WATER HYACINTH PONDS AS AN ATERNATIVE TO POLISHING PONDS FOR THE TREATMENT OF EFFLUENT FROM UASB

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by

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CERTIFICATE

This is certified that the thesis entitled **"Water Hyacinth ponds as an aternative to Polishing Ponds for the treatment of effluent from UASB"** submitted in partial fulfillment of requirement for the award of the **degree of Master of Technology in Environmental Science and Technology** at Thapar University (Patiala), is an authentic record of my own work carried out under the supervision and guidance of Dr. A.S. Reddy (Associate Professor, SEE), during September' 2012 to July' 2013. The report has not been submitted for the award of any other degree or certificate in this or any other university or institution.

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ABSTRACT

With increasing population and advancement of technology, especially in developing countries, the stress on the environment is increasing day by day. The pollutant load (readily biodegradable organic matter, inorganic and organic chemicals, toxic substances and disease causing agents) of the municipal sewage and industrial wastewaters is frequently discharged into aquatic environments (oceans, rivers, lakes, wetlands) without any treatment. This results in contamination of water and making it unsuitable for human consumption, land irrigation, fish production or recreation. Many Sewage Treatment Plants have been designed to treat the municipal sewage to make the water comply with the prescribed standards and for enhancing reclamation and re use of the water. But the effluent from the STPs does not follow up with the standards due to the inefficiency of their treatment units. The STP under study is situated at Bhattian (a village in Ludhiana). UASB is used as the biological or secondary treatment unit in this STP but due to its inefficiency in removing coliforms and nutrients from the wastewater, it does not provide a effluent complying with the standards. So, a polishing pond is provided after this unit for the post treatment of the effluent. The STP (Bhattian) is using facultative pond as the polishing pond. But, this polishing pond releases high amount of TSS (algal cells) in the effluent due to which the BOD, COD, ammonical-Nitrogen and TSS itself is higher than the limits in the effluent. And these pollutants consumes the chlorine dose (5ppm) applied for the disinfection of the effluent to reduce the MPN to 5000/100ml (a PPCB norm) and hence high dose of chlorine is required (20-25 ppm) which is not recommendable. So, Water Hyacinth ponds have been focused to be used as an alternative to the polishing ponds at the STP. The TSS, BOD, COD and ammonical Nitrogen removal efficiency in Water Hyacinth pond was found to be 79.34%, 79.38, 70.3% and 30.5% respectively, whereas, it was 63.55%, 74.39%, 38.45%, and 16.65% respectively, in the polishing pond. So, it is concluded from this study that the effluent treated with Water Hyacinth is having better characteristics than the existing polishing pond.

In this regard a design of water hyacinth pond for this STP has been designed. All the dimensions of the pond and hydraulic dimensions have been provided for the design.

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1.1 Background information

With the growth of population, urbanization and industrialization, pollution is increasing at a faster rate. Sewage is generated from every area of the world (domestic, commercial, industrial and agricultural). The ultimate receivers of this sewage are the water bodies. Sewage has a number of constituents, such as organic matter, solids, pathogens, nutrients, heavy metals etc. The wastewater is needed to be treated before disposal on land, and in rivers etc. to comply with the strict standards of wastewater discharges as well as treatment is necessary to decrease the scarcity of water and increase the possibility of water reuse.

The wastewater is directed to the sewage treatment plants and is treated by several treatment processes that includes preliminary treatment, primary treatment, secondary treatment and tertiary or advanced treatment. The process is shown in fig 1.1.

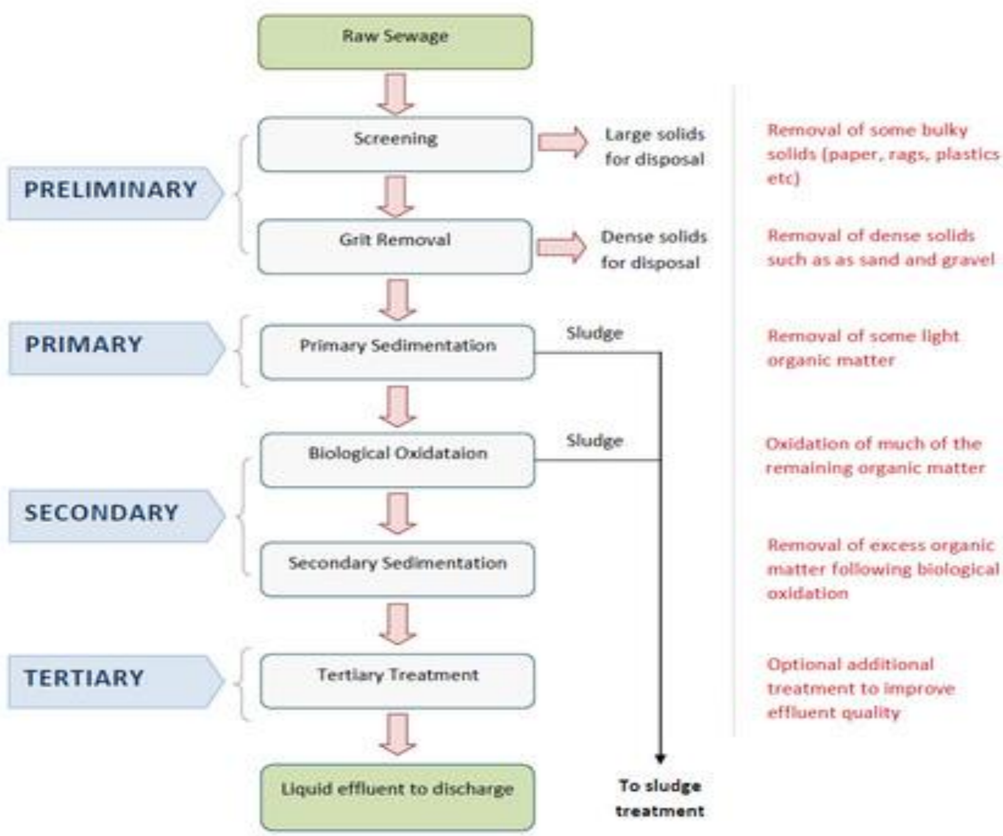

Fig 1.1 typical stages in a conventional wastewater treatment operation

CHAPTER 1
INTRODUCTION

The STP situated at Bhattian in Ludhiana, commissioned by Punjab Water Supply and Sewarage Board under the Satluj River Action Plan, is an 111MLD design capacity, UASB and polishing pond based plant. This STP treats the municipal wastewater coming from the nearby municipal area. The raw sewage after preliminary and primary treatment is distributed to the UASB cells and its effluent is then polished in a polishing pond (a facultative pond). The STP is provided with a chlorination unit just after the polishing pond to disinfect the effluent and reduce the MPN to comply with 5000/100ml (a PPCB norm). The effluent from the polishing pond was observed to have huge and variable TSS levels and ammonical nitrogen. This was hampering the chlorination process and required higher chlorine dose. At present 5ppm chlorine dose is applied which is not effective and 20-25 ppm is needed for disinfection which is very high and not recommendable. If TSS level (algal cells) and ammonical nitrogen can be lowered, the chlorine dose needed will be relatively low.

Studies show that phytoremediation technology is a good treatment option for removing contaminants from wastewater [Kutty et. al (2009) and Dhote & Dixit (2009)]. It is the least harmful method which preserves the natural state of the environment [Kutty et. al, 2009]. In this regard, Water Hyacinth (*Eichhornia crassipes)* has been studied extensively. Water Hyacinth although considered a worst weed due to its tendency to accumulate solids, heavy metals, organic matter and nutrients from water bodies and hence growing fast leading to many problems, like obstruction in navigation, interference with fishing activity, breeding of mosquitoes and other related problems. But exploiting the same properties it can be used as a resource for wastewater treatment if it can be managed properly.

So, the efforts have been made to use water hyacinth ponds for wastewater treatment. Water hyacinth ponds have been designed to treat the UASB discharged effluent of the STP for the removal or reduction of TSS, BOD, COD, nutrients and heavy metals. The performance of the water hyacinth pond is evaluated over the polishing pond. The harvested water hyacinth biomass is planned to be managed by using it as the substrate for mushroom culturing and vermicomposting. The study has been done in concern with replacing the polishing pond with water hyacinth pond.

1.2 Objectives of the study

To assess the suitability of water hyacinth pond in place of the polishing pond for the secondary treatment of sewage and making the chlorination process effective.

1.3 Importance and usefulness of work

The chlorination process is used to reduce the MPN of the effluent so that it may comply with standards but the chlorination unit of this STP is ineffective due to the high and variable TSS and ammonical nitrogen in the polishing pond effluent and high chlorine dose is needed. So, finding a technology to tackle this problem is highly needed. The technology should also be cheap, viable and eco friendly.

This work emphasizes on the evaluation of such technology for its performance over the existing polishing pond to further treat the UASB effluent of the STP and make the chlorination effective with lower doses of chlorine.

1.4 Contents of the report

This thesis report includes six chapters along with references and bibliography.

Chapter 1 (Introduction): It includes the background information of the present scenario of wastewater treatment technologies and information about the STP under study. It clearly defines the objectives fulfilled during work. It concludes the importance and usefulness of the work and states the overview of the contents of report.

Chapter 2 (Review of literature): It includes the literature survey about wastewater treatment technologies (UASB),need of polishing ponds, water hyacinth and other macrophytes and their potential utilization for wastewater treatment.

Chapter 3 (Methodology): This chapter deals with the work elements involved in the thesis including the method of collection of information about STP, development of facilities for wastewater treatment. It includes the different parameters monitored and the analytical techniques followed for analysis.

Chapter 4 (Sewage Treatment Plant, Bhattian): This chapter includes the detailed information about the STP being studied.

Chapter 5 (Results and discussion): This chapter includes the results obtained along with the discussion during thesis.

Chapter 6 (Conclusion): This chapter includes the conclusion derived from the thesis work. It also indicates the future prospects of the work and the requirements that were not fulfilled during the thesis to be fulfilled in further works.

CHAPTER 2
LITERATURE REVIEW

2.1 UASB technology for sewage treatment and the need of post-treatment of UASB effluent.

Application of UASB reactor technology for domestic wastewater treatment is rapidly growing in developing countries because of its high efficiency of organic matter removal for a variety of waste waters including sewage, its low construction costs and land requirement and its simple operation. It has great potential for sewage treatment in tropical and subtropical regions where the average sewage temperature is ~18-20 °C [**Haandel and Lettinga, 1994**].

Khalil et al. (2008) discussed about the key factors that influenced selection process against the conventional aerobic systems were their high energy requirements, unreliable power supply situation in the states, and higher O&M costs; while those in favour of UASB were their robustness, low or no dependence on electricity, low cost of O&M. Moreover, the possibility of resource recovery from biogas and aquaculture respectively also influenced the selection process.

