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Study of the Effectiveness of Water Hyacinth on Textile Dye-House Effluent Treatment: An Eco-friendly Approach

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Abstract:
The dye effluents from the various branches of the textile industry, leather industries, paper production, food technology and agriculture industries produces pollution when they are discharged in natural resources like underground stream, rivers, ponds and lakes which are the drinking water sources without any treatment. Textile dye effluent contains substantial pollution load which increases the change of physicochemical parameters. Aquatic macrophytes like water hyacinth uptake contaminants and stores in its biomass. They have high tolerance against contaminants like heavy metals and are able to absorb large quantities. In this study, an attempt is made to compare the efficiency of water Hyacinth to treat the dye effluents. Water was initially analyzed for physicochemical parameters i.e., pH, TS, DO, COD and dye concentration. In general, all the effluent samples collected were devoid of DO. There was increase in the DO after treatment as indicated by reduction of COD in the effluents. The results indicate that the water hyacinth is very efficient in reducing the pollution loads in dye effluents.

Keywords: *Water Hyacinth, effluent treatment, biological treatment, textile effluent.*

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I. Introduction

For the last many decades textile industry is the major source of environment pollution of our country. The textiles chemicals and auxiliaries are the major reason of processing water pollution. Most textile effluents (water) are discharged into surface waters such as rivers, lakes or canal either directly or through municipal sewers. This effluent contains heavy metals, organo-chlorine compounds, sulphides, dyes, oils, acids and alkalis, carbohydrates etc. Few of these chemicals are biodegradable rest are not, which have very harmful result on public health and environment.

Due to the high concentration of metallic effluents such as Ag, Cd, Zn, Fe, Mn, Cr etc generating from the untreated effluents interferes with the enzyme activity and the formation of red blood cells that may cause harmful effect in humans. Small changes in P^H may influence on the solubility of all chemical forms in the wastewater and hence leading to worsen the nutrient problems. High temperature rise due to effluent discharge may cause decrease in the amount of oxygen that can be dissolved in the water, consequently leading to oxygen stress of the water in receiving high loads of organic matter. Fine suspended solids clog the respiratory organ of fish causing it impossible to survive. These dyestuff industries discharge variety of pollutants in different processes (Mall et al., 2006). Dyes exhibit considerable structural diversity and thus become difficult to treat them by a single process. It is a fact that due their visibility, dyes are recognized easily even at the levels as less as 1 ppm. Toxicity of dyes to fauna and flora is well documented (Karaca *et al.,* 2008). Colour of textile effluents escalates environmental problem mainly because of its non-biodegradable characteristics (Southern, 1995).Color is a visible pollutant and the presence of even very minute amount of coloring substance makes it undesirable due to its appearance. The effluents from dye manufacturing and consuming industries are highly colored coupled with high chemical and biochemical oxygen demands (COD and BOD) and suspended solids. Discharge of such effluents imparts color to receiving streams and affects its aesthetic value (Aksu, 2005). The dyes are, generally, stable to light, oxidizing agents and heat, and their presence in wastewaters offers considerable resistance to their biodegradation, and thus upsetting aquatic life (Robinson *et al.*, 2001).

Lot of works has been undertaken recently to find cheaper substitutions to conventional effluent treatment processes. Recent developments of new strategies of making use of low cost, easily available biological and agricultural materials for the treatment process are gaining much importance. Water Hyacinth (*Eichhorniacrassipes*) is an aquatic plant has a huge potential for removal of the vast range of pollutants from water(Ayaz & Acka, 2001).*E.crassipes* is well studied as an aquatic plant that can improve the effluent quality from oxidation ponds and as a main component of one integrated advanced system for the treatment of municipal, agricultural and industrial waste waters(Sangeeta & Savita, 2009).

In this study, effluent was treated with Water Hyacinth to measure the parameters like BOD, COD, DO, P^H, Hardness, Temperature, TDS, TSS and Heavy metals (Cu, As, Cr, Zn, Mn, Hg) of the effluent, the efficiency of the treatment process was evaluated. Besides, the results were compared with the same parameters of effluent which was biologically treated. This study covers most of the parameters of effluent and compares the efficiency between Water Hyacinth treated and biologically treated effluent; which really make this study important.

Figure 1.1: Root of Water Hyacinth &Water Hyacinth in environment (inset)

II. Experimental

2.1 Material

Fresh & young Water Hyacinths were collected from National Botanical Garden (pollitants free fresh water), Mirpur, Dhaka, which were rinsed with tap water & preserved for about a day with tap water.The effluent was collected at day time during production peak hours from Equalization tank of ETP (Mymun Complex, DBL Group, Gazipur, Bangladesh) in suitable glass jar & a suitable plastic jar to prevent contamination of effluent for heavy metal measurement.

2.2 Methods

2.2.1 Sample preparation

Several parameters were measured for the raw effluent & then 4 liter of effluent was poured in a glass jar & another 4 was poured in plastic jar. Ensuring the roots of 2 plants was drowned into the effluent of each jar carefully. The jars were placed in an open environment, preventing from direct rain & sunlight. The parameters of the treated effluent were measured after 24 hours intervals except heavy metals. The parameters of the outlet effluent of ETP or biologically treated effluent were measured after about 72 hours for inlet effluent to process & travel through the whole setup of ETP. The parameters were measured 3 times & mean values were considered.

2.2.2 Evaluation procedure

The parameters were measured using standard methods & equipment. BOD was measured using BOD incubator, COD using COD test kit, DO using portable DO meter, temperature using standard thermometer, TDS & TSS using Digital TDS meter & Digital TSS meter, P^H using Digital P^H meter & Hardness using standard titration method. These parameters were measured in the in-house lab of DBL ETP.The Heavy metals were measured (ICP-OES by the test method EPA 3015.A) in ITS Labtest Bangladesh Ltd., Tejgaon, Dhaka, Bangladesh.

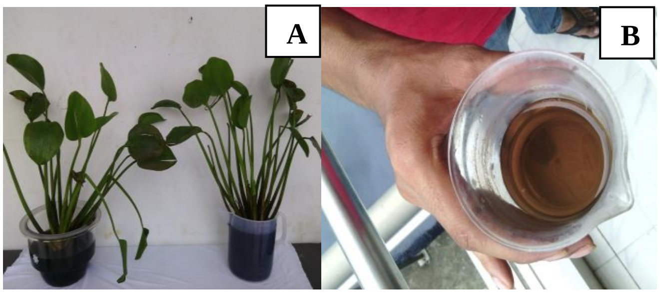

Figure 2.1: (a) Effluent under treatment with Water Hyacinth (b) effluent after treated with Water Hyacinth.

