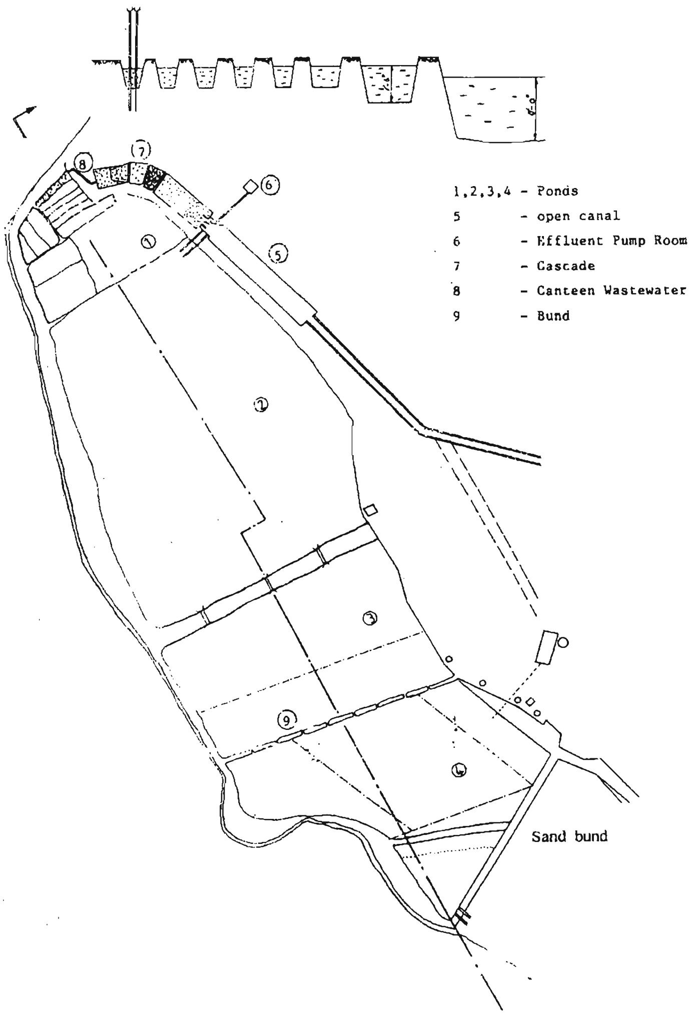

Figure 1: Wastewater treatment system at Veyangoda Textile Mills.

The objective of the present investigation was to study the performance of the treatment system with water hyacinth at VTM, in relation to environmental standards for various pollutants namely Total Solids (TS), Suspended Solids (SS), Dissolved Solids (DS), Volatile Solids (VS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Nitrogen (TN).

METHODS AND MATERIALS

Veyangoda Textile Mill situated at Bandaranayake Mawatha, Veyangoda at a distance of 6 km from the Colombo-Kandy Road, is basically involved in carrying out spinning, weaving, knitting and finishing. It has a capacity to produce 60,000 meters of cotton fabric and 7,000 kg of yarn per day. During a 24 hour period, the factory processes consume an average of 1500 cubic meters of water. These involve desizing, pre-and post-washing, bleaching, mercerizing, dyeing and printing processes. During these processes nearly 1130 cubic meters of effluent is discharged daily.

The effluent generated at the VTM flows through a canal to a cascaded aerator and then to the treatment system. The existing treatment system is a multipond water hyacinth treatment system which consists of four ponds in a series and a sand filter (Fig - 1). Ponds 3 and 4 contain water hyacinth. The treated effluent passes through a bulk sand filter before being discharged into a nearby water course which runs through abandoned paddy fields and ends up in a water course called the Dee-Eli Oya.

In order to study the performance of the treatment system grab samples of wastewater were collected at the channel (inlet water) and from the outlet of the system at monthly intervals for a periods of twelve months. The samples were analysed for pH, TS, SS, DS, VS, BOD, COD, TN, NO_3^-, PO_4^{3-}, Cl^-, Na^+ and K^+. These parameters were determined by the methods described in Examination of Water and Wastewater APHA .[3] Statistical analysis of the data collected was carried out by using student 't' (Paired) test.

