Performance Evaluation of SBR in Combination with Macrophyte for Treating Wastewater Generated from Galgotias University

A Dissertation

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ENERGY &ENVIRONMENTAL ENGINEERING
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CERTIFICATE

I hereby certify that the work which is being presented in the dissertation titled, **“Performance evaluation of SBR in combination with microphyte for treating wastewater generated from galgotias university”** in partial fulfilment of the requirement of the award of the Degree of Master of Technology in Civil Engineering (Energy &Environmental Engineering), Galgotias university, is an authentic record of my own work carried out during the period from January 2020 to May 2020, under the supervision of Mr sugandhsingh, Assistant Professor, Department of Civil Engineering, Galgotias University.

The matter embodied in this dissertation is original and has not been submitted by me to any other University/Institute for the award of any Degree or Diploma.

ABDUL QUDOOS RAFI

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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NOMENCLATURE

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DT	Detention Time
EC	Electrical Conductivity
HLR	Hydraulic Loading Rate
HRT	Hydraulic Retention Time
TN	Total Nitrogen
TP	Total Phosphorus
TS	Total Solids
US EPA	United States Environmental protection Agency
VF	Vertical Flow
APHA	American Public Health Association
CPCB	Central Pollution Control Board
°C	Degree Celsius
Hr	Hour
L	Litre
m	Metre
mm	Millimetre
cm	Centimeter
mg	Milligram
µg	Microgram
%	Percentage
Min	Minute

ABSTRACT

Galgotia's university has 26000 students and working staff in its campus, every single person consume approximately 45 litre water on daily basis (IS1172:1993 R 2012), therefore the total quantity of water consume per day is 1.17 million litre. More than 80% of consumed water is wasted as wastewater hence various methods were designed and developed to treat wastewater at its source so that treated wastewater can be used for secondary consumption. Sequencing Batch Reactor (SBR) in combination with macrophytes become more popular for treating wastewater. It can treat small to large volume of wastewater having varying contamination level. Attempts have been made in past to understand the complex processes involved in SBR in combination with macrophytes. The present study was carried out to study problem related to conventional wastewater treatment and provide effective solution to enhance its efficiency and also to reduce the wastewater impurities below its permissible limit.

The major focus of present study was to evolve better understanding of the effect of artificial aeration, vegetation and externally added microbial consortium on performance of SBR in combination with macrophyte for removal of total nitrogen, total phosphorus, BOD, COD, total solids and microorganisms. The wastewater generated from Galgotia's University with pH (7.91 – 8.84), conductivity (375 – 398μS/cm), TS (2654 – 2987 mg/L), COD (298 – 376 mg/L), BOD (120 – 280 mg/L), TN (7.6 – 10.9 mg/L), TP (1.2 – 2.4 mg/L) was treated sequentially treated in SBR and a unit which contain *Eichhornia Crassipes* macrophyte in it. The systems were operated in batch mode.

Aeration facilitated oxidation of impurities in SBR and Eichhornia *Crassipes* absorb TN and TP as a necessary nutrient for its growth. This lab scaled system is able to reduce the total nitrogen to zero at an overall detention time of 5 days. There was no significant removal of total phosphorus in SBR. Removal of total solids (60 – 78%), BOD (40 – 99%), COD (55 – 98%), TN (79 – 100%), TP (80 – 100%) and bacterial count (> 99%) were observed. The results shows that treated effluent from this system can be discharge into environment without any risk.

Keywords: Substrate, Constructed Wetland System, Wastewater treatment, Macrophytes.