2.2.2.1 Biological Oxygen Demand (BOD)
Amount of dissolve oxygen consumed by sample of effluent incubated for 5 days at 20^0 C. (Winkler's method used with the support of BOD Incubator (VelpScientifica, Model: FOC 215i and Origin: Italy).
2.2.2.2 Chemical Oxygen Demand (COD)
The amount of oxygen was measured from one litter effluent sample by COD test using the Dichromate Reflux Method (Brand name: Hach, Model: DR900 and Origin: USA).
2.2.2.3 Dissolved Oxygen (DO)
Amount of oxygen dissolved (and hence available to sustain marine life) in a body of water such as a lake, river, or stream was measured using Portable DO meter (Brand name: Lutron, Model: YK-22DO and Origin: Taiwan.)
2.2.2.4 Total Suspended Solids (TSS)
A sample of waste water is filtered through a standard filter and the mass of the residue is used to calculate TSS. Digital TSS Meter was used (Brand name: Hach, Model: DR900 and Origin: USA).
2.2.2.5 Total Dissolved Solids (TDS)
Total dissolved solids are a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular (colloidal sol) suspended using Digital TDS Meter (Brand name: EZODO, Model: TDS5031 and Origin: Taiwan).

2.2.2.6 Heavy Metals:
The Heavy metals (Hg, As, Cr, Cu, Zn, Mn) were measured using ICP-OES and ICP MS instrument (Brand name Agilent Technologist by the test method EPA 3015.A)

2.2.2.7: *p*H
The p^H values were measured using Digital PH Meter was used (Brand name: Hanna, Model: HI 2211 and Origin: Romania.)

III. Results and Discussions

Attempted have been taken to explain the possible mechanism involved in the Water Hyacinth-based treatment systems(Zhenbim, Yicheng, Jiaqi, Qijun, & Xitao, 1993), (Reddy K. R., 1983), (Reddy K. R., 1981), (Mandi, 1994). Among them, Phytoremediation is one of the best ecological and emerging technologies for treating hazardous textile effluent. 'Phyto' means plant and 'remediation' means restoring balance or remediating.
Phytoremediation is an emerging technology that is rapidly gaining interest and promises effective and inexpens ive cleanup of hazardous waste sites contaminated with metals, hydrocarbons, pesticides & chlorinated solvents (Macek, Mackova, & Kas, 2000), (Susarla, Medina, & McCutcheon, 2002), (Xia, Wu, & Tao, 2003).Inorganic contaminants such as nitrate, ammonium, soluble phosphorus(Reddy K. R., 1983), (Reddy, Campell, Graetz, & K.M., 1982) and heavy metals(Muramoto & Oki, 1983), (Zhu, Zayed, Qian, Souza, & Terry, 1999) can be removed efficiently by Water Hyacinth through uptake and accumulation. Water Hyacinth is anionic in nature while heavy metals are cationic. So heavy metals are easily absorbed by Water Hyacinth. Considerable absorption takes place through stem (rhizome) and roots of Water Hyacinth. Considering all these, the initiation of a cost-effective and environment friendly effluent treatment process such as by Water Hyacinth can be appreciable. The main focus of this study is to observe the efficiency of Water Hyacinth for effluent treatment and compare that with the efficiency of biological treatment.

The effectiveness in the experimental result is because of bacteria and microorganisms are abundant in the subsurface root zone (rhizosphere) of the macrophytes and that reductions occur as the water passes through the rhizosphere complex of the floating macrophytes(Zhenbim, Yicheng, Jiaqi, Qijun, & Xitao, 1993). These experiments demonstrate that BOD, COD, TSS, N, P can be greatly reduced and that the resulting water can be used for irrigation and aquaculture. The extensive removal of heavy metals by Water Hyacinth may be due to extensive adventitious root system, which absorbs these toxic substances from wastewaters.

3.1 Biological Oxygen Demand (BOD)

The BOD values of raw effluent, biologically and Water Hyacinth treated effluent and standard values are shown in below:

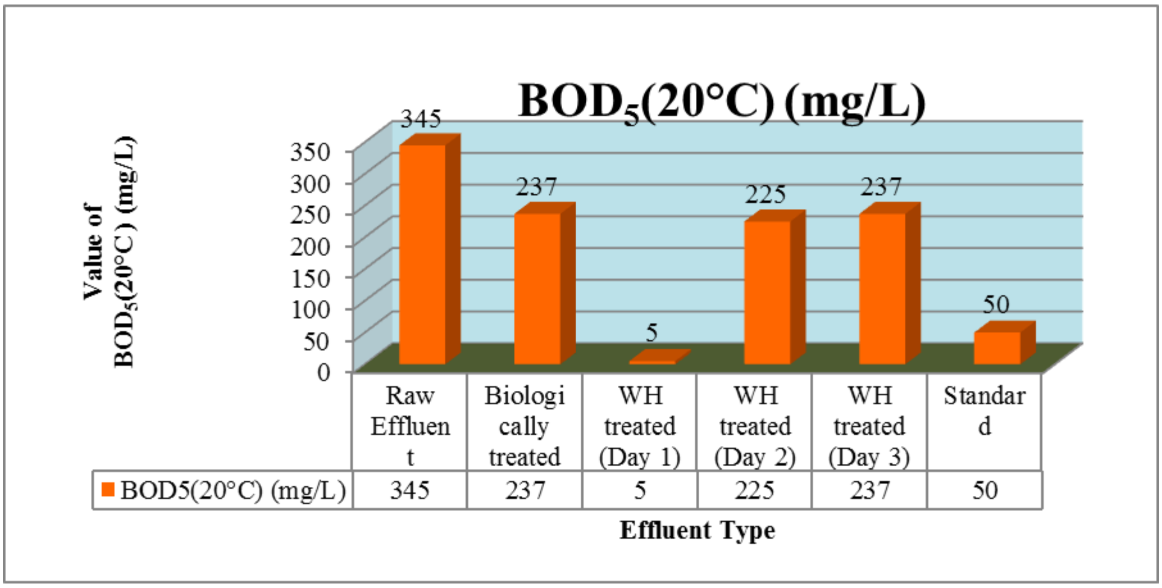

Figure 3.1 Shows that BOD value of Water Hyacinth treated effluent decreases after different time intervals on 1st day and was within standard but increased on subsequent days of treatment.