RESULTS AND DISCUSSION

pH : The maximum pH value recorded in the inlet waters was 12.8 and the minimum was 7.0 while the maximum and minimum values of outlet waters were 8.52 and 6.50 respectively. The permissible pH range for discharge of textile mill wastewater into inland surface waters is 6.5 to 8.5 (Table 1). It was observed that pH of the effluent discharged from the treatment system exceeds the permissible levels occasionally. However, the pH value of the outlet water was found to be within the acceptable range of 6.5 to 8.5 (Fig. 2).Such reductions in pH have been reported by previous workers too; Wolverton et al[20] reported a decrease of pH from 8.8 to 7.2 with water hyacinth plants compared to 8.8 to 8.2 without plants.

BOD : The mean BOD of the inlet water during the one year period was 168.8 mg/l (range 103mg/l-268 mg/l). BOD load of the system was 179 kg/day. The maximum and minimum values of BOD in outlet waters for the period were 77 mg/l and 11 mg/l respectively with a mean value of 39.2 mg/l (Fig 3). Although the mean BOD value of outlet water (39.17 mg/l) was well below the permissible level of 50 mg/l) allowed by environmental authorities occasional exceeding of the permissible limit was observed (Table 1). However, in general the system was able to reduce the BOD load from 179 kg/day to 44 kg/day (i.e 75% mean reduction). Similar reductions in BOD have been reported by other workers; Wolverton et al[20] reported a 77% reduction in BOD in a system with water hyacinth plants compared to 6% reduction without plants. Kulatillake & Yapa[10] have reported a 99% reduction of BOD with water hyacinth in a treatment system for rubber factory effluents.

Table 1: Summary of characteristics of final discharge during the monitoring period of VTM ponding system

Parameter	Mean	Range	P Value Inlet vs Outlet	Permissible Level *
pH	7.59	6.5-8.52	0.0089	6.5-8.5
BOD	39.17	11.0-77.0	0.0004	50.0
COD	122.83	56.0-258.0	0.0003	250.0
TS	551.6	235.0-1010.0	0.0012	-
TSS	63.3	50.0-120.0	0.0090	50.0
VS	235.6	375.0-115.0	0.0009	-
DS	479.5	155.0-952.0	-	2100**
TN	15.9	7.0-31.5	0.0074	-
Na^+	109.8	40.0-288.0	0.1000	-
K^+	21.7	8.5-40.0	-	-
Cl-	23.56	12.0-35.0	0.0520	600**
NO_3N	16.17	0.0-5.4	0.0540	10***
$PO_{4\text{-}}P$	24.19	5.0-76.5	0.0004	-

All values except pH are expressed in mg/l
* Standards introduced by Central Environmental Authority (1990) for textile factory effluents
** Standard for industrial effluents discharged on land for irrigation purposes (Anon, 1990)
*** WHO standard for potable water

COD : The mean COD values of the inlet and the outlet waters of the system during the study period were 662.83 mg/l and 122.83 (i.e. a mean reduction of 81.4%). This reduction is quite comparable to that of Kulatillake & Yapa,[10] who achieved a reduction of 80% for rubber factory effluents, with water hyacinth. The COD values of the inlet water varied from 380 mg/l to 1444 mg/l with a standard deviation of 328.25 (Figure 4). The COD values of the outlet waters of the system varied from 56 mg/l to 258 mg/l with a standard deviation of 62.27. The mean COD value during the 12 months monitoring period was generally well below the tolerance limit of 250 mg/l although there were instances of slight fluctuation exceeding the limit (Table 1).