Foresti et al. (2006) explained in his study that anaerobic processes have been extensively applied for the digestion of primary and secondary sludge in wastewater treatment plants based on conventional aerobic systems such as the activated sludge and trickling filter systems. The settleable solids fraction in the raw sewage (separated in primary settlers) corresponds to about 40–50% of the total influent organic matter, whereas the organic-rich supernatant is treated in aerobic units, where a considerable fraction of dissolved organics is converted into biological solids. A fraction of produced biological solids is returned to the aeration units (activated sludge systems) but ultimately most of it is discharged from secondary settlers as excess sludge. Therefore, the suspended solids fraction (sum of primary and secondary sludges) may account for about 40–60% of the total organic matter (present in raw sewage) to be treated in anaerobic digesters before final disposal. Thus, it is evident that anaerobic processes have played an important role in the organic load abatement and sludge manageability, mainly in large conventional aerobic treatment plants.

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Nidal Mohmoud (2008) reports that treating high strength sewage during hot period, in Palestine, in a UASB digester system is very promising. Here high strength sewage was passed through one stage upflow anaerobic sludge blanket (UASB) reactor and a UASB digester system. The one stage UASB reactor was operated in Palestine at a hydraulic retention time (HRT) of 10h and at ambient air temperature for a period of more than a year in order to assess the system response to the Mediterranean climate seasonal temperature fluctuation. Afterward, the one stage UASB reactor was modified to a UASB digester system by incorporating a digester operated at 35^0C.

The achieved removal efficiencies in the one stage UASB reactor for total, suspended, colloidal, dissolved and VFA COD were 54, 71, 34, 23% and 7 % respectively during the first warm six months of the year. The modification of the one stage UASB reactor to a UASB digester system had remarkably improved the UASB reactor performance as the UASB digester achieved removal efficiencies for total, suspended, colloidal, and dissolved and VFA COD of 72, 74, 62 and 70%.

Mirepasi et al. (2006) carried out the performance evaluation of full sacle UASB reactors in treating stillage wastwatwer. In this study two full scale UASB reactors ($420m^3$) were investigated. Conventional parameters such aa pH, temperature and efficiency of COD, BOD, TOC removal and also the upflow velocity, organic loaring rate (OLR) and hydraulic retention time were investigated. It was concluded that COD removal efficiency can be enhanced by enhancing of orgaic loading rates (OLRs) and upflow velocity, by decreasing hydraulic retention time (HRT) and by operating the reactors with new sludge.

In spite of their great advantages, anaerobic reactors hardly produce effluents that comply with usual discharge standards established by environmental agencies **[Chernicharo, 2006].**

Moreover, the anaerobic process cannot remove other undesirable constituents of sewage such as pathogenic bacteria (quantified by fecal coliforms) and nutrients expressed as nitrogen and phosphorous. From this standpoint, post-treatment is necessary to remove these parameters **[Sato et al, 2006].** The main role of the post-treatment is to complete the removal of organic matter, as well as to remove constituents little affected by the anaerobic treatment, such as nutrients (N and P) and pathogenic organisms (viruses, bacteria, protozoans and helminths) **[Chernicharo, 2006].**

Tare and Nema (2006) talked about the lacunae of this technology and its wide scale adoption specifically for sewage treatment. The said when it is applied for sewage treatment (where the undiluted BOD is between 200-300 mg/L), the unique features are not convincing for a variety of reasons. They also stated that for low strength wastewaters, there are more disadvantages than the upfront perceived advantage. They found it evident that partial primary treatment through UASB reactor makes the raw sewage more problematic to treat. Considering all problems and consequences of the technology, especially the need for an elaborate secondary or tertiary treatment, the rational for adopting a UASB for sewage is debatable.

Kumar M (2009) studied the UASB process to improve effluent quality and explained that UASB process is mostly followed by post treatment processes like extended aeration lagoon, stabilization pond, biological activated sludge, physical sand filtration to remove macronutrients, pathogens and organic materials, which is a limitation of the UASB process. In the Indian scenario, performance of UASB followed by post treatment shows considerably good results, with an average removal efficiency of BOD, COD and TSS up to 70%, 75% and 74% respectively. It is time to replace all conventional STPs by UASB process-based systems followed by post treatment to make them energy-efficient and economical.

So, at most of the STP's these UASB reactors are employed with a polishing pond which treats the UASB effluent to further polish its quality. **Oliveira and Sperling (2009)** concluded that the inclusion of a post-treatment step, be it aerobic, anaerobic or physical-chemical, can provide a substantial improvement of the effluent quality from UASB reactors in terms of BOD and TSS.

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Jordao (2004) investigated about the post treatment of UASB reactor and explained that seen as pretreatment for a secondary plant; the UASB can double the BOD or COD removal rates of conventional primary treatment, while at the same time producing lower volume of sludge. Total construction and operational cost for such type of plant comes out to be lower than that of the conventional primary plus secondary plant. Also, according to available funds, the plant may be constructed in stages: first the UASB reactor, with effluent quality better than conventional primary treatment; afterwards, as the second phase of the project, an aerobic polishing treatment.

2.2 WSP or Facultative Ponds as Polishing Pond

Traditionally waste stabilisation ponds (WSPs) are built as flow-through systems with an anaerobic, a facultative and one or more maturation ponds in series. The anaerobic pond can be substituted with great advantage by an upflow anaerobic sludge blanket (UASB) reactor. The practical advantages are that the required volume for the UASB reactor is much smaller than the anaerobic pond (20 to 30 times) and that the biogas in the UASB reactor is captured, so that odour problems can be eliminated. The UASB reactor is neighbour friendly and can be used in densely populated areas **[Frassinetti et al., 1996]. Frassinetti** also said that since the UASB effluent has good transparency, photosynthesis in the ponds is intense and pH increases due to biological carbon dioxide consumption, accelerating the death rate of pathogens and opening the possibility of reducing nutrients: Nitrogen by desorption of gaseous NH_3 and phosphorus by phosphate precipitation.

Rapid and efficient pathogen removal can be achieved in shallow stabilization ponds but their effluent BOD and TSS is relatively high, due to presence of algae **[Steen et al., 1999].**

Cavalcanti et al. (2001) described in his study that facultative ponds are largely used for post- treatment of effluents from anaerobic reactors. When an efficient anaerobic pretreatment is applied prior to the sewage discharge into the pond, the residual organic material and suspended solids concentrations in the digested sewage are reduced, but often the main objective of polishing ponds is to improve the hygienic quality, measured by the concentration of two indicator organisms: helminth eggs and faecal coliforms (FC). The FC removal is normally the slowest process and for that reason becomes the main design criterion for a polishing pond. For this the nomenclature polishing pond has been adopted to name those ponds intended for the post treatment of effluents from efficient anaerobic systems, thus distinguishing them from the stabilization pond, which treats raw sewage.

The Brazilian experience has shown that polishing ponds can absorb the UASB effluent's organic load, so that they can be designed as maturation-like ponds, i.e. shallow ponds, aiming at pathogens removal **[Cavalcanti 2003; von Sperling & Mascarenhas 2005].**

Abis and Mara (2003) constructed three pilot-scale facultative ponds at Esholt wastewater treatment works in Bradford, West Yorkshire, UK. The ponds were operated in parallel to test the effect of surface BOD loading on performance and the maintenance of facultative conditions. The performance criteria adopted were BOD, SS and ammonia removal. The criterion for facultative conditions was the presence of an algal population maintaining aerobic conditions at the pond surface. Filtered BOD removal was found to be more than 90%, non-seasonal, and related to areal BOD loading. SS removal was also found to be non-seasonal, at around 95% but not related to areal BOD load. Ammonia removal was seasonal (32-48% October to March; 60-81% March to July) and related to areal BOD load. At the test loadings (60, 110 and 169 kg/ha.d) an algal population was not maintained in winter. The initial results indicate that a much lower loading is required to maintain facultative conditions than to optimise BOD and SS removal.

Polishing ponds are units conceived for the post-treatment of the effluents from anaerobic reactors, are designed as maturation ponds, and aim at a further removal of organic matter and a high removal of pathogenic organisms **[Sperling and Mascarenhas, 2005].**

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Waste stabilization ponds (WSPs) are widely used as natural treatment systems because of their low cost and simplicity of construction, operation, and maintenance. However, the major operational problem encountered in WSPs is the excessive discharge of particles in the effluent caused by algal activity especially during the summer season. Therefore, it is essential to polish the effluent from the WSPs by removing over-discharged suspended solids (SS), biochemical oxygen demand (BOD), and nutrients **[Yi et al., 2009].**

The discharge of nutrients into surface water bodies may cause increased algal biomass as a result of the eutrophication process (abnormal algae growth due to the nutrients discharged). It is known that 1.0 kg of phosphorus can result in the reconstruction of 111 kg of biomass, which corresponds to approximately 138 kg of chemical oxygen demand in the receiving body. Similarly, the discharge of 1.0 kg of nitrogen can result in the reconstruction of approximately 20 kg of chemical oxygen demand under the form of dead algae [**Chernicharo, 2006**].

The major operational problem encountered in WSPs is the excessive discharge of particles in the effluent caused by algal activity especially during the summer season. Therefore, it is essential to polish the effluent from the WSPs by removing over-discharged suspended solids (SS), biochemical oxygen demand (BOD), and nutrients **[Yi Q et al., 2009].**

2.3 Macrophyte ponds for wastewater treatment

Kivaisi (2001) studied about the potential of constructed wetlands and stated that they are among the recently proven efficient technologies for wastewater treatment. Compared to conventional treatment systems, constructed wetlands are low cost, are easily operated and maintained, and have a strong potential for application in developing countries, particularly by small rural communities. However, these systems have not found widespread use, due to lack of awareness, and local expertise in developing the technology on a local basis.

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It has been seen from his study that at a hydraulic application of 0.86–1.44 m^3 d^{-1}, reed beds with *Phragmites australis*, organic removal of 48–62%, TSS of 58–67% and a parasitic removal of 71–95% were obtained in Morocco.

He stated in his literature that in Egypt, 100% removal of parasitic ova from domestic wastewater intended for agricultural use was achieved. In Iran, a subsurface flow reed bed (*P. australis*) of 150 m^2 was tested for treating municipal wastewater. At an organic loading of 200 kg/ha/day which is higher than previously recommended (<133 kg/ha/day), removal efficiencies of 86, 90, 89, 34, 56 and 99% for COD, BOD, TSS, TN, TP, and fecal coliform bacteria, respectively, were obtained. No clogging problems were experienced.

Aquatic systems are special type of constructed wetlands that treat industrial, municipal and agricultural wastewaters by floating and submerged aquatic plants. They can remove suspended materials, nutrients and heavy metals from wastewater with great efficiency **[Zawahry and Kamel, 2004].**

Cristian Frers in his article explained that Treatment systems using aquatic plants consist of shallow reservoirs containing floating or submerged aquatic plants. The best studied wastewater systems are those utilizing duckweed (Lemna minor). Generally, treatment systems break into two types based on the dominant plant types. The first type uses floating plants which are distinguished by their ability to meet their need for carbon dioxide and oxygen directly from the atmosphere. Such plants derive their mineral needs from the water. The second type of treatment system consists of submerged plants, which are distinguished by their ability to absorb oxygen, carbon dioxide, and minerals directly from the water column. Submerged plants are easily inhibited by high turbidity because their photosynthetic parts are under water.