CHAPTER – 1

INTRODUCTION

Water is essential for all form of life. Like many other countries, India is likely to be water scarce by 2050 and therefore rain water harvesting, water conservation, water pollution control, recycling and reuse of treated wastewater is necessary. The quality of fresh water is deteriorated by discharge of domestic (Tee, 2009), municipal (Despland, 2014), agriculture and industrial wastewater (Chandra, 2012;Kafle, 2013 and Rossmann, 2013) and in few cases by the discharge of nuclear waste (Lavrentyeva, 2014). Adequate wastewater treatment before final discharge into the environment is necessary so that it cause less damage and can be reused for other purposes. For wastewater treatment, various techniques have been successfully applied. Methods such as activated sludge treatment process (Miyata, 2000), and physio-chemical treatment such as ozonation (Kim, 1985), flocculation (Migo, 1997) and activated carbon adsorption method (Rao, 2008) are available but these methods are uneconomically on large scale and generate huge amount of sludge and secondary pollutants.

In many cases untreated wastewater is let out which either sinks into the ground as a potential pollutant of ground water or is discharged into the natural drainage system causing pollution in downstream areas (CPCB, 2013). It is necessary to treat domestic wastewater using appropriate physical and biological treatment methods to avoid pollution of ground and surface source of water.The biological treatment processes use organic matter, nutrients, and other substances present in the wastewater as a source of food for the mixed microbial culture. The biological treatment processes are commonly classified as aerobic, anaerobic and biological nutrient removal processes.Since its inception in 1914, the activated sludge system has become one of the most widely used biological wastewater treatment processes. It is an aerobic suspended growth system in which microorganisms are grown for the purpose of removing soluble organic matter (Grady et al., 1999). Major process modifications of activated sludge processes include tapered aeration, contact stabilization, high-purity oxygensystem,conventional, step aeration, high-rate aeration and extended aeration system (Al-Malack, 2006).Sequencing batch reactor (SBR) is a variation of the activated-sludge process. It differs from activated-sludge system because SBR combines all of the treatment steps and processes into a single basin or tank, whereas conventional treatment facilities rely on multiple basins. The operation of an SBR is based on a fill-and-draw principle, which consists of five phases - fill, react, settle, decant, and idle. These phases can be altered for different operational applications (Al- Rekabi, 2007).

Earlier designs of biologicalwastewater treatment processes were based on the empirical parameters developed byexperience, which included hydraulic loading, organic loading, and retention time. However, now - a - days the design utilizes empirical as well as rational parameters based on biological kinetic equations. These equations describe growth of biological solids, substrate utilization rates, food-to-microorganisms ratio, and the mean cell residence time. The various parameters that can be calculated from these equations include reactor volume, substrateutilization, biomass growth, and effluent quality (Al-Malack, 2006).

These include studies using anaerobic and aerobic SBR (Banik et al., 1988;Singh and Viraraghavan, 2002 ; Durai et al., 2011; Rao et al., 2015). Although many studies have been carried out for anaerobic SBR, studies on SBR in combination with macrophytesare limited. Also, very few studies have been carried out for assessing the effect of SBR in combination with macrophytes. The main focus of present study is toprovide sustainable solution to industry or society for wastewater recycling , to reduce the wastewater impurities below its permissible limit and to study problem related to conventional wastewater treatment and provide effective solution to enhance its efficiency.

CHAPTER – 2

LITERATURE REVIEW

It is estimated that about 38,254 million litres per day (mld) of wastewater is generated in urban centres comprising Class I cities and Class II towns having population of more than 50,000 (accounting for more than 70 per cent of the total urban population). The municipal wastewater treatment capacity developed so far is about 11,787 mld, that is about 31 per cent of wastewater generation in these two classes of urban centres. Treatment technologies adopted under NRCD funded schemes can be classified in three broad groups: Natural system, conventional technology andadvanced technology. State-wise summary of treatment technologies observed that the most used technologies are UASB, activated sludge process, oxidation pond and waste stabilization pond.Advanced treatment technologies incur higher expenses towards operation and maintenance. Energy demand also depends on the type of treatment. Power consumption of ASP in comparison to UASB is higher. Land requirement for MBR and SBR plant is least among all treatment process whereas energy requirement is highest.Treated effluent quality with respect to BOD, COD, SS, coliform reduction is better in SBR and MBR plant among other treatment technologies (CPCB, 2013).