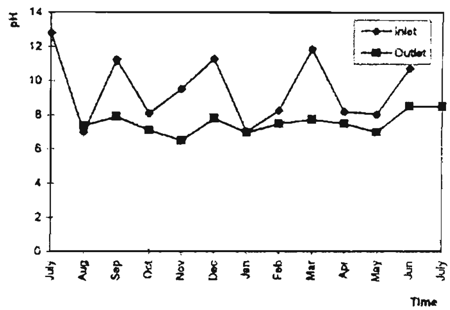

Figure 2: Monthly variation of pH of effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

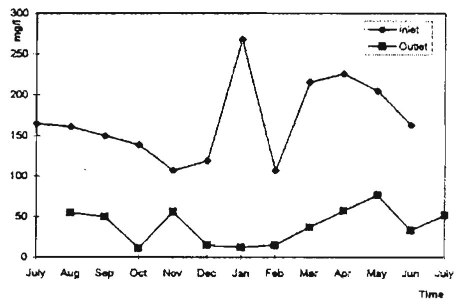

Figure 3: Monthly variation of biochemical oxygen demand of effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

TS: The mean value of total solids for VTM effluent was 1491.9mg/l while the lowest and highest values were 386.0 mg/l and 2770.0mg/l respectively. The monitoring study carried out in order to examine the efficiency of the existing treatment system at VTM when water hyacinth is also used revealed a highly significant difference in total solid concentration between inlet and outlet effluent (Figure 5). The mean percentage reduction of total solid was 59.4. The mean value of outlet water was 551.6mg/l and the lowest and highest values were 235.0mg/l and 1016.0mg/l respectively. The difference in total suspended solid between inlet and outlet effluent was also highly significant. The mean reduction was 46.6 percent. Wolverton et al[20] have reported a reduction of 75% in TS in a system with water hyacinth plants compared to 15% without plants. In the present study the mean suspended solid content exceeded the tolerance limit of 50 mg/l for discharge of textile mill effluents into inland surface waters. It appears that there is room for improvement with regard to TSS and the reports by previous workers show that further reductions can be achieved by using water hyacinth.

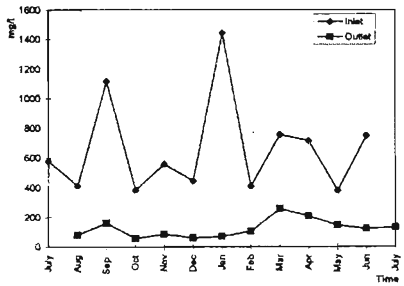

Figure 4: Monthly variation of chemical oxygen demand of effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

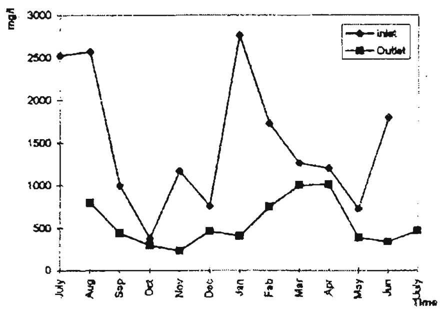

Figure 5: Monthly variation of total solid content of effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

VS : A significant reduction in volatile solids of 72.6 percent was observed. The mean volatile solid content of the outlet waters of the system was 235.6 mg/l compared to 1057.6 mg/l for inlet water (Figure 6 & Table 1).

DS : The mean value of dissolved solids for VTM effluent was 1379.6 mg/l. A similar range of total dissolved solid concentrations has been reported by NBRO[1] i.e. 1200-4438 mg/l for textile processing wastewater. The final discharge from the system had a maximum 952 mg/l and minimum 155mg/l with a mean value of 479.5 mg/l (Table 1). This means that it has been possible to achieve a 61.07% mean reduction of dissolved solids through the ponding system containing water hyacinth (Figure 7).

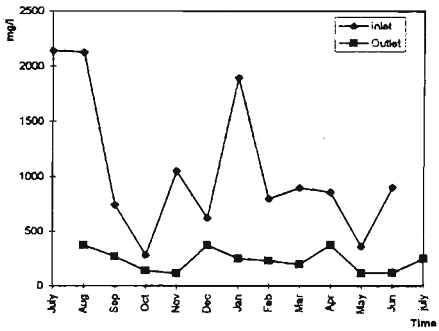

Figure 6: Monthly variation of volatile solid content of effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