Stottmeister et al. (2003) in his study on effects of plants and microorganisms in constructed wetlands for wastewater treatment stated that the active reaction zone of constructed wetlands is the root zone (or rhizosphere). This is where physicochemical and biological processes take place that are induced by the interaction of plants, microorganisms, the soil and pollutants. Further he explained that one important aspect of the complex processes taking place in the rhizosphere is the interaction between roots/rhizomes and the soil matrix. The soil is the main supporting material for plant growth and microbial films. Moreover, the soil matrix has a decisive influence on the hydraulic processes. Both chemical soil composition and physical parameters such as grain-size distributions, interstitial pore spaces, effective grain sizes, degrees of irregularity and the coefficient of permeability are all important factors influencing the biotreatment system. As far as constructed wetlands are concerned, it seems that the main parameter influencing the soil hydraulics is the grain-size distribution.

Zimmels et al., 2004 showed in his study that plants enhance the removal of pollutants by consuming part of them in the form of plant nutrients. This applies to urban and agricultural wastewater, in particular, where treatment units of different sizes can be applied at the pollution source. The effectiveness of wastewater purification by different plants was tested on laboratory and pilot scales. The growth rate of the plants was related to the wastewater content in the water. Batch and semicontinuous experiments verified that the plants are capable of decreasing all tested indicators for water quality to levels that permit the use of the purified water for irrigation. This applies to biochemical oxygen demand (BOD), chemical oxygen demand, total suspended solids. pH, and turbidity. The higher the wastewater content in the mixture, the more effective the treatment by the plants.

Reddy et al. (1989) Laboratory experiments were conducted to determine the effectiveness of three floating and six emergent aquatic macrophytes in improving domestic wastewater quality, based on their capacities for O_2 transport into the effluent. Oxygen transport by the plants was measured in terms of both O_2 consumed by the effluent (biological O_2 demand reduction--BODs) and increased effluent dissolved O_2. Two floating plants, pennywort (Hydwcotyle nmbellataL.) and waterhyacinth [Eichkornia crasslpes (Mart.) Solms], and the emergent plants pickerelweed (Pontederla cordata L.) and common arrowhead (Sagittaria latifolia L.), were superior in improving primary sewage effluent quality, by reducing BOD5 up to 88%, NH_4- N up to 77%, and increasing dissolved O2 up to 6.1 mg L^{-I}. Nitrification rates in pennywort- and water hyacinth-based water treatment systems were calculated to be in the range of 12 to 47 kg NH_4- N ha^{-1} d^{-1}. Oxygen transport through plants accounted for up to 90% of the total O_2 transported into the effluent. In the biological aeration treatments, negligible effluent (NO_3 + NO_2)- N levels were measured, but 65 to 100% NH_4-N loss occurred both by plant assimilation ad by sequential nitrification-denitrification reactions.

Zimmo et al. (2005) assessed the removal efficiency in pilot scale algae- based ponds (ABP) and duckweed ponds (DBPs) for two periods of 4 months each. He studied the effect of in both the systems a linear correlation between ponds organic surface loading rates and the corresponding BOD removal rates was observed in both the systems. For both the period higher BOD and TSS removal efficiencies were found in DBPs compared to ABPs. Nitrogen removal rates in ABP were linearly correlated with BOD surface loading rates and nitrogen loading rates, while in DBPs, N removal rates were almost constant irrespective of BOD or Nitrogen. Overall Nitrogen removal rate in algae system was significantly higher than that in duckweed system. Organic loading had no effect on total phosphorous removal efficiency in both the systems. Higher phosphorous removal efficiency was achieved in the duckweed system than in algae system. In ABPs as well as in DBPs, fecal coliform were better removed during low organic loading in comparison with high organic loading. During the two operational periods, higher fecal coliform removal efficiency in the algae system than in the duckweed system was observed.

2.4 Water hyacinth for wastewater treatment

Water hyacinth belongs to the family *Pontederiaceae* and genus *Eichhornia*. The flower resembles those of the family *Liliaceae*, genus *Hyacinthus*; therefore it is called water hyacinth. The mature water hyacinth plant consists of roots, rhizomes, stolons, leaves, inflorescences and fruits clusters.

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Biological classification of the common water hyacinth

Kingdom: *Plantae*

Subkingdom: *Tracheobionta*

Superdivision: *Spermatophyta*

Division: *Magnoliophyta*

Class: *Liliopsida*

Subclass: *Lilidae*

Order: *Liliales*

Family: *Pontederiaceae*

Genus: *Eichhornia*

Species*: crassipes*

Source: (USDA, 2010)

Water hyacinth (*Eichhornia crassipes)* is a noxious weed that has attracted worldwide attention due to its fast spread and congested growth which lead to serious problems in navigation, irrigation, power generation. On the other hand when looked from a resource angle, it appears to be valuable resource with several unique properties **[Malik A., 2007].**

Fresh water hyacinth plant contains 95.5% moisture, 0.04% N, 1.0% ash, 0.06% P_2O_5, 0.20% K_2O, 3.5% organic matter. On a zero-moisture basis, it is 75.8% organic matter, 1.5% N, and 24.2% ash. The ash contains 28.7% K_2O, 1.8% Na_2O, 12.8% CaO, 21.0% Cl, and 7.0% P_2O_5. **[JAFARI N., 2010].**

Water hyacinth systems were used mostly in regions with warm climate because of plant sensitivity to low temperatures and frost **[Singhal and Rai, 2003].**

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From a pilot plant study, **Kim and Kim (2000)** examined the individual effects of water hyacinth leaves, stems, and root mats on algal concentration. He stated that waste water as flows from WSPs passed through the WHPs, root mats in the bottom as well as leaves and stems on the water surface of WHPs separated and controlled significant amount of algal cells by various mechanisms such as attachment, settling, respiration and suppression of algal growth. Attachment of algal particles to the plant roots was very similar to adsorption processes; i.e. there is a maximum capacity in a given weight of roots. However, effluent algal concentrations did not increase at saturation probably because of the sloughing-off of attached particles as a clump from the roots and generation of new attachment sites due to the growth of roots. The result of his study inferred that filtration and settling contributed almost equally to the separation of algal particles.

E. crassipens an aquatic plant that can improve effluent quality from oxidation ponds and as a main component of one integrated advanced system for treatment of municipal, agricultural and industrial wastewaters **[U.S. EPA, 1988; Sim, 2003; Wilson et al., 2005; Mangabeira et al., 2004; and Maine et al., 2001].**

Water hyacinth roots naturally absorb pollutants, including such toxic chemicals as lead, mercury, and strontium 90 (as well as some organic compounds organisms is either destroyed or changed, and the biological diversity of the invaded area is greatly reduced **[Masifwa, WF et al., 2001, Brendonck, 2003].**

Sooknah and Wilkie (2004) studied the potential of three floating aquatic macrophytes (water hyacinth, pennywort and water lettuce) to improve the water quality of anaerobically digested flushed dairy manure wastewater (ADFDMW). In terms of reductions in nutrients, chemical oxygen demand (COD), solids and salinity, water hyacinth performed better than water lettuce and pennywort in diluted ADFDMW. Reduction in nutrients and COD followed first-order kinetics, with water hyacinth exhibiting the highest rates. For water hyacinth, total

Kjeldahl nitrogen was reduced by 91.7%, ammonium by 99.6%, total phosphorus by 98.5%, and soluble reactive phosphorus by 96.5% in 31-day batch growth.

The water hyacinth plants and bacteria only take up ammonium as a nitrogen source because plants and bacteria prefer ammonium as a nitrogen source over nitrate. Recent experiments have verified this hypothesis suggesting that nitrate uptake by plants in CWs is almost 0.5% compared to that of ammonium **[Mayo and Mutamba, 2005].**

Mangkoedihardjo (2006) investigated the performance of a low BOD/COD ratio, ranging from 0.05 and 0.11 by means of phytotreatment using a plant species Eichhornia crassipes. The initial concentrations of BOD and COD were less than 100 mg/L and 1.000 mg/L respectively. The hyacinth treatment in a batch reactor demonstrated that the final BOD/COD ratios increased ranging from 0.3 and 0.5 during 2 months. The hyacinth treatment performances on increasing biodegradability were dependent on the initial COD concentration. For the initial COD of less than 500 mg/L brought about the increasing rate of the BOD/COD ratio was 1.5 times faster than for the initial COD of more than 500 mg/L.

An effective method to separate algae and other particles from the effluent of WSPs is the use of water hyacinth ponds (WHPs). The WHPs can remove particles through sedimentation and filtration (due to the dense root system of the water hyacinths). Their leaves and stems help control algal growth by preventing sunlight from reaching the water surface. **(Yi Q et al., 2009)**

Two principal mechanisms for the biological removal of nitrogen are nitrification and denitrification. In nitrification and denitrification, a reduction of nitrogen is accomplished by two conversion steps. In the first step, ammonia is nitrified to nitrate. In the second step, nitrate is reduced to nitrogen gas. For nitrification to occur, each gram of ammonia nitrogen theoretically requires 4.57 g of oxygen. Denitrification requires an anoxic condition because denitrifying bacteria obtain energy for growth from the conversion of nitrate to nitrogen gas, but require a carbon source for cell synthesis. Thus, to convert each gram of nitrate to nitrogen gas, 5–9 g of carbon must be supplied. The approach for achieving nitrification and denitrification includes the creation of a series of alternating aerobic and anoxic stages which are usually established by external oxygen and carbon supplies [R. Crities, 1998]

Rogers and Davis (1972) estimated that absorption by a hectare of water hyacinth amounted to 2,500 kilogram (kg) of nitrogen and 700 kg of phosphorus per year if maximum growth could be sustained, which is equal to nitrogen and phosphorus released by 800 people in a day.

In the comparative experiment carried out by Orth and Sapkota (1988), Total Kjeldahl Nitrogen or TKN (which is ammonium nitrogen plus organic nitrogen) and Total Phosphorus (TP) were reduced by 73.7% and 71.4% respectively in the facultative pond with water hyacinth whereas TKN in the facultative pond without water hyacinth was reduced to 30% only during the same period and TP reduction was not realized at all (**Maharjan and Ming, 2012).**

Maharjan and Ming (2012) also showed the fate of metals with respect to water hyacinth in his study. He stated that water hyacinth has the potential for purifying not only domestic wastewater but also industrial wastewater. It can readily absorb and concentrate heavy metals such as lead, cadmium, mercury, and nickel in high quantity without exhibiting visible signs of toxicity. Tissue analysis of plants from different sources reveals that water hyacinth is able to absorb and accumulate a variety of heavy metals such as iron, manganese, zinc, aluminium, cadmium, lead, mercury, nickel, silver, cobalt, strontium, chromium and copper. Even platinum was found in traces

CHAPTER 3
METHODLOGY

3.1 Introduction

To achieve the objective, work was carried out on the following work elements:

- Study of STP and its performance for understanding the problem
- Learning and standardizing the analytical techniques
- Development of experimental water hyacinth pond to be used as an alternative to the existing polishing pond
- Treatment of the UASB effluent in the water hyacinth pond
- Evaluation of the treatment process and design of water hyacinth pond

3.2 Study of STP and its performance for understanding the problem

The STP under study was visited for understanding the scheme of treatment, dimensional details, operation and control details and the treatment units. The treatment process, treatment units and their dimensions and the actual performance of the STP were obtained and understood.