Increase of DO creates aerobic conditions in wastewater which favor the aerobic bacterial activity to reduce the BOD (Reddy K. R., 1981).The reduction in BOD can result to an increase in dissolved oxygen concentration of waste water. Considerable organic matter would reach the water by the loss of root fragments from the Hyacinths and the leaking of soluble organic compounds from the roots. Therefore, the water would probably have a fairly high biological oxygen demand (BOD)(Boyd C. E., 1970).

3.2 Chemical Oxygen Demand (COD)

The COD values of raw effluent, biologically and Water Hyacinth treated effluent and standard values are shown in below chart:

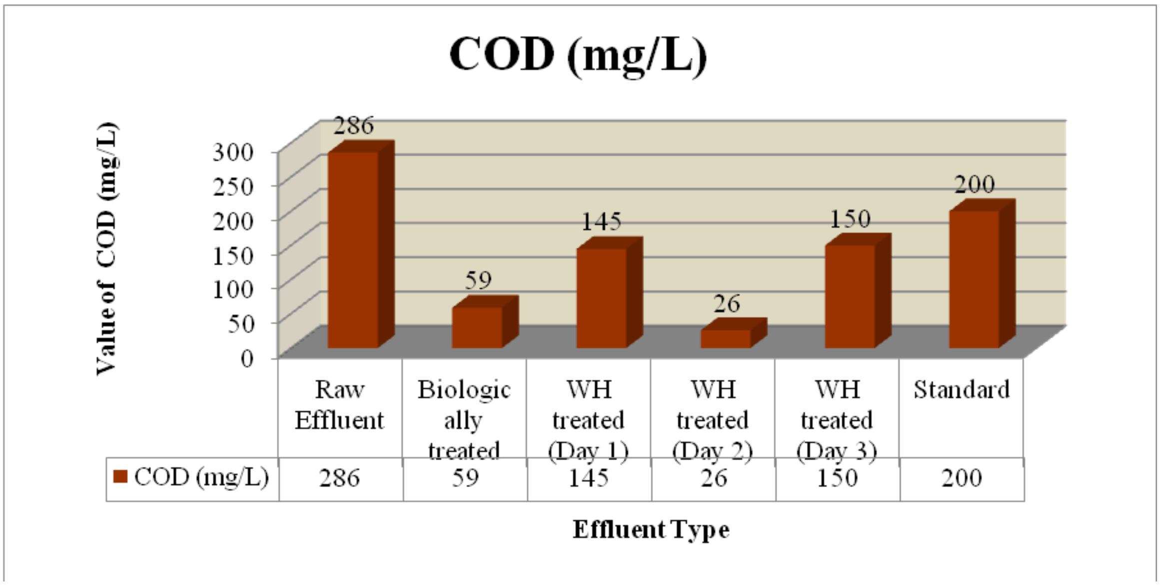

Figure 3.2: Chart showing results of COD

Figure 3.2 Shows that COD values of Water Hyacinth treated effluent were within standard on all of the days of treatment and were close to the value of biologically treated effluents.

3.3 Dissolved Oxygen (DO)

The DO values of raw effluent, biologically and Water Hyacinth treated effluent and standard values are shown in below chart:

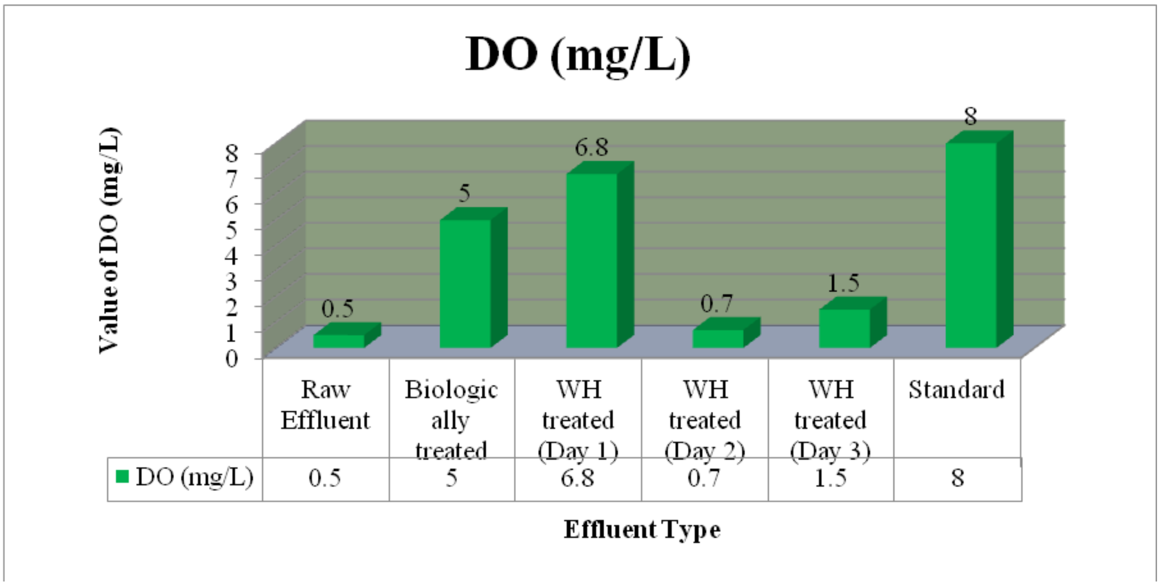

Figure 3.3 Shows that DO values of Water Hyacinth treated effluent were within standard on all of the days of treatment and were close to the value of biologically treated effluent.

Increase of DO creates aerobic conditions in wastewater which favor the aerobic bacterial activity to reduce the COD (Reddy K. R., 1981).The reduction in COD can result to an increase in dissolved oxygen concentration of wastewater.