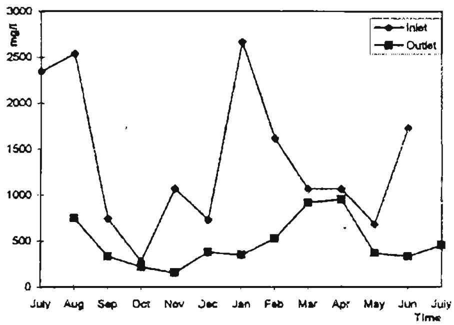

Figure 7: Monthly variation of dissolved solid content of effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months

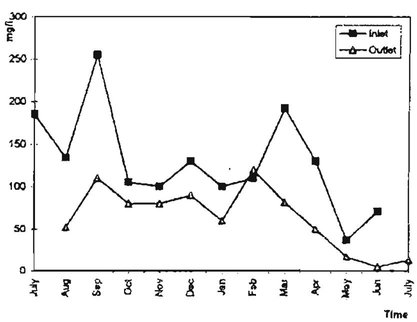

Figure 8: Monthly variation of suspended content of effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

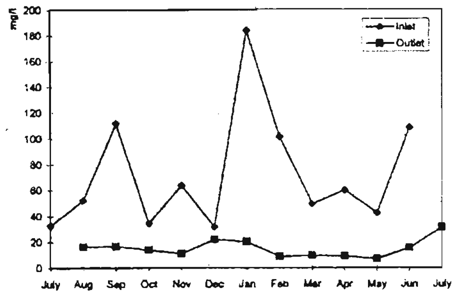

Figure 9: Monthly variation of total nitrogen in effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

Total N: The performance of the treatment system with respect to total nitrogen content is indicated in Table 1 & Figure 9. A 83.45% reduction in total N was observed. The mean total nitrogen content of inlet waters was 72.89 mg/l ± 45.55 (range 32.2 mg/l to 261.45 mg/l) whilst the mean total nitrogen content of outlet waters was 15.19 mg/l ± 6.9836 (range 7.00 mg/l to 31/50 mg/l). Several previous workers have studied the reduction in Total N in water hyacinth systems. Oki et al[11] reported that nitrogen and phosphate levels can be reduced in wastewaters by using water hyacinth, with nitrogen removal always being higher than that of phosphate. Similar observations have been made by Wolverton & McDonald[17] who reported a 60% removal of nitrogen in sewage lagoons with water hyacinth. In a subsequent study Wolverton et al[20] also reported a 75% reduction in Total N content with water hyacinth compared to 13% without plants. The 83.45% reduction in Total N content in the VTM treatment system therefore is quite satisfactory compared to reports by previous workers.

Sodium : A highly significant reduction of sodium ion content with respect to inlet waters was observed (Figure 10). The sodium ion concentration of inlet waters varied from 220 mg/l to 504 mg/l with a mean of 205.92mg/l ± 132.82. The sodium ion concentration of outlet waters varied from 40 mg/l to 288 g/l. The mean value of the sodium ion concentration for outlet waters, during the study period was 109.79mg/l., giving a reduction of 40.2% (Table 1). The sodium removal in the system is quite high compared to previous reports where only a 16% removal of sodium has been achieved.[10] The outlet waters (final discharge) are not used directly for irrigation purposes and therefore, no attempt was made to determine the sodium absorption ratio (SAR) which is a requirement only if the final discharge is used directly for irrigation purposes. For textile factory effluents discharged into internal water bodies, after treatment, the level of sodium or SAR, is not a parameter stipulated by the CEA.[2]

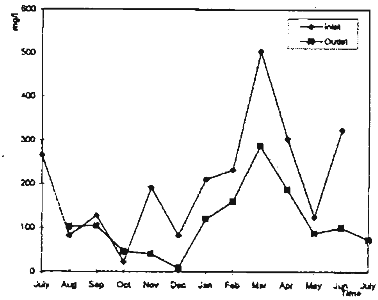

Figure 10: Monthly variation of sodium in effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

Potassium : The potassium ion concentration of inlet water varied from 5.5 mg/l to 195 mg/l during the study phase of twelve months with a mean value of 59.975mg/l. The outlet waters showed a variation from 8.5 mg/l to 42 mg/l with a mean value of 21.66mg/l. The reduction in potassium ion concentration was 64.43% in the treatment system with water hyacinth plants (Table 1 & Figure 11).