3.3 Learning and standardizing the analytical techniques

Sampling and analysis of water and wastewater for the parameters, given in table 3.1, has been learnt and standardized. The American Public Health Association (APHA) manual of Standard Methods For The Examination Of Water And Wastewater (20th edition, 2012) was followed for the analysis of the parameters indicated in the table.

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S. no.	Parameters	Method	Reference
1	Alkalinity	Titrimetric method	APHA(2008), 20th edition, method 2320 B
2	COD	Open reflux method	APHA(2008), 20th edition, method 5220 B
3	BOD	5- day BOD test	APHA(2008), 20th edition, method 5210 B
4	TSS	Total suspended solids dried at 103°-105 °C	APHA(2008), 20th edition, method 2540 D
5	TDS	Total dissolved solids at 180 °C	APHA(2008), 20th edition, method 2540 C
6	Total-P	Vanado-molybedo phosphoric acid method	IS-3025 (PART 31)
7	TKN	Macro kjeldhal method	APHA(2008), 20th edition, method no. 4500-N
8	Nitrite	Colorometric method	APHA(2008), 20th edition, method no. 4500- NO_2 B
9	Nitrate	UV Spectrophotometry	APHA(2008), 20th edition, method no. 4500- NO_3 B
10	Sulphate	Gravimetric method	APHA(2008), 20th edition, method no. 4500- SO_4^{2-} C
11	Chloride	Argentometric method	APHA(2008), 20th edition, method no. 4500- Cl^- B

Table3.1 Analytical techniques for testing of wastewater parameters

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3.4 Development of experimental water hyacinth pond

Four experimental water hyacinth ponds were established adjacent to the polishing pond and the pre aeration unit of the STP. The ponds were erected to evaluate the potential of water hyacinth to treat the waste water and also to understand the pattern of uptake and allocation of heavy metals from the waste water. Pond 1 was supposed to serve as control pond with no water hyacinth and treatment to take place as it takes place in the polishing pond. Pond 2 was to serve as water hyacinth pond to treat the waste water. The other two ponds were constructed to check the dynamics of heavy metals between water and the water hyacinth at different heavy metal concentrations of the wastewater. Due to time constraints, only pond 2 was worked upon for the treatment of the waste water.

The system has horizontal water flow. Each pond was be 1m wide, 3m long and the liquid depth was kept 1m. Each pond had a total area of 3 m^2 and the capacity of 3 m^3. The inlet to the pond was a flexible pipe of 1 inch diameter carrying the effluent from UASB Reactor to the Water Hyacinth Pond at the rate 20 m^3/day. The experimental system design is shown in fig 3.1 (a) and fig 3.1(b) and the dimensions of the pond are shown in fig. 3.2.

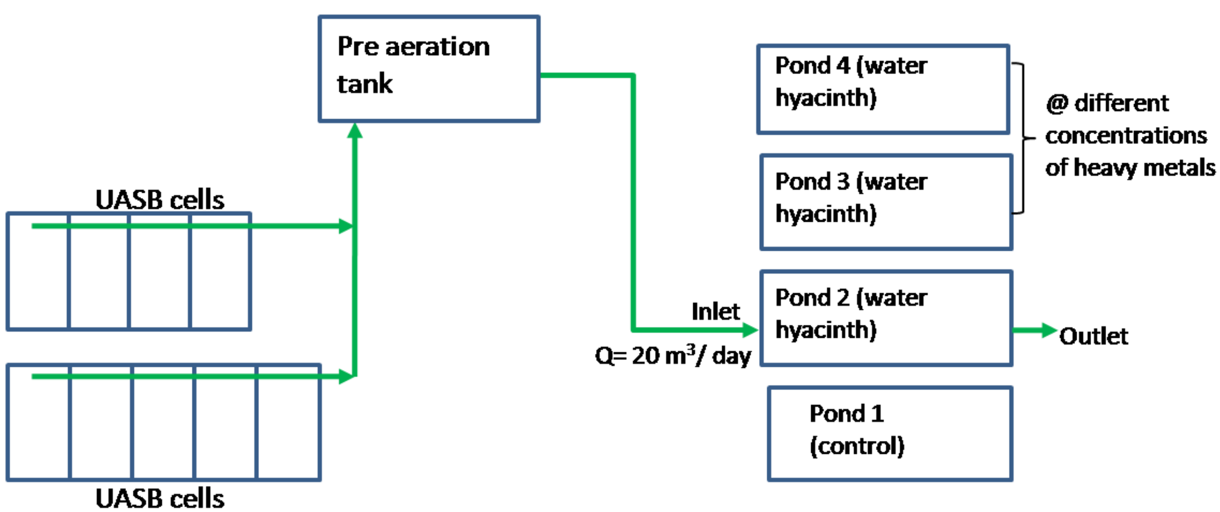

Fig.3.1 (a) line diagram of experimental design

Fig 3.1 (b) experimental water hyacinth ponds

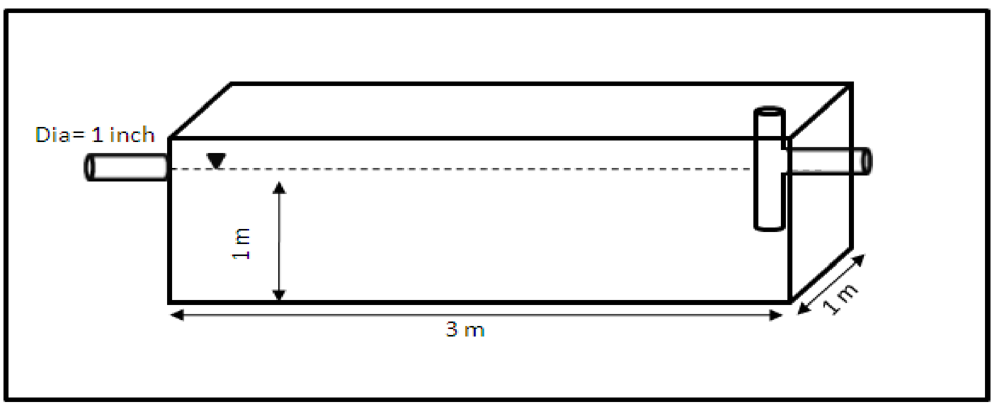

Fig.3.2 dimensions of each pond

Young plants of the aquatic weed, Water Hyacinth, were collected from a natural pond near Gill village (10 km east of Ludhiana City) and planted into the pond (4kg weed biomass was planted).

3.5 Treatment of the UASB effluent in the water hyacinth pond

The UASB effluent was passed through the water hyacinth pond for the treatment. Retention time of the wastewater in the water hyacinth pond was about 5 days to one week (the doubling time of water hyacinth) and surface loading rate was 0.2 m/day.

Weekly once, one third of the water hyacinth biomass was harvested and removed. For this the pond was divided into 3 sections and the biomass was harvested from one section at a time. The harvested biomass was weighed (wet weight) and then chopped, sun dried, weighed (dry weight) and stored for metal analysis.

3.6 Evaluation of the treatment process and design of water hyacinth pond

Influent and effluent from the water hyacinth pond was collected on weekly basis (April to June 2013).

The collected sample were analyzed for the parameters mentioned in table 3.2. Until the analysis was over the samples were stored at 4^0C in a cold storage room.

Parameters	Sampling points(water hyacinth pond)	
	Inlet (UASB dicharge)	outlet
pH	✓	✓
Alkalinity	✓	✓
COD	✓	✓
BOD	✓	✓
TSS	✓	✓
TDS	✓	✓
Total-P	✓	✓
TKN	✓	✓
Nitrite	✓	✓
Nitrate	✓	✓
Sulphate	✓	✓
Chloride	✓	✓

Table 3.2 Parameters to be characterized at different sampling points

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The performance of water hyacinth pond was evaluated over the existing polishing pond for the effectiveness of treatment. The outlet concentrations of the polishing pond and of the water hyacinth pond were shown in table 3.1 for comparison. The outlet concentrations of WH pond were also compared with the prescribed effluent limits for discharge into surface water bodies.

Designing of the pond

The influent and effluent concentrations of BOD, TSS, Nitrogen and Phosphorous were used into the design.

Using the influent BOD and the inflow rate of the pond, BOD loading was found out.

Typical BOD_5 loading rates, for the water hyacinth ponds, are given in table 3.3.

Type	Purpose	Typical BOD_5 Loading, kg/ha-d	Advantages	Disadvantages
Aerobic Non-aerated	Secondary Treatment	40-80	Limited mosquitoes; limited odors	More land area required; harvesting may be more dffficult (depends on pond configuration)
Aerobic Non-aerated	Nutrient Removal	10-40	Limited mosquitoes; limited odors nutrient removal	More land area required; harvesting may be more difficult (depends on pond configuration)
Aerobic Aerated	Secondary Treatment	150-300	No mosquitos; no odors; higher organic loading rates; reduced land area	Additional harvesting required; supplemental power required
Facultative/Anaerobic*	Secondary Treatment	220-400	Higher organic loading rates; reduced land area	Increased mosquito population; potential for odors

a Only suitable where odors and mosquitoes may not be a problem.

(Source- **EPA/625/1-88/022, September 1988)**

<u>Table 3.3</u> type of water hyacinth systems.

Area of the water hyacinth pond is obtained as:

$$\textbf{Area of water Hyacinth pond}(\textbf{ha}) = \frac{\textbf{BOD}_5\ \textbf{loading}\left(\frac{\textbf{kg}}{\textbf{d}}\right)}{\textbf{typical BOD}_5\ \textbf{loading}\ (\textbf{kg}/\textbf{ha.day})}$$

$$= \frac{\textbf{BOD}_5 \times \textbf{Q}}{\textbf{typical BOD}_5\ \textbf{loading}}$$

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Surface loading rate was calculated/

The no. of cells of the pond to be designed was planned. Aspect ratio of each cell was decided and the dimensions of the pond were calculated.

Depth of the pond is taken as the maximum root zone depth, i.e. 1m and additional depth for sediment sludge storage is taken as 0.2 m. the freeboard for macrophyte pond is typically taken as 0.3m.

Then the inlet and outlet channel and its slope, width and depth of flow were calculated using the manning's equation:

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

No. and dimensions of the distribution boxes head of the pipe, inlet channel to the cell of the pond, the dimensions of each cell of the pond, weir loading rate for inlet and outlet weirs, depth of flow over the weir were calculated based on the results obtained from the tudy.

CHAPTER 4
SEWAGE TREATMENT PLANT (BHATTIAN)

4.1 STP under study

The STP is situated at Bhattian village in Ludhiana. It has a design capacity of 111 MLD and receives wastewater from the municipal area of the village. The STP began its operation in year 2007 on UASB (Upflow Anaerobic Sludge Blanket) Technology under Sutlej Action Plan (SAP). Presently this STP is managed by Punjab Water Supply & Sewage Board. Dimensions and capacity details of various units and facilities of the STP are given in the table 3.3.