In general, all the waste samples collected were devoid of dissolved oxygen (DO). There was increase in the DO after treatment as indicated by reduction of BOD and COD in the wastewater. According to Reddy (1981), the presence of plants in wastewater can deplete dissolved CO_2 during the period of high photosynthetic activity. This photosynthetic activity increases the dissolved oxygen of water; Large Water Hyacinth mats prevent the transfer of oxygen from the air to the water surface, or decrease oxygen production by other plants and algae. When the plant dies and sinks to the bottom, the decomposing biomass depletes oxygen content in the water body. Thus dissolved oxygen levels can reach treacherously low concentrations. This study, low dissolved oxygen (DO) might result from algae growth caused by phosphorus. Nitrogen is another nutrient that can contribute to algae growth. As the algae die and decompose, the process consumes dissolved oxygen. This can result in insufficient amounts of dissolved oxygen available for fish and other aquatic life. Die-off and decomposition of submerged plants also contributes to low dissolved oxygen. The process of decomposition is called Carbonaceous Biochemical Oxygen Demand (CBOD) (Low Dissolved Oxygen in Water, 2009).

3.4 Total Suspended Solids (TSS)

The TSS values of raw effluent, biologically and Water Hyacinth treated effluent and standard values are shown in below chart:

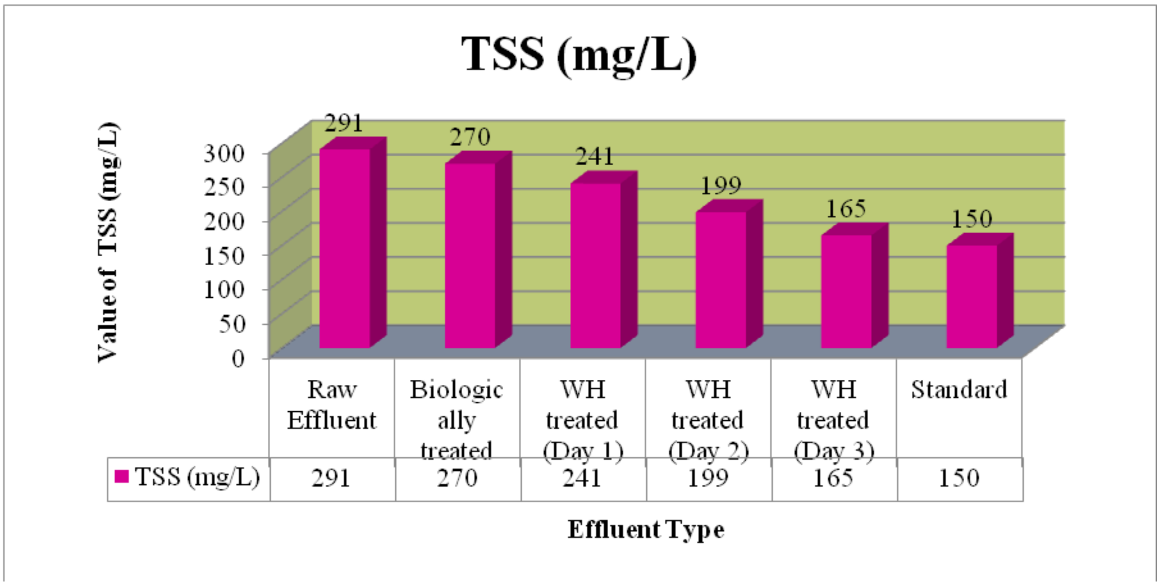

Figure 3.4: Chart showing results of TSS

Figure 3.4 Shows that TSS values of Water Hyacinth treated effluent were not within standard on all of the days of treatment but were close to the value of biologically treated effluent.
Normally it is very difficult to reduce the TSS value of effluents with many chemical treatments. In our work treatment with Water Hyacinth showed comparatively efficient results by the route that the suspended solids get trapped into the fibrous and feathery roots of Water Hyacinth. Bacteria are also trapped in the rhizosphere of the macrophytes with TSS. The fibrous - feathery roots provide attachment sites for bacterial and fungal growth.

3.5 Total Dissolved Solids (TDS)

The comparison of TDS values of raw effluent, biologically and Water Hyacinth treated effluent and standard values are shown:

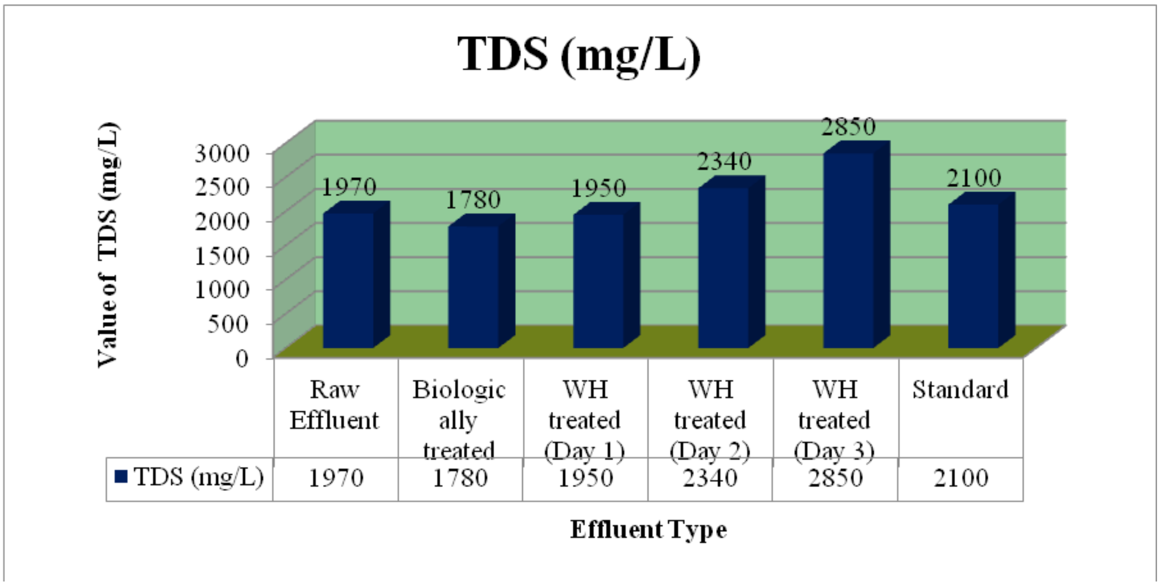

Figure 3.5. Shows that TDS value of Water Hyacinth treated effluent decreased on 1st day and was within standard and also close to the value of biologically treated effluent. The values increased on subsequent days of treatment.