2.1 Wastewater Treatment Technologies

The principal objective of wastewater treatment is to remove harmful substances and microorganisms from domestic and industrial wastewater and dispose offtreated effluent without danger to human health or unacceptable damage to the natural environment. Conventional wastewater treatment consists of a combination of physical, chemical, and biological processes and operations to remove solids, organic matter, and sometimes, nutrients from wastewater.

2.1.1 Preliminary and Primary Treatment

The objective of preliminary treatment is the removal of coarse solids and other large materials often found in raw wastewater. Removal of these materials is necessary forproper functioning of subsequent treatment units. Preliminary treatment operations typically include coarse screening, grit removal, and, in some cases, communication of large objects. The objective of primary treatment is the removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float by skimming.

2.1.2 Secondary Treatment

The objective of secondary treatment is to remove the residual dissolved and fine suspended organic matter. In most cases, secondary treatment follows primary treatment and involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes. Aerobic biological treatment is performed in the presence of oxygen by aerobic microorganisms (principally bacteria) that metabolize the organic matter in the wastewater, thereby producing more microorganisms and inorganic end-products (principally CO_2, NH_3, and H_2O). Several aerobic biological processes are used for secondary treatment differing primarily in the manner in which oxygen is supplied to the microorganisms and in the rate at which organisms metabolize the organic matter. The common treatment technologies used in India for treatment of sewage and industrial effluents include activated sludge process, trickling filters, rotating biological contactors, up-flow anaerobic sludge blanket process,waste stabilization ponds,aerated lagoons, duckweed ponds, fluidized bed reactor, sequential batch reactor, etc.

2.1.3 Tertiary Treatment

Tertiary wastewater treatment is employed when specific wastewater constituents which cannot be removed by secondary treatment are to be removed. The treatment processes are necessary to remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals, and dissolved solids. Because advanced treatment usually follows high-rate secondary treatment, it is sometimes referred to as tertiary treatment.

2.2 Activated Sludge Process

Since its inception in 1914, the activated sludge system has become one of the most widely used biological wastewater treatment processes. It is an aerobic suspended growth system in which microorganisms are grown for the purpose of removing soluble organic matter (Grady et al., 1999).The suspended microbes are collectively referred to as biomass.This wastewater and biomass is mixed into large basin called aeration tank. Aerobic conditions are maintained in these aeration tanks by diffused air aerator or mechanical surface aerators. With proper adjustments, the activated sludge technique can be used to achieve removal of nutrients also. The performance of the activated sludge process is affected by several factors like temperature, pH, sludge return rates, dissolved oxygen levels, food to microorganism ratio, aeration rates and wastewater toxicity. This is why there are many different configurations of the activated sludge system which are classified according to the nature of these factors(Grady et al., 1999). Major process modifications of activated sludge processes systeminclude taperedaeration, contact stabilization, and high-purity oxygensystem,conventional system, step aeration, high-rate aeration and extended aeration type system (Al-Malack, 2006).

In a typical activated sludge process, the biomass is recycledinto the aeration basin and mixed into the influent wastewater stream. Themixed liquor is kept well aerated and dissolved oxygen levels are usually maintained at a minimum of 2mg/L to limit filamentous bulking sludge characteristic. The aerobic bacteria metabolizes the organic matter , which is then removed by gravity settling in secondary sedimentation chambers to produce effluent that is low in suspended solids. This settled material is removed and a portion is returned to the beginning of the aeration basin to maintain a viable biomass concentration. This fraction is referred to as return activated sludge (RAS). The remaining fraction is disposed of and called waste activated sludge (WAS) (Grady et al., 1999).