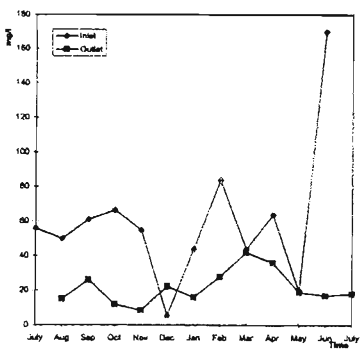

Figure 11: Monthly variation of potassium in effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

Chloride: A significant reduction in chloride ion concentration with respect to inlet effluents was observed. The chloride ion concentration of inlet waters varied from 16 mg/l to 90 mg/l during the period of study. The mean chloride ion concentration was 27.35 mg/l (±20.23). The chloride ion concentration of outlet waters varied from 12 mg/l to 35 mg/l (mean 23.56 mg/l ± 6.62). The reduction in chloride ion concentration by the treatment system with water hyacinth was 36.03% (Table 1, Fig 12). Wooten & Dodd[21] in a 5-pond system with 2000 water hyacinth plants observed hardly any removal of chloride ions.

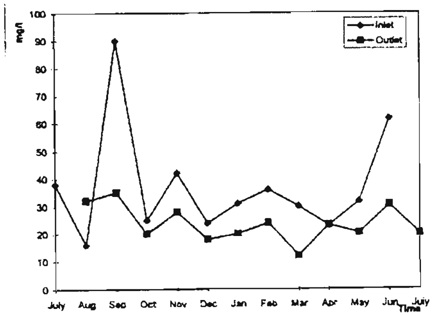

Figure 12: Monthly variation of chloride in effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

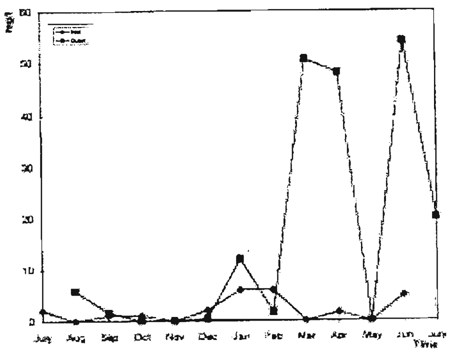

Figure 13: Monthly variation of nitrate in effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

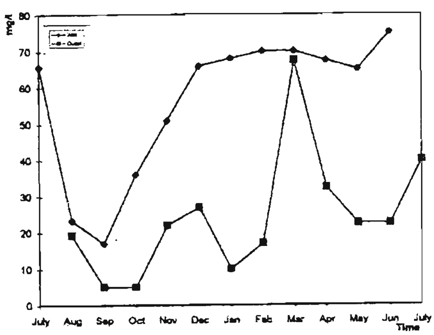

Figure 14: Monthly variation of phosphate in effluent discharged from the treatment system at VTM (Inlet and Outlet) during a period of twelve months.

Nitrate - N: An interesting increase in nitrate ion concentration was observed during the study period (Table 1, Figure 13). The nitrate ion concentration of the inlet waters was 2.05 mg/l (±2.31, range 0.00 to 6.00 mg/l). The nitrate ion concentration of outlet waters varied from 0.00 to 54.00 mg/l with a mean value of 16.17 mg/l (±21.80). The increase in nitrate ion concentration was quite substantial being as high as 16.17 percent. Several previous workers have reported of substantial reductions in nitrate-N levels in water hyacinth systems. Wooten & Dodd[21] reported a 100% removal of nitrate-N whereas Sinclair & Forbes[18] reported a 52.6 % removal of nitrate-N. Clock reported (as quoted by Cornwell et al[6]), a 75% removal of nitrate-N in a system containing water hyacinth. In a 10-month period of operation of a water hyacinth system, Cornwell et al[6] reported a 8.4% removal of nitrate-N. The increase in nitrate-N concentration as was observed in VTM ponding system, has not been reported by any previous workers. This indicates a process of nitrification of organic nitrogen contained in the media during the long retention time of thirty days in the treatment system. The existence of bacteria, some of them tolerant to heavy metals, has been reported recently by Pathiraja et al[12] and Tennakone et al in textile wastewaters although no attempt has been made by them to see if they are nitrifying bacteria.