In practical situation it is very difficult to reduce the TDS value of effluent. In that sense our approach of treatment with Water Hyacinth showed moderately good results. The TDS values increased on placing the plants in the jar. This increase is due to the presence of clay or other fine particles present in the plant root (Madhu & Lissy, 2011).

3.6 P^H variation

The P^H values of raw effluent, biologically and Water Hyacinth treated effluent and standard values are shown below:

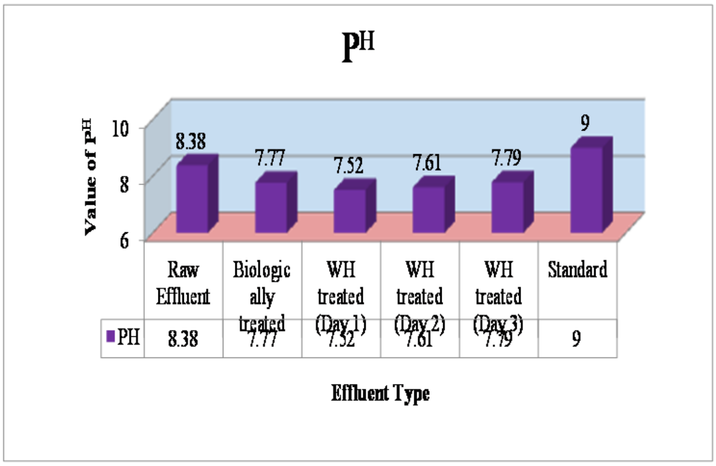

Figure 3.6 Shows that P^H values of Water Hyacinth treated effluent were within standard on all of the days of treatment and were close to the value of biologically treated effluent.

The results before and after the natural treatment with Water Hyacinth showed a considerable reduction in P^H of the wastewater. The P^H was reduced to nearly neutral in all of the days studied. The reduction in p^H is due to absorption of nutrients or by simultaneous release of [H+] ions with the uptake of metal ions(Mahmood, *et al.*, 2005). The reduction in P^H favored microbial action to degrade BOD and COD in the wastewater.

3.7 Total Hardness

The Total Hardness values of raw effluent, biologically and Water Hyacinth treated effluent and standard values are shown below:

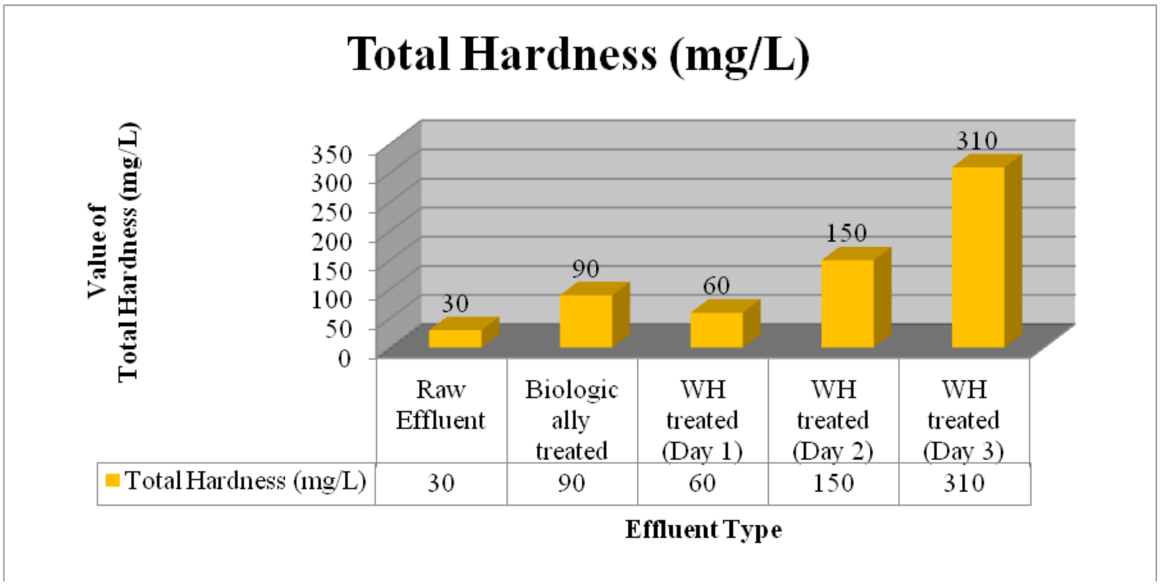

Figure 3.7 shows that Total Hardness values of Water Hyacinth treated effluent increased gradually which is favorable for aquatic lives.

3.8 Temperature variations

The values of Temperature of raw effluent, biologically and Water Hyacinth treated effluent and standard values are compiled below:

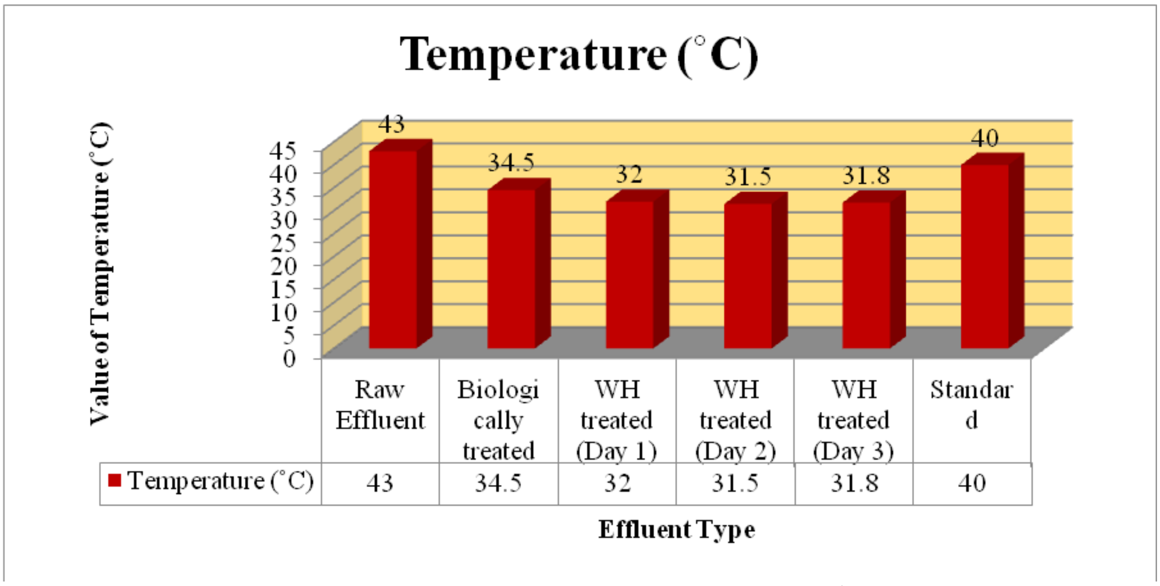

Figure 3.8: Chart showing results of Temperature (^{0}C)

Figure 3.8 shows that values of Temperature of Water Hyacinth treated effluent were within standard on all of the days of treatment and which is favorable for environment and aquatic lives.