The average amount of time the biomass dwells within the system is referred toas the solids retention time (SRT). SRT is critical in the design of activated sludge process because of its impact on process performance, reactor sizing, oxygenrequirements and bacterial growth rate (Metcalf & Eddy, 2003). A short SRT of around 3to 5 days is required for the removal of most organic matter. Longer SRTs can allow fornitrification which may or may not be desirable depending on operational requirements. In thecase where a wastewater treatment plant is required to remove nitrogen as part of their permit requirements abiological nutrient removal (BNR) process may be employed which makes use of a long SRT (Brennan, 2012).

2.3 Sequencing Batch Reactor (SBR)

Sequencing batch reactor is a variation of the widely used activated sludge process. As shown in Figure 2.1, the operation of an SBR is based on a fill-and-draw principle, which consists of five phases - fill, react, settle, decant, and idle. These steps can be altered for differentoperational applications(Al- Rekabi, 2007).

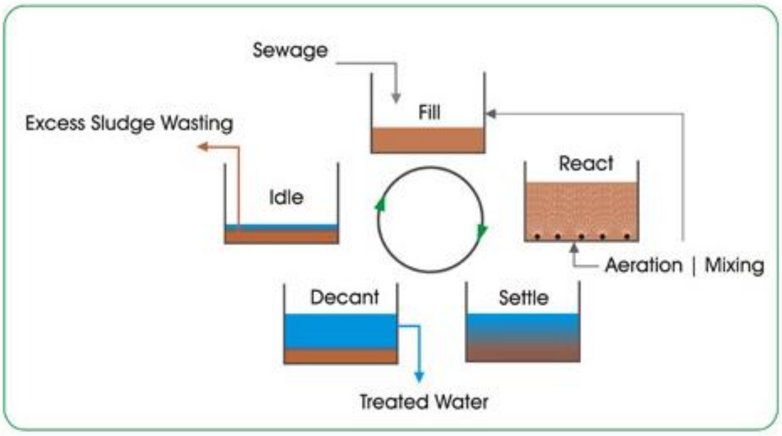

Figure 2.1: SBR Operating Phases

Fill Phase

During the fill phase, the basin receives influent wastewater. The influent brings food tothe microbes in the activated sludge, creating an environment for biochemical reactions totake place. Mixing and aeration can be varied during the fill phase to create the followingthree different scenarios:

a)Static Fill– Under a static-fill scenario, there is no mixing or aeration while theinfluent wastewater is entering the tank. Static fill is used during the initial start-upphase of a facility, at plants that do not need to nitrify or denitrify, and during lowflowperiods to save power. Because the mixers and aerators remain off, this scenariohas an energy-savings component.

b)Mixed Fill– Under a mixed-fill scenario, mechanical mixers are active, but theaerators remain off. The mixing action produces a uniform blend of influentwastewater and biomass. Because there is no aeration, an anoxic condition ispresent, which promotes denitrification. Anaerobic conditions can also be achievedduring the mixed-fill phase. Under anaerobic conditions the biomass undergoes arelease of phosphorous. This release is reabsorbed by the biomass once aerobicconditions are re-established. This phosphorous release will not happen with anoxicconditions.

c)Aerated Fill– Under an aerated-fill scenario, both the aerators and the mechanicalmixingunit are activated. The contents of the basin are aerated to convert the anoxicor anaerobic zone over to an aerobic zone. No adjustments to the aerated-fill cycle are needed to reduce organics and achieve nitrification.

React Phase

This phase allows for further reduction or "polishing" of wastewater parameters. Duringthis phase, no wastewater enters the basin and the mechanical mixing and aeration unitsare on. Because there are no additional volume and organic loadings, the rate of organicremoval increases dramatically.Most of the carbonaceous BOD removal occurs in the react phase.

Settle Phase

During this phase, activated sludge is allowed to settle under quiescent conditions—noflow enters the basin and no aeration and mixing takes place. The activated sludge tendsto settle as a flocculent mass, forming a distinctive interface with the clear supernatant.The sludge mass is called the sludge blanket. This phase is a critical part of the cycle,because if the solids do not settle rapidly, some sludge can be drawn off during thesubsequent decant phase and thereby degrade effluent quality.