Units	**Details**
Inlet pump and inlet chamber	Inlet Pumps :-10 each of 36 MLD Inlet Chamber :- One unit Size:- 4m x 2 m Receive@2.57 m^3/sec at peak flow Detention Period :- 30 Seconds
Screen Chamber	2 no. Size:- 2.2m x 8.0m Manual Screen: 6 mm bar Spacing – 1 no. Mechanical Screen: 15 mm bar Spacing – 1 no. Conveyor Belt motor:- 0.5 HP with suitable chute arrangement Volume of Screening:- 0.6-0.9 m^3 /d Angle of inclination: - 60 degrees. Velocity through Screen :- 0.6 to 1.2 (m/sec)
Grit Chamber	3 no. Size:- 3.5 m wide x 14 m long Fitted with -3 No. Aluminium propotional wiers Volume of the Grit:– 11 m^3 /d

Mechanical Degritter	7 nos. Diameter:- 10.35m Area:- 84.1 m^2
Division Box & Distribution Box	18 no.
UASB reactor	9 cells Size:- 30m length x 32m width x 5.06m liquid depth Freeboard:- 0.80m
Pre aeration tank	Single unit Size:- 12 m length x 20m width x 3.5 m depth
Polishing pond	Single pond Size- 630m length, 270m width, 1.8m liquid depth and 0.2m freeboard. Two baffles at distance of 90m along the width.
Chlorination unit	Single unit Dose applied is 5ppm
Sludge drying beds	72 beds Volume:- 256 m^3 Depth: - 0.25m.
Biogas storage, handling and flaring system	Gas stored in gas holder of 16m diameter, 1000m^3 of capacity

Table 4.1 dimensions and capacity details of the units at STP

4.2 The treatment process

The municipal wastewater passes through bar screens and gets collected in the sewage collection sump. From the sump the wastewater is pumped and passed through the bar screen and degritting chamber. The degritted sewage is directed to the division boxes and gets uniformly distributed among the distribution boxes. The wastewater is conveyed to the bottom of the UASB cells through distribution tubes coming out of the distribution boxes. The wastewater flows upwards with a uniform upflow velocity. The suspended solids settle down by the action of gravity and the biodegradable material gets stabilized anaerobically producing biogas. The effluent of UASB flows under gravity into the polishing ponds via a pre-aeration tank (where toxic and inhibitory gases are removed by air stripping). The treated effluent from the polishing pond is then chlorinated for MPN reduction prior to discharge in the river Satluj. Sludge accumulated in the UASB reactor is drained out and loaded on the sludge drying beds for dewatering and drying, whenever required. Biogas produced from the UASB reactor after mist elimination is collected into a floating gas dome and excess biogas is metered and flared. The schematic process flow diagram of the STP is shown in the fig 4.1 (a).

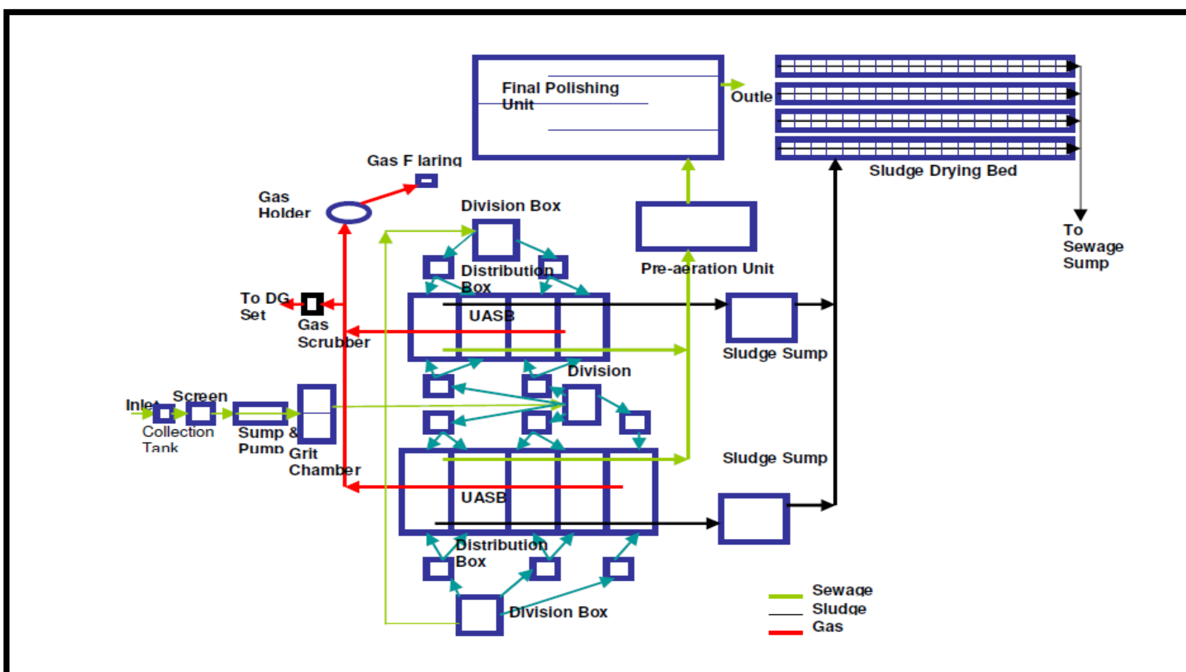

Fig 4.1 (a) schematic process flow diagram of STP at Bhattian (Ludhiana)

The site for placing the ponds was chosen to be adjacent to the polishing pond and the pre aeration unit. The area of study at the STP is shown in fig 4.1 (b).

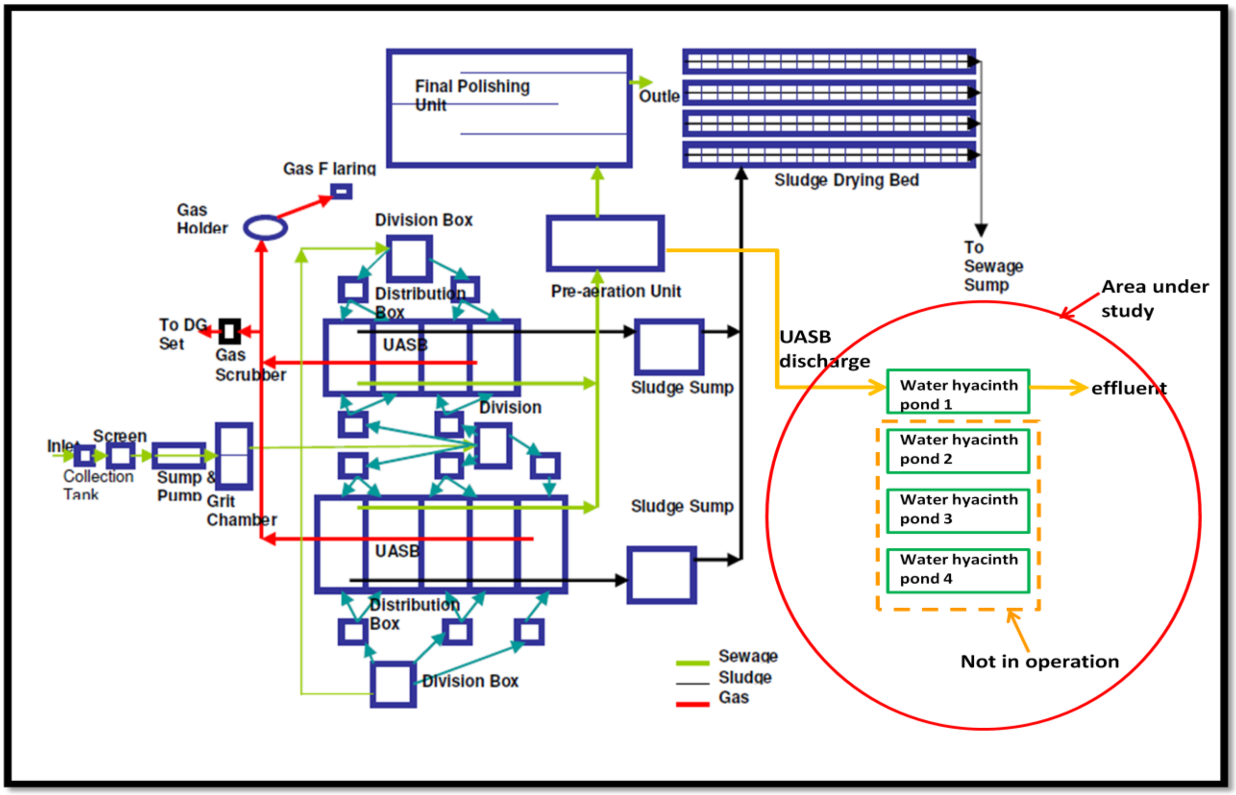

Fig 4.1 (b) diagram of STP showing area of study

CHAPTER 5
RESULTS AND DISCUSSION

5.1 Introduction

Results obtained from the study of STP and analysis of the wastewater treated in water hyacinth pond, are presented in this chapter. The outlet data in the form of mean and standard deviation of the STP under study is given in table 4.13. The comparison between the water hyacinth pond's analysis data, polishing pond effluent characteristics and the prescribed limits have been shown in table 4.14.

The main focus of this work is on the removal of suspended solids, BOD and ammonical nitrogen from the wastewater by using water hyacinth pond so that the disinfection (MPN reduction) by chlorination can be made effective as it is not achieved sufficiently through the existing polishing pond and needs high dose of chlorine which is not recommendable.

5.2 Growth of water hyacinth during experimentation at pilot scale

The weed, Water Hyacinth, is known to double its population in a week. Initially 4 kgs of water hyacinth was grown in the pond. The results of initial population of water hyacinth (immediately after harvesting the one third biomass) and final population of water hyacinth (at the end of the week) are shown in fig 4.1 and fig 4.2 respectively.

Fig. 5.1 initial (just after harvesting)

Fig.5.2 final (at the end of the week)

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The biomass productivity is the most appropriate parameter for evaluating the efficiency of nutrient removal in these ponds. When the water hyacinth density in a pond is low, an exponential growth of the water hyacinth is observed. When the water hyacinth surpasses a certain density in the pond, its growth rate tends to decrease and, consequently, its biological capacity to remove the organic load also reduces. For this reason, it is necessary to continually control the density of the water hyacinth at a level that corresponds to the best performance of the pond (Costa et al, 2003)

The one third biomass of water hyacinth harvested weekly was weighed (on fresh weight basis) to be 2.75 kg. This is shown in fig 4.3. The dry weight of water hyacinth after sun drying was also taken and was weighed to be 0.18kg. The moisture content was calculated to be 93.5%.

Fig.5.3 mass of water hyacinth evacuated at the end of every week

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5.3 Sample characteristics

4.3.1 TSS, BOD and COD

The TSS at the inlet ranged from 168 mg/L to 233 mg/L and the TSS at outlet ranged from 30mg/L to 56 mg/L which was under the prescribed limits. When compared to the existing Polishing Pond, Water Hyacinth pond was found to be more effective in removing TSS as shown in fig. 4.4. The removal efficiency of the ponds has been shown above the bars in the figure. The relatively high TSS concentration in the Polishing Pond effluents is due to the presence of algal cells in the polishing pond. Water Hyacinth ceases the growth of algae by both shading effect and taking up all the essential nutrients. Further water hyacinth root system provides quiescent conditions and roots for better removal of TSS.