3.9 Heavy Metals

The values of Heavy metals (Hg, As, Cr, Cu, Zn, Mn) of raw effluent, biologically and Water Hyacinth treated effluent and standard values are shown in below charts:

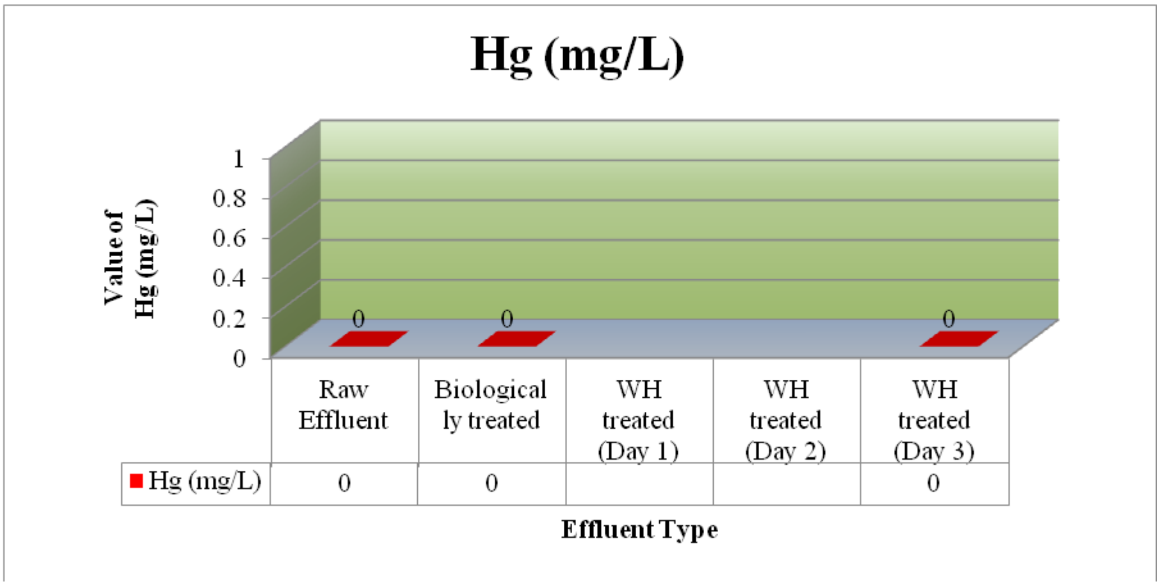

Figure 3.9.1: Chart showing results of Heavy Metal- Hg.

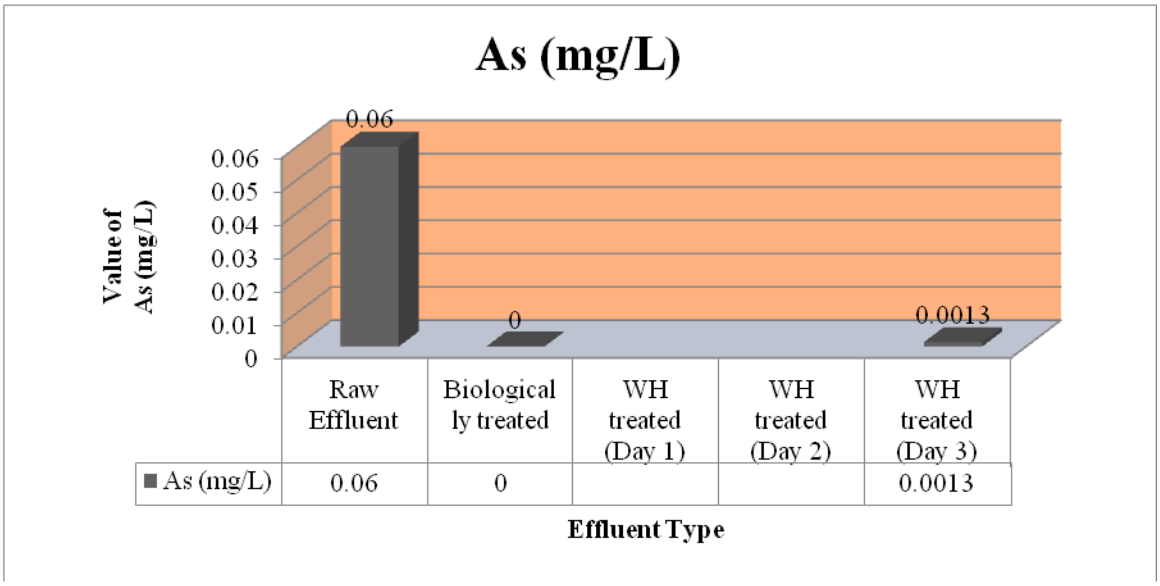

Figure 3.9.2: Chart showing results of Heavy Metal-As.