Decant Phase

During this phase, a decanter is used to remove the clear supernatant effluent. Once thesettle phase is complete, a signal is sent to the decanter to initiate the opening of aneffluent-discharge valve. It isoptimal that the decanted volume is the same as the volume that enters the basin duringthe fill phase.

Idle Phase

This step occurs between thedecant and the fill phases. During this phase, a small amount ofactivated sludge at the bottom of the SBR basin is pumped out—a process called wasting. However, for uniform wasting, sometimes small amount of mixed liquor is pumped out during react phase.

The differences between key features of ASP and SBR are listed in Table 2.1.

Various laboratory scale studies have been undertaken using SBR. Li and Zang (2002) studied the SBR performance for treating dairy wastewaters with various organic loads and HRTs. At 1 day HRT and 10000 mg/L COD, the removal efficiency of COD, total solids, volatile solids, Total Kjeldal Nitrogen (TKN) and total nitrogen was reported to be 80.2,63.4,66.3,75.0 and 38.3%, respectively.Mohseni-Bandpi and Bazari (2004) investigatedthe bench scale aerobic SBR to treat the wastewater from an industrialmilk factory. The SBR system was operated in three phases involving variation of organic loading, aeration period and cycle period.The COD removal was more than 90% in all

Table 2.1: Differences Between Key Features of ASP and SBR

S.No.	Activated Sludge Process(ASP)	Sequencing batch reactor(SBR)
1.	ASP employs multiple tanks for processes like reaction and settling.	SBR has only one reactor tank. The whole process takes place in the same tank.
2.	ASP systems are space oriented. Wastewater flow moves from one tank to next on a continuous basis and virtually all tanks have predetermined liquid volume.	SBR is a time oriented system, with flow, energy input and tank volume varying according to predetermined strategy.
3.	ASP has higher cost of external energy inputs and skilled operation requirements.	SBR is relatively economical and has lesser cost and operation requirements.
4.	In ASP, the relative tank volume is fixed and cannot be shared or redistributed as easily as in SBR.	Relative tank volumes in the SBR can be redistributed easily by adjusting the mechanism which controls the time planned for either function.
5.	No changes in the objectives can be incorporated in ASP after the process has begun.	Operational flexibility allows designers to use SBR to meet objectives other than the ones aimed at the start of the construction.

conditions. Treatment of grey waterusing SBR was investigated with HRTs 0.6 days and 2.5 days (Lamine, 2007). The observed COD removal was more than 90%. The SVI was 100 mL/g. The phosphorus removal performance was decreased and ammonium concentration was high at 0.6 days HRT whereas it was less affected at 2.5 days HRT. Subbaramaiah and Mall (2012) worked on treatability of benzoic acid (BA) using SBR system. Two sets of SBRs were operated with 12 hrs. cycle, 6-12 hrs. HRT and 72-120 hrs. SRT. It was concluded that optimum MLSS concentration was 5000 mg/L. Treatability of benzoic acid above 200 mg/L was good, optimum operating temperature was 30ºC and optimum time for aeration was 3hrs. Application of sequence batch reactor technology for the treatment of domestic grey water with cycle times of 6, 8 and 12 hr has been studied at laboratory temperature 26-32.5 ˚C(Sabri et al., 2013). The efficiency of COD removal at 6, 8, 12 hr were 65%, 80%, 83%, respectively. It was concluded that the removal of organic matter increased with increasing the cycle time. Maharajh (2010)studied the effect of SRT and substrate loading rate on activated sludge using bench scale SBRs. PFR and CSTR configurations were simulated by adjustingthe fill period to be shorter or longer respectively. A series of SBRs were operated, each with anoperating volume of 6L, to obtain data for PFR (fast feed) versus CSTR (slow feed)configurations at 10 day, 5 day and 2 day SRTs. Effluent quality was found to be better for the fast feedsystem at all SRTs, with all monitored parameters being of similar or significantly lowerconcentration than for the slow feed system. It was observed overall for the aerobic phase that the performance of the fast feed system wassuperior to the slow feed system at all SRTs operated. Durai et al. (2011) studied the performance of a bench scale aerobic sequencing batch reactor (SBR) for the treatment of tannery wastewater. Mixed culture obtained from the activated sludge process treating tannery wastewater was used in the reactor. SBR was operated at different operating conditions by changing the hydraulic retention time (HRT 5 – 2 days) and initial substrate concentration (6240 mgCOD/L, 4680 mgCOD/L, 3220 mgCOD/L and 1560 mgCOD/L). Each cycle lasted for 24 hr: filling 1 hr, reaction 20 hr, settling 2 hr, withdrawal 0.75 hr and idle 0.25 hr.The maximum reduction in COD and colour were found to be 79% and 51%, respectively.