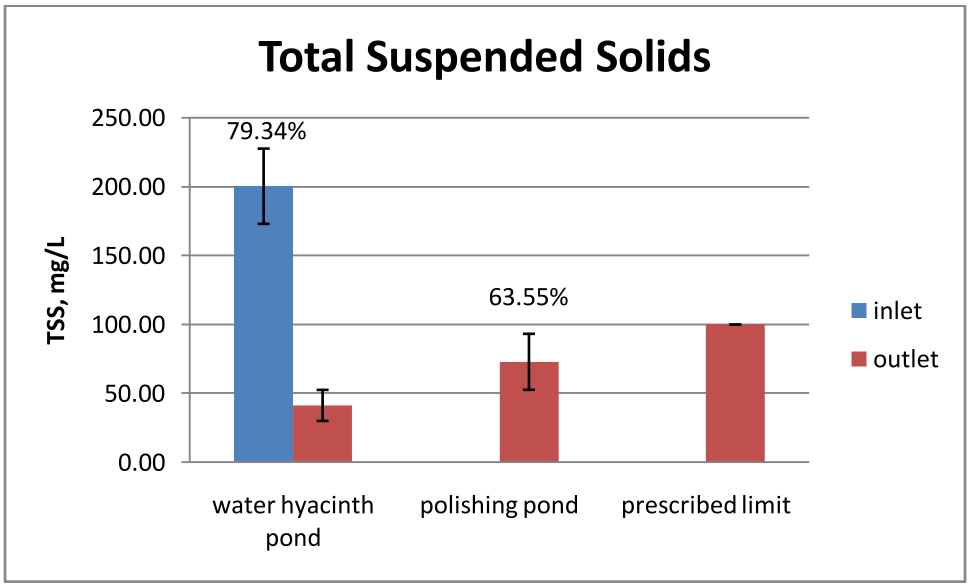

Fig. 5.4 mean and standard deviation values of water hyacinth pond data and polishing pond data, and the prescribed limit of TSS

The average removal efficiency of Water Hyacinth pond for BOD_5 (at 20^0C) and COD was about 79.4% and 70.4% respectively and that for polishing pond was 74.39% and 38.45%. The results are shown in fig. 4.5 and 4.6. The comparison between the two pond systems showed that the effluent of Polishing Pond had high BOD_5 and COD values due to high TSS concentration of the effluent. The average BOD_5 to COD ratio in influent and effluent of the water hyacinth pond is 0.612 and 0.425 respectively and in polishing pond it was found to be 0.250 at the effluent.

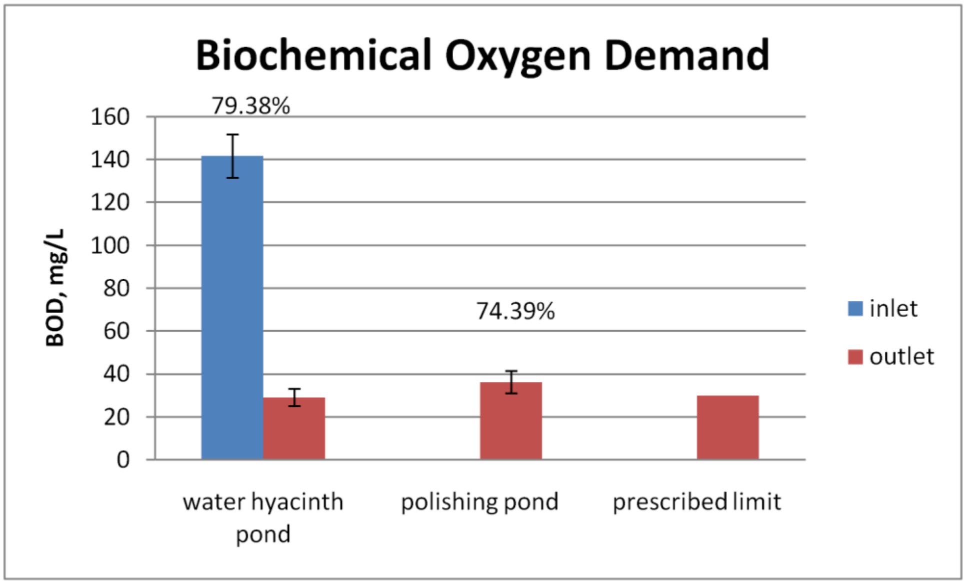

Fig. 5.5 BOD_5 of water hyacinth samples, polishing pond effluent and prescribed limit

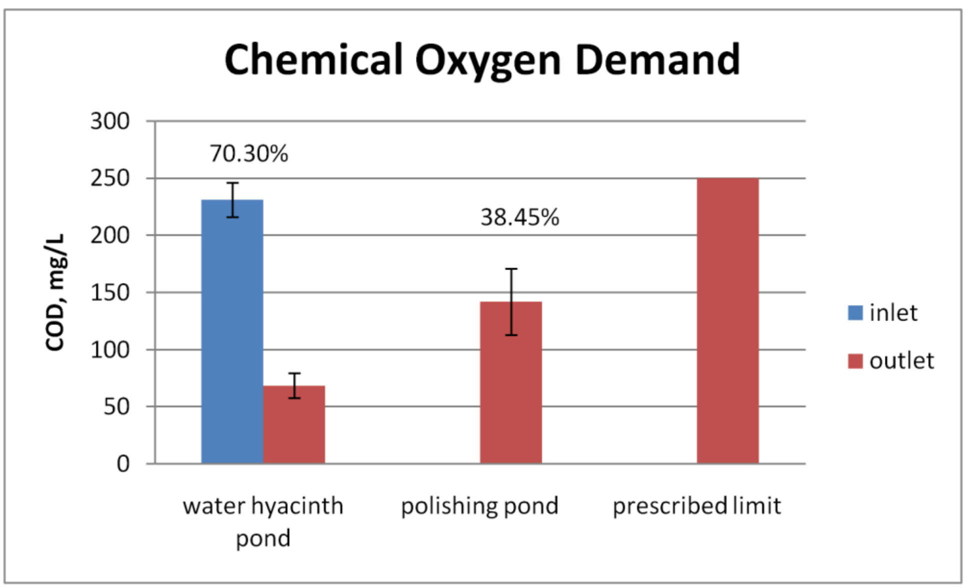

Fig. 5.6 COD of water hyacinth pond samples, polishing pond and prescribed limit

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4.3.2 NUTRIENTS (TOTAL KJELDAHL NITROGEN, NITRATE and NITRITE NITROGEN, and TOTAL PHOSPHOROUS)

Nitrogen and phosphorus are the most important elements when discussing water pollution. Wastewater is usually rich in nitrogen and phosphorus and water hyacinth can grow luxuriously in such nutrient rich water environment. Processes like nitrification and denitrification are involved in the removal of nutrients from wastewater under a water hyacinth treatment system [**Maharjan and Ming, 2012]**.

The analysis results for the nitrogen concentration and their comparison with the outlet concentration of Polishing Pond and with prescribed limits are shown in fig. 4.7 and fig. 4.8. The average removal efficiency of total kjeldahl nitrogen was estimated to be 23.6% which is less than what is indicated in the literature and that for nitrate and nitrite nitrogen was 24%.

Comparison of outlet concentration of TKN in both the pond systems reveals that Water Hyacinth pond removes the TKN with efficiency better than that of Polishing Pond.

The nutrients accumulate in the water hyacinth and removed from the wastewater by harvesting removal of the biomass. Optimizing water hyacinth biomass may lead to further removal of nitrogen from the water hyacinth ponds. The water hyacinth plants and bacteria only take up ammonium as a nitrogen source because plants and bacteria prefer ammonium as a nitrogen source over nitrate **[Yi et al, 2009].**

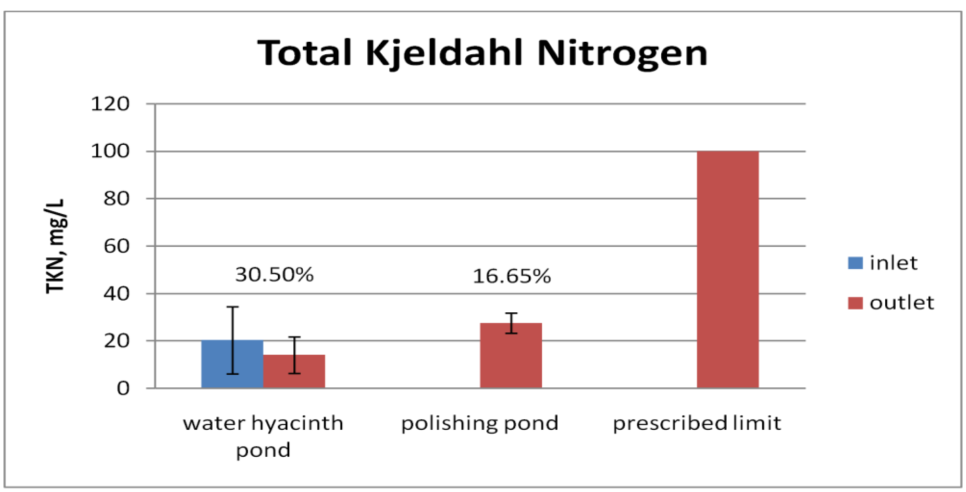

Fig. 5.7 TKN removal data of water hyacinth pond and polishing pond

Nitrogen in the Water Hyacinth pond can be removed through various physico-chemical and biomechanisms such as filtration and precipitation of algal particles; plant uptake; and nitrification and denitrification. A nitrogen mass balance showed that nitrogen was mostly removed by nitrification and denitrification **[Yi et al, 2009]**

The analysis results and comparison results for total phosphorous are shown in fig. 4.8. The removal efficiency of total phosphorous was found to be 48.3%. The comparison of Polishing Pond with Water Hyacinth pond described the better performance of Water Hyacinth pond in removal of nitrogen from wastewater but phosphorous removal was significant in Polishing Pond.

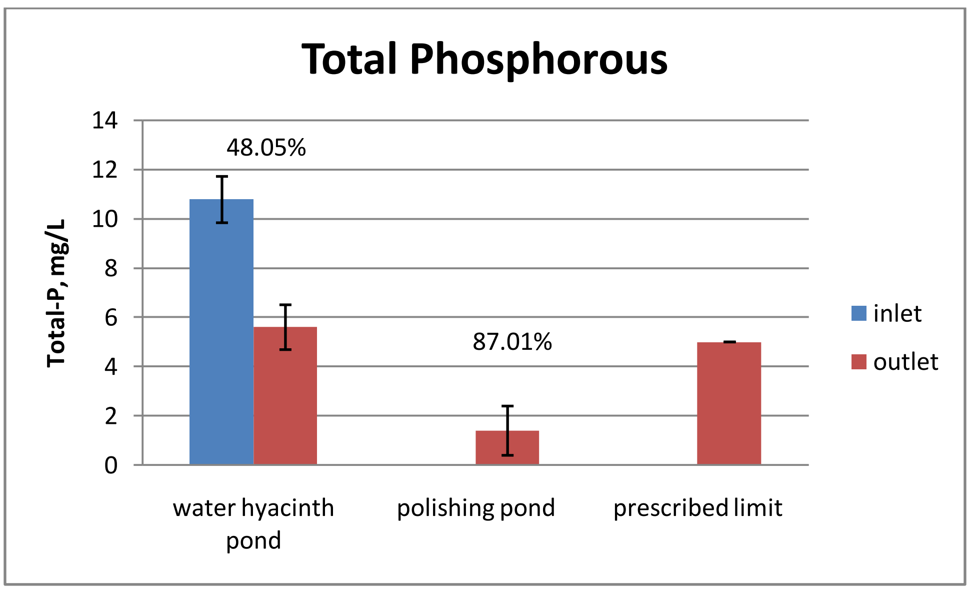

Fig. 5.8 phosphorous analysis data for water hyacinth pond, polishing pond, and its prescribed limit

CHAPTER 5
RESULTS AND DISCUSSION

4.3.3 TDS, SULFATE, ALKALINITY AND CHLORIDE

The range of TDS at the inlet was 1210- 1256 mg/L, and that at the outlet was 965- 1025 mg/L. the mean and standard deviation values of both the ponds have been shown in fig. 4.5. TDS is removed well in polishing ponds but in both the ponds the value is under prescribed limits.