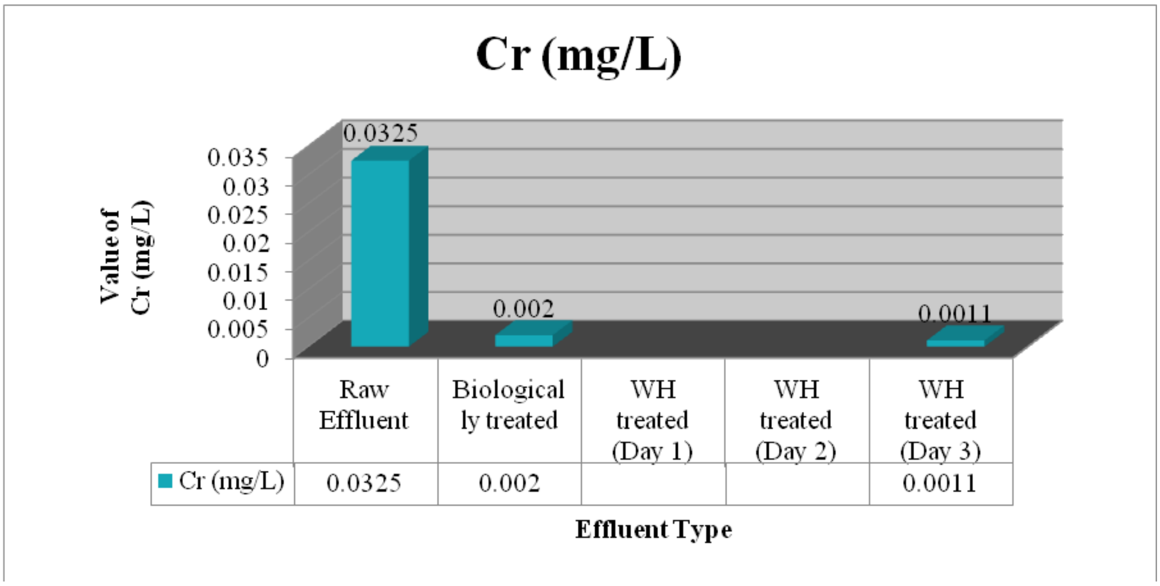

Figure 3.9.3: Chart showing results of Heavy Metal- Cr

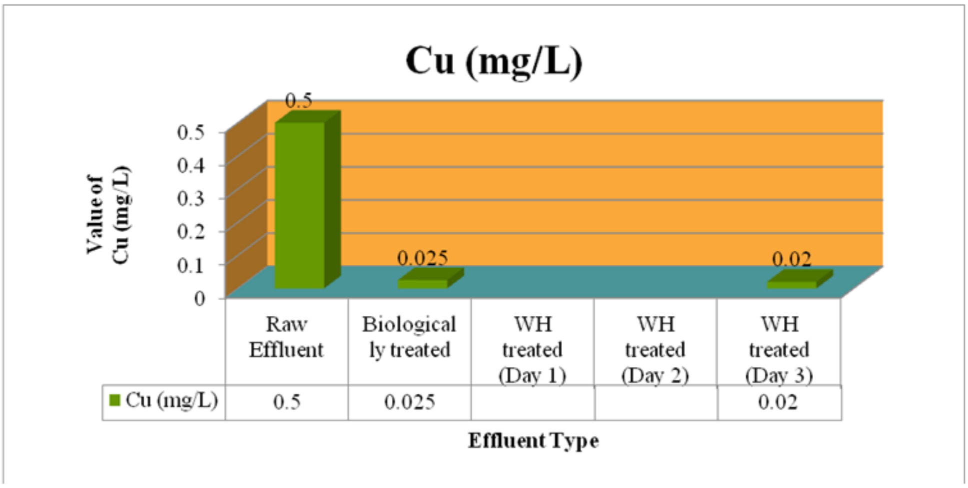

Figure 3.9.4: Chart showing results of Heavy Metal- Cu

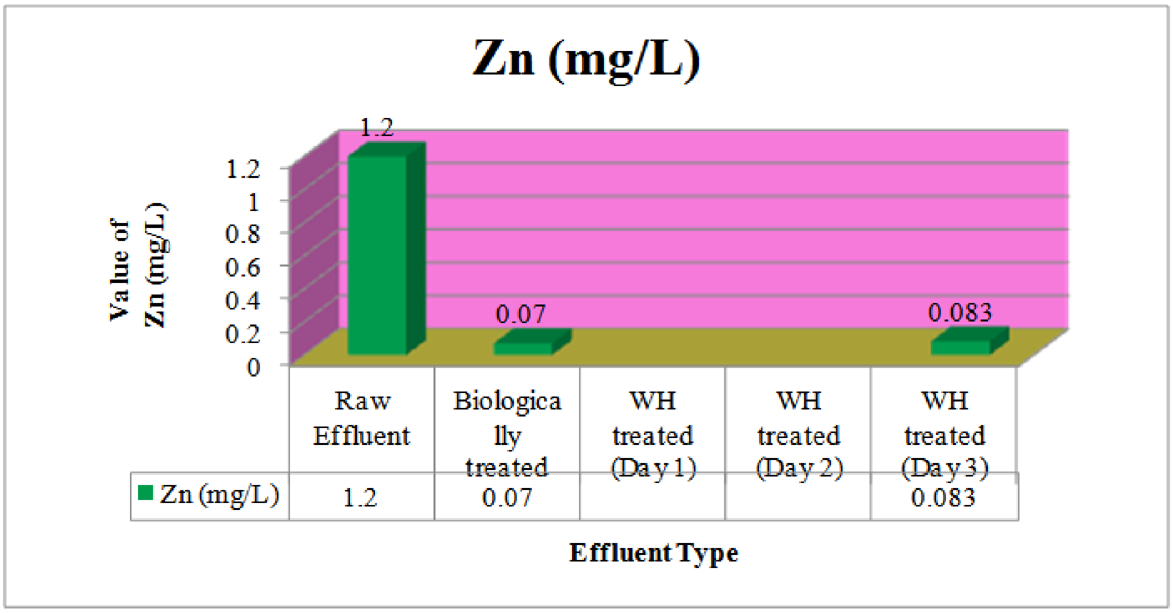

Figure 3.9.5: Chart showing results of Heavy Metal- Zn

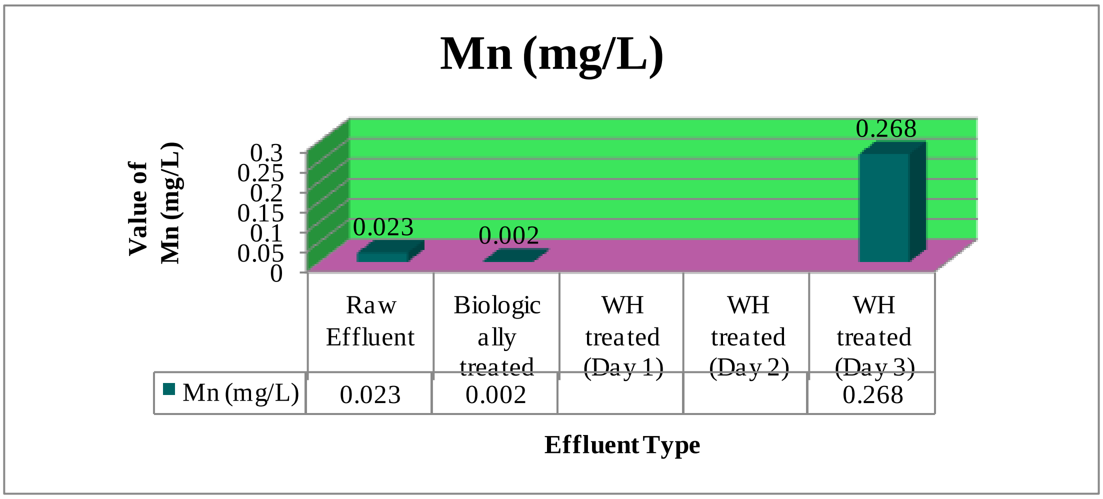

Figure 3.9.6: Chart showing results of Heavy Metal- Mn

Figures 3.9.1- 3.9.6 show that the content of Heavy metals (Hg, As, Cr, Cu, Zn) of Water Hyacinth treated effluent decreased comparatively from that of raw effluent, except that of Mn. The results were close to the value of biologically treated effluent.

The extraction of heavy metals from polluted water bodies (phytoextraction) eliminates is by three methods-

Root absorption- The roots absorb water, together with the contaminants in water. The presence of carboxyl groups at the roots system induces a significant cation exchange through cell membrane and this might be the mechanism of moving heavy metal in the roots system where active absorption takes place. In sewage systems, the root structures of Water Hyacinth (and other aquatic plants) provide a suitable environment for aerobic bacteria to function.

Foliar absorption- In addition to root absorption, plants could also derive low amounts of some contaminants through foliar absorption. They are passively absorbed through stoma cells and cracks in cuticle.

Adsorption- The fibrous and feathery roots can trap suspended solids (SS) and bacteria, which provide attachment sites for bacterial and fungal growth. The contaminants get adsorbed to the root surface by the bacteria present there. It is also due to ionic imbalance across the cell membrane of the root of immersed water haycinth.

3.10 Comparison of the experimental results with that of biologically treated effluent and some other standards

Table 1: Results of the experiment and comparison with some standards

Effluent Type / Parameter	Raw Effluent	Biologically Treated Effluent	Water Hyacinth (WH) Treated Effluent (Day 1)	Water Hyacinth(WH) Treated Effluent (Day 2)	Water Hyacinth(WH) Treated Effluent (Day 3)	DoE Standards[1]	ECR Standards[2]	BSTI Standards[3]
P^H	8.38	7.77	7.52	7.61	7.79	6-9	6.5-9	6-9
Temperature (°C)	43	34.5	32	31.5	31.8	40-45	40	40
DO (mg/L)	0.5	5	6.8	0.7	1.5		4.5-8	
Hardness (mg/L)	30	90	60	150	310			
TDS (mg/L)	1970	1780	1950	2340	2850	2100	21000	
TSS (mg/L)	291	270	241	199	165	150	100	150
COD (mg/L)	286	59	145	26	150	200	200	200
BOD_5(20°C) (mg/L)	345	237	5	225	237	50	150	50
Hg (mg/L)	<0.001	<0.001			<0.001	Varies depending on type of metal		
As (mg/L)	0.06	<0.001			0.0013			
Cr (mg/L)	0.0325	0.002			0.0011			
Cu (mg/L)	0.5	0.025			0.02			
Zn (mg/L)	1.2	0.07			0.083			
Mn (mg/L)	0.023	0.002			0.268			