The Dee-Eli Oya water to which VTM effluents are discharged, is not generally used for drinking purposes. The mean nitrate level of VTM effluents (16.17 mg/l) is slightly higher than the rather stringent WHO regulation of 10 mg/l for potable water. However, when compared to standards of other countries VTM effluents are not so badly affected. The maximum permissible level for nitrates in drinking water in European Commission countries is 40 mg/l with a guide level of 25 mg/l whereas in India the maximum permissible level is 45 mg/l. The slightly higher nitrate -N content is something that has originated in the water hyacinth system and was not originally present in inlet waters. However, further investigations on this aspect would be of importance.

Phosphate - P: Mean phosphate ion concentration of inlet waters during the study period was 53.08 mg/l whilst that of outlet waters was 24.18 mg/l. Phosphate ion concentration of inlet water varied from 9.0 mg/l to 86.25 mg/l (± 23.59). In outlet water it varied from 5.00 mg/l to 67.50 mg/l (± 17.128) (Table 1, Figure 14). The removal of phosphates by the system with plants was 52.87 percent ($P= 0.0004$). Phosphate ion concentration of VTM effluent (35.08 mg/l) was very much higher than values reported for wastewater of some textile factories in West Java.[15] High phosphate ion concentration may be due to phosphates used for softening of water to feed boilers. A reduction of 52.87% was observed in the VTM ponding system. Mosse and Chagas (1984) have reported a 33.2 percent reduction in phosphate when water hyacinth plants were grown in the tertiary treatment system for domestic sewage.Wooten & Dodd[21] have reported a 11% reduction of phosphate-P with water hyacinth while Sinclair & Forbes[13] reported a reduction of 52.7%. Wolverton & McDonald[20] reported a removal of 26% with water hyacinth and in a subsequent study Wolverton & Mc Donald[20] reported a 87% reduction in total phosphates with water hyacinth compared to 11% without plants. In contrast, Cornwell et al[6] have managed to get only a 6.6% removal of phosphate-P and they concluded nutrient removal capability is directly related to pond surface area. They showed that 2.1 ha of water hyacinth were needed in order to remove 80% of N. The corresponding P removal was about 44%. The phosphate removal efficiency of water hyacinth has been reported to decline with time. Sheffield reported (as quoted by Cornwell et al[6], that initial phosphate removal efficiency of 40 -55% declined to 5-8% after 25-30 days of operation. He recommended harvesting of water hyacinth at regular intervals for better efficiency. Harvesting of water hyacinth plants at 5 week intervals for maximum phosphate removal has also been suggested by Wolverton & McDonald.[17] Such a harvesting of water hyacinth plants has been in practice at VTM, and the 52.87% reduction in phosphate-P can be attributed to this practice of regular harvesting.

General: One of the noticeable observations made with regard to several parameters namely potassium, BOD, COD, TN, TS, VS and DS was their high levels in inlet waters, in the month of January (Figs.3, 4, 6, 7, 8, 9, & 14). According to rainfall figures for the area, the three months period from January to March had been dry with hardly any rain recorded. The high values observed can be attributed to the conservation measures adopted by the factory due to limited water resources resulting in an increase in concentration of waste constituents in inlet waters. However, what is interesting is that these parameters have not shown an unusual increase during this period in outlet waters, indicating that the treatment system has performed quite satisfactorily in keeping the pollutant levels down despite the high pollutant loads in inlet waters.

CONCLUSION

The VTM ponding system containing water hyacinth was found to perform well with regard to pH and chloride levels. It also performed satisfactorily with regard to BOD and COD with occasional fluctuations. Suspended solids of the final discharge were high and the colour was also not satisfactory. Further investigation, to overcome these drawbacks, is necessary. In general, the performance of *Eichhornia crassipes* at VTM treatment system can be described as highly promising and worthy of further investigation.

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