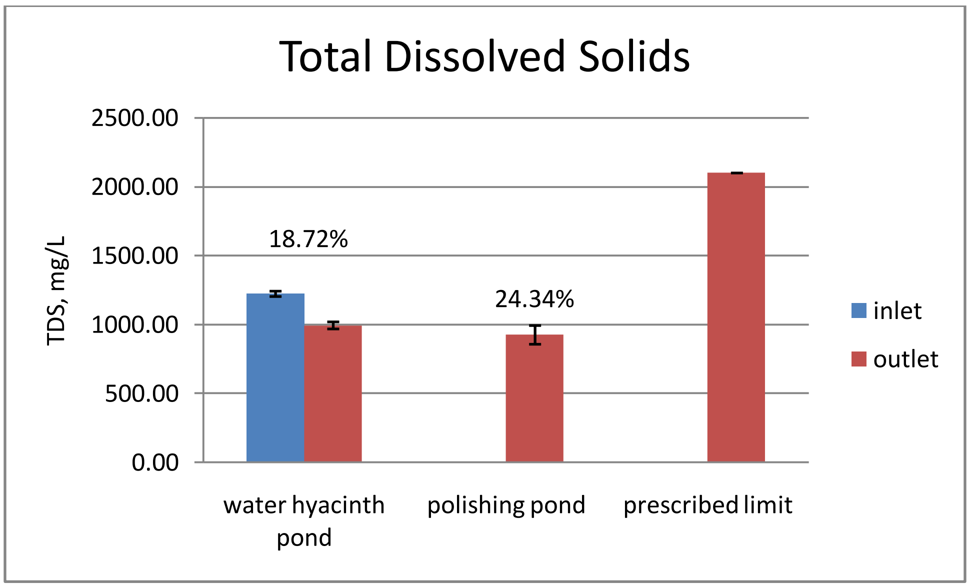

Fig. 5.9 mean and standard deviation values of water hyacinth pond data and polishing pond data, and the prescribed limit of TSS

The average removal efficiency of sulfate was found to be 28.5% with value at influent ranging from 41.9mg/L to 229.6 mg/L and effluent concentration ranging from 34mg/L to 198 mg/L.

The concentration of chloride in the influent ranged from 285 mg/L to 480 mg/L and in the effluent ranged from 200 mg/L to 360 mg/L. when compared to the Polishing Pond effluent, the chloride concentration in the effluent of Water Hyacinth pond was found to be higher still under the prescribed limits. The results have been shown in fig. 4.10.

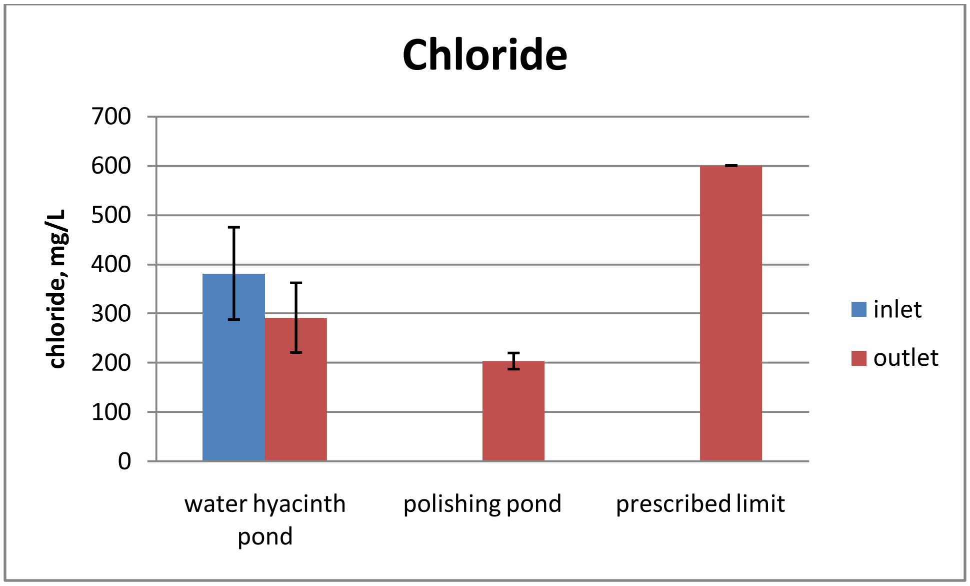

Fig. 5.10 chloride concentration in water hyacinth pond samples, polishing pond and prescribed limits

The comparison of sulfate and alkalinity concentration at outlet of Polishing Pond and Water Hyacinth pond, and the prescribed limits have not been shown due to the data unavailability.

4.3.4 COLOR, ODOR, pH AND ALKALINITY

The acceptance of people for water use primarily depends on the color and odor. The grayish black color of wastewater turned colorless in the treatment process.

The substances responsible for the diffusion of odors into the atmosphere in the vicinity of treatment plants are generally gaseous inorganic products or highly volatile organic compounds. The following compounds are associated with bad odors: mercaptans, skatoles, indoles, inorganic acids, aldehydes, ketones and organic compounds containing nitrogen or sulfur atoms. Among the inorganic compounds, ammonia and hydrogen sulfide are considered to be the main causes of odor when the sewage comes from mainly households **[http://www.spartanwatertreatment.com/odor-control-sewage-municipal-wastewater.html].** The overpowering pungent smell at the inlet was no more noticeable at the outlet.

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The water hyacinth pond do not had much impact on pH and alkalinity of the sample. pH of the sample ranged from 7.3 to 7.6 at the inlet and 7.2 to 7.4 at the outlet. Polishing Ponds tend to increase the pH to provide alkaline conditions for anaerobic treatment of waste water. The average alkalinity at inlet and outlet is 854 and 762 mg/L as $CaCO_3$ respectively.

5.4 Designing of the water hyacinth pond at the STP

The influent characteristics of the water hyacinth pond analysis data was used to design the pond.

The data has been given below in table 4.1.

Influent	**Effluent requirements**
Q= 111000 m^3/d	BOD_5 < 30 mg/L
BOD_5= 142 mg/L	Soluble BOD< 10mg/L
Suspended solids= 200 mg/L	Total Suspended solids < 50mg/L
Total Nitrogen= 20 mg/L	
Total phosphorous= 10 mg/L	
Temperature= 20^0C	

Table 5.1 influent (UASB discharge) characterization data of the polishing pond

Using the influent BOD of water hyacinth pond and the flowrate, BOD loading was calculated

$$= 142 \times 111000$$

$$BOD\ loading = \mathbf{15762\ kg/d}$$

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From table 3.3, typical BOD organic loading for facultative pond was chosen to be 220- 400 kg/ ha-d,

$$total\ area\ required = \frac{15762\ kg/d}{400\ kg/ha - d}$$

$$= 39.4\ ha \approx \boldsymbol{40\ ha}$$

Surface loading rate was found, using flowrate and area, to be 0.28 m/day.

For ease in harvesting and ensuring better maintenance, provide 10+2 cells each with aspect ratio of 4:1. But, only 10 ponds would be in working condition at a time and 2 ponds will be used for emptying the other ponds for the removal of sludge accumulated.

Each cell of the pond has an area of 40000 m^2.

The sludge storage depth at bottom is taken as 0.2m and the maximum root zone depth, 1m, is taken as the effective depth. So the total depth of pond water was designed to be ***1.2m*** and a freeboard of 0.3m was also provided above the water level.

The carrying capacity of each cell of the rectangular concrete water hyacinth pond was calculated, using the dimensions of the pond, as 48000 m^3.

By dividing the pond into number of cells, the hydraulic retention in effective treatment zone is reduced to 0.5 day whereas without divisions the HRT was 4-5 days. The HRT of the existing polishing pond calculated was 2.75 days.

The inlet is designed in a way such that the UASB effluent flows through an open channel and gets distributed in the cells through a distribution box. The distribution box is provided between the two sets of cells of the pond having 6 cells each.

Open channel (inlet)

The concrete channel is supposed to be of most economic section, i.e. H= W/2. The velocity is supposed to be 1m/s. The channel (as calculated) was found to be 1.6 m wide and depth of flow is 0.8 m. using manning's equation $\left[V = \frac{1}{n}(R)^{\frac{2}{3}}(S)^{\frac{1}{2}}\right]$ the channel's slope was worked out to be $7.6 * 10^{-4}$.

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Distribution Box

The dimensions of distribution box were found to be 0.5 m width and 0.25 m depth.

The water flows through the distribution box to the cells through pipes.

The pipe diameter was calculated, using the velocity of 1m/s, to be 0.4 m.

Losses major and minor losses were calculated. The head required (using length as 10m) was found out to be 0.742 m.

Water hyacinth cell

Each cell will be provided with an inlet channel through which the water will overflow into the cell. The weir length for each cell is 100m and weir loading rate and depth of flow over the weir was calculated to be 1.28 L/m. sec and 8mm respectively.

$$q = 0.0567h^{\frac{3}{2}}$$

Where, q= weir loading rate (L/m.sec) and h= depth of flow over the weir (mm)

Outlet channel

A common outlet channel is provided at the end of the cells. Each set has one outlet channel. The flowrate gradually increases at each outlet of the adjacent cells. The width, depth and slope of the first section that carries flow from the first cell were found out to be 0.5m, 0.25 m and $3.6*10^{-3}$ respectively, keeping the velocity of flow 1m/s. the slope and width were then kept constant and the depth of flow and velocity at each section was calculated using manning's equation by applying iterations. The depth and velocity was found to be 0.43 m and 1.17 m/s respectively for 2nd section, 0.6m and 1.26 m/s respectively for the 3rd section, 0.7 and 1.31 m/s respectively for the 3rd section and 0.94m and 1.35 m/s for the 5th section.

The line diagram of the design planned and the hydraulic diagram showing the levels of the liquid is shown in fig. 4.11 and 4.12.