The result of the effectiveness of dye-house effluent treatment by Water Hyacinth are summarized (Table-1), which shown that during the biological treatment, P^H decreases about 7%. After treating with Water Hyacinth a remarkable 10% decrease on 1st day proves the role of wattle hyacinth. For temperature, biological treatment decreased 20% but Water Hyacinth treatment results 27%. In case of biological treatment DO increased 90%, whereas with Water Hyacinth treatment increased 93% on 1st day of treatment. For Hardness comparison 67% increase by biological treatment bur remarkable efficient result (80-90) % Hardness increased by Water Hyacinth on 2nd and 3rd days of treatment. Though the effectiveness is very marginal in case of TDS observation by Water Hyacinth treatment. For TSS effectiveness comparison Water Hyacinth treatment decreased 17% in comparison to 7% decrease by biological treatment. Although there was 79% decrease in COD by biological treatment, 49% decrease on 1stday and 91% decrease on 2nd day was observe under Water Hyacinth treatment. Most significantly, Water Hyacinth treatment decreased BOD by 99%ascomparedto 31%only by biological one.

In case of Heavy metals (Hg, As, Cr, Cu, Zn, Mn), about (91-95) % decrease has been observed by biological treatment on average, whereas (93-98) % decrease by Water Hyacinth based treatment.

IV. Conclusions

The study showed that Water Hyacinth can treat effluent successfully with the reduction of many harmful parameters to a great extent. From the obtained results of the experiments we can conclude that the effluent treatment by Water Hyacinth can be considered feasible as compared to biological treatment, in terms of cost-effectiveness (as expensive chemicals and processes can be eliminated) and environment friendliness (as the treatment is with natural plant and used Water Hyacinth is completely biodegradable and can be used for biogas production). Further work is ongoing to find out the maximum efficient conditions and clear mechanism how water hyacinth play role in the purification of Due-House Effluents also to establish a path to a standard model for ‘Water Hyacinth based effluent treatment plant’ which can start a new era in the field of effluent treatment in Bangladesh and globally.

[1]DoE Standards for waste for discharge into an inland surface water body (Guide for Assessment of Effluent Plants in EIA/EMP Reports for Textile Industries, 2008)

[2]Schedule-12 (B), Environmental Conservation Rules, 1997, Bangladesh

[3]Bangladesh Standards and Testing Institute standards for wastewater

Author conflicts:
All the authors are declaring that the work is an original work by the rechargers mentioned above and there are no conflict about the work procedure and even no manipulation any part or copied.

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