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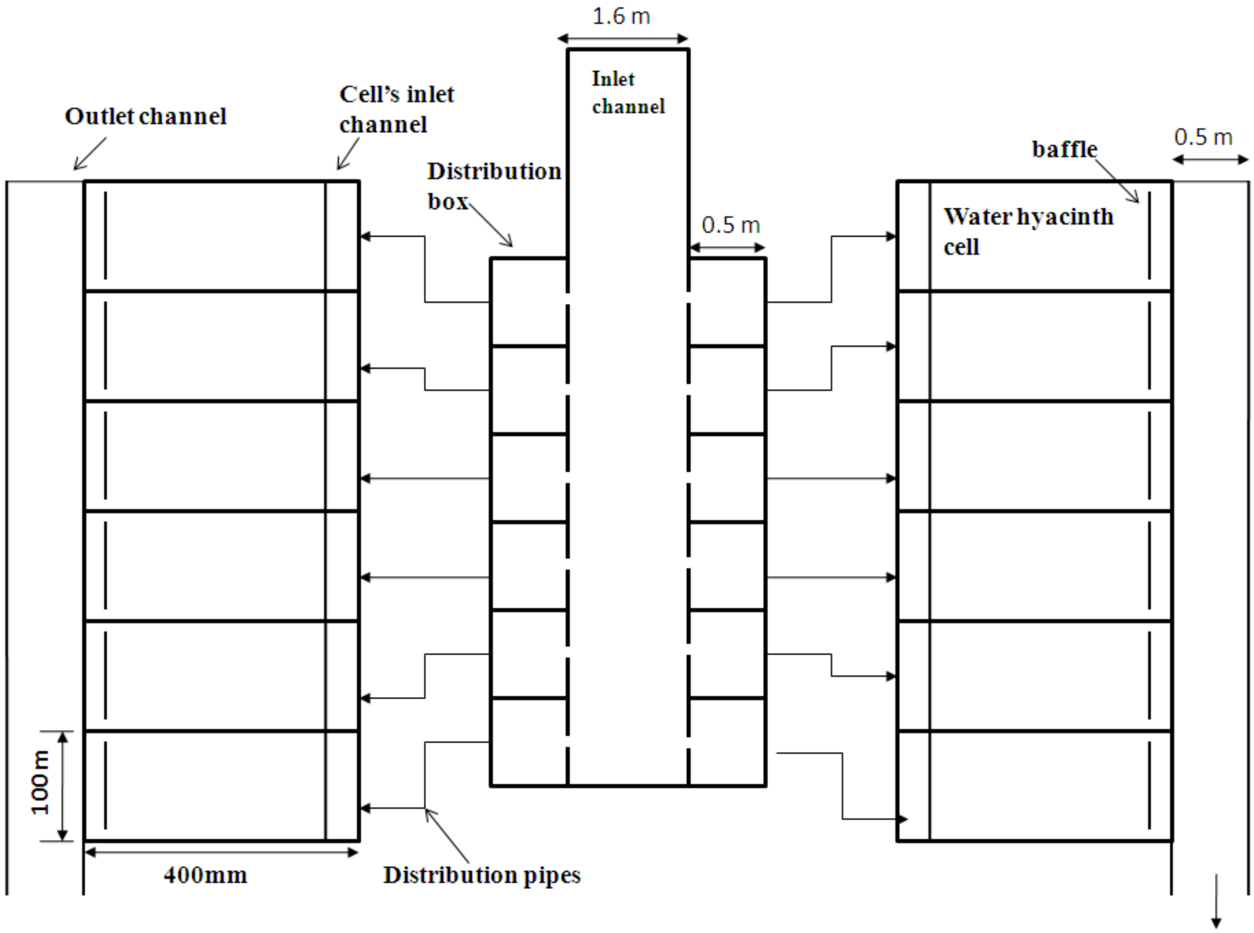

Fig. 5.11 line diagram of the design

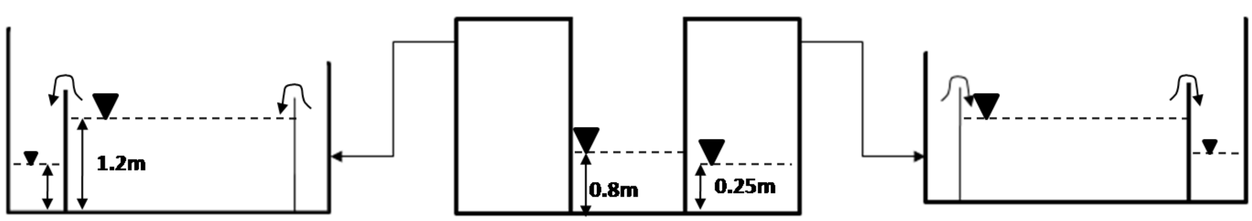

Fig. 5.12 hydraulic diagram of the design

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Parameters / months	Temp., deg. C	pH	TDS, mg/l	TSS, mg/l	TKN, mg/l	Total-P, mg/l	NO2+NO3 - N, mg/l	BOD, mg/l	COD, mg/l	Chloride, mg/l	MPN
january	18±1.5	8±0.7	954±98.2	112±65.5	27±11.8	1±0.6	1±0.6	38±3	140±83	205±62.3	$1.63*10^{6}$
febuarary	19±1	8±0.5	895±161.2	93±47.5	32±13.9	1±0.6	1±1.1	29±4.8	135±59.4	197±77.5	$3.69*10^{6}$
march	25±1.8	7±0.2	1006±321.2	52±37.3	28±10.5	1±0.5	2±1.2	28±7.7	121±54.1	214±69.4	$7.11*10^{5}$
april	29±3.5	7±0.1	934±260	57±45.2	20±7.2	2±3.3	1±1.5	41±17.4	152±53.2	226±42.9	$1.93*10^{5}$
may	30±1.1	7±0.4	867±207.8	83±32.5	30±9.1	4±3.6	1±1.3	37±13.3	121±21.2	232±59.7	$2.36*10^{6}$
june	32±1.1	8±0.5	876±194.8	87±38.5	26±11.4	1±0.3	1±0.6	38±17.3	149±70.9	214±52.8	$2.62*10^{6}$
july	31±1	7±0.4	838±236.7	54±24.3	31±12.5	1±0.2	1±0.4	32±11.5	160±55.4	181±25.7	$3.48*10^{6}$
august	32±2.2	7±0.3	823±157.2	54±32.1	28±9.3	1±0.8	2±2.7	32±7.5	216±28.8	192±34.7	$5.04*10^{4}$
september	31±2.06	8±0.7	911±72.23	77±19.72	25±12.47	1±0.58	1±1.65	41±8.92	101±15.09	204±25.95	$2.69*10^{5}$
october	28±3.22	8±0.26	986±159.5	55±23.45	30±5.07	0±0.32	1±0.6	42±17.3	153±65.2	195±12.11	$6.32*10^{6}$
novemver	23±1.25	8±0.46	988±187.5	60±27.27	30±3.46	2±1.7	1±0.67	43±21.09	118±27.22	179±25.16	$2.68*10^{6}$
december	21±1.5	7.75±0.55	1028.7±237.5	92.5±47.2	32.7±2.9	1.8±1.01	2.6±3	34.1±6.4	140±74.04	200.1±12.6	$8.43*10^{5}$

Table 5. 2 Inlet and outlet data (september' 2008- july' 2012) of the STP at Bhattian (Ludhiana)

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parameters		date of sampling					mean±SD	Removal efficiency (%)	polishing pond mean± SD	removal efficiency (%)	prescribed limits
		22/4/2013	30/4/2013	10/5/2013	21/5/2013	15/6/2013					
colour	inlet	greyish black	greyish black	greyish black	greyish black	greyish black	NA		NA		
	outlet	water like	water like	water like	water like	water like	NA	NA	NA	NA	NA
odor	inlet	pungent	pungent	pungent	pungent	pungent	NA		NA		
	outlet	ok	ok	ok	ok	ok	NA	NA	NA	NA	NA
ph	inlet	7.5	7.6	7.3	7.6	7.5	NA		NA		
	outlet	7.4	7.3	7.2	7.2	7.2	NA	NA	NA	NA	5.5-9
TSS(mg/l)	inlet	168	185	224	233	192	200.4±27.28		200.4±27.28		
	outlet	30	30	56	45	46	41.4±11.26	79.34	73.04±20.3	63.55	100
TDS(mg/l)	inlet	1210	1215	1210	1226	1256	1223.4±19.36		1223.4±19.36		
	outlet	998	965	1012	972	1025	994.4±25.62	18.72	925.56±67.9	24.34	2100
BOD(mg/l)	inlet	146	134	152	128	148	141.6±10.14		141.6±10.14		
	outlet	35	24	28	29	30	29.2±3.96	79.38	36.26±5.2	74.39	30
COD(mg/l)	inlet	257	227	230	219	222	231±15.15		231±15.15		
	outlet	87	70	64	62	60	68.6±10.95	70.30	142.17±29	38.45	250
CHLORIDE (mg Cl^-/l)	inlet	480	480	354.88	305.905	284.9	381.14±93.75		381.14±93.75		
	outlet	360	360	244.92	291.9	199.9	291.34±70.61	23.56	203.26±16.3	46.7	600
SULFATE(mg/l)	inlet	229.6	169.538	41.973	148.14	115.22	140.89±69.26		NA		
	outlet	198.343	98.76	33.7	90.53	82.3	110.73±60.14	28.51	NA	NA	NA
ALKALINITY (mg $CaCO_3$/L)	inlet	800	850	800	910	900	852±52.63		NA		
	outlet	760	830	780	720	730	764±43.93	10.33	NA	NA	NA
TKN(mg/l)	inlet	8.064	9.52	12.88	34.384	37.072	20.38±14.15		20.38±14.15		
	outlet	7.056	7.504	11.64	22.736	21.9	14.17±7.66	30.50	27.6±4.3	-35.43	100
TOTAL- P(mg/L)	inlet	11.3	10.7	9.2	11.6	11.1	10.78±0.94		10.78±0.94		
	outlet	6.2	5.4	4.1	6.3	6	5.60±.91	48.05	1.4±1	87.01	5
NITRITE+ NITRATE (mg/L)	inlet	0.26	0.076	0.103	0.131	0.193	0.15±0.07		0.15±0.07		
	outlet	0.145	0.073	0.097	0.094	0.12	0.11±.03	30.56	1±0.6	-170	10

<u>Table 5.3</u> showing comparison between the water hyacinth pond analysis results, polishing pond data and prescribed limits

NA= not available

CONCLUSION

The potential of water hyacinth pond to treat the UASB effluent of the STP has been evaluated over the potential of the existing polishing pond in this study. The main focus was the unsuccessful MPN reduction (by chlorination) from the treated effluent of polishing pond, which is due to high algal concentration and ammonical nitrogen. The average BOD, COD, TSS and TKN of the treated effluent of the polishing pond was 36mg/L, 142 mg/L, 73 mg/L and 28 mg/L respectively whereas for water hyacinth pond, it was found to be 29mg/L, 69 mg/L, 41 mg/L and 14 mg/L respectively. When compared, the water hyacinth system was found to be much more effective than the polishing pond. It is concluded from the study that replacing the polishing pond with the water hyacinth pond will reduce the load in the effluent and hence lower dose of chlorine will satisfactorily reduce the MPN so that it will comply with the standards prescribed. Due to limitation of time, heavy metal dynamics between water body and water hyacinth could not be established. The water hyacinth biomass harvested from the pond can further be used as a substrate to mushroom culturing and vermicomposting. In this study, MPN test of treated effluent of the water hyacinth pond was felt needed so that the chlorine dose for this pond could be worked out and compared with that of the polishing pond. Residual chlorine estimation, of the effluent coming out from chlorination unit of the STP, would have been better to understand the problem more clearly.

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