Constructed Wetlands

As per US Fish and Wildlife Service, a wetland can be defined as the transition area between aquatic and terrestrial system where water surface is near the ground surface to maintain saturated soil condition and thus water plays a dominant role in determining development of soil and related biological communities i.e. plants and microorganism (Sundaravadiveland Vigneswaran, 2009). Marshes, bogs, and swamps are some of the example of naturally occurring wetlands (US EPA, 1993). Those wetlands which are dominated by water-tolerant woody plants are generally called swamps; those with soft stemmed macrophyte species as marshes; and those with mosses as bogs. Swamps and marshes can be either freshwater or saline water type. Saline water type swamps are commonly known as mangroves

(Sundaravadiveland Vigneswaran, 2009). Natural marsh systems can be divided into two physical categories based on water salinity: freshwater marshes that are inundated with freshwater (salinity: ≤ 1,000 mg/L) and salt marshes that are inundated with brackish or saline waters (salinity: > 1,000 mg/L), (Kadlec and Knight, 1996). The characteristic plant species found in freshwater marshes as well as in salt marshes are emergent, herbaceous macrophytes, also known as helophytes, adapted to intermittent to continuous flooding. Constructed wetland system (CWS) involves the use of plants, substrates and associated microbial assemblages, more reliable control over the hydraulic regime to treat wastewater (US EPA, 1993; Vymazal*et al*., 2006 and Wang *et al*., 2009). The first experiment in the field of constructed wetland system undertaken by a German scientist, Dr.Kathe Seidel, in early 1950s at the Max Planck Institute, aimed at the capabilities of wastewater treatment by bulrush (*Schoenoplectuslacustris*) grown in artificial environment (Vymazal, 2005). The first full scale constructed wetland system was put in operation in the 1960s and since then constructed wetland system were used for treatingpoint-source pollutions i.e. municipal, domestic and industrial wastewaters or non-point-source pollutions such as agricultural runoff, landfill leachate, acid mine drainage, etc. (Vymazal, 2008).This system could be used in various potential industries such as agro-industries, aquaculture industries and tourism industry etc. Constructed wetlands are usually designed as a secondary treatment for removal of suspended solids and organic matter (TSS, BOD and COD) and as a tertiary (advanced) treatment for nutrient removal (nitrogen and phosphorus).

CHAPTER – 3

MATERIALS AND METHODS

The main focus of present study is to provide sustainable solution to industry or society for wastewater recycling , to reduce the wastewater impurities below its permissible limit and to study problem related to conventional wastewater treatment and provide effective solution to enhance its efficiency.

Experimental Setup

A laboratory simple scale SBR was used for the present study. The reactor, made of local plastic (plastic cans) was 13 cm in diameter and had a working volume of 5 L. Inlets and outlets were provided as per requirements. Aqua air pump with air diffuser and mechanical stirrer was used to maintain aerobic conditions in the reactor. A schematic diagram of the setup is given in Figure 3.1. Pictorial view of laboratory-scale SBR is given in Figure A2.1 (Appendix-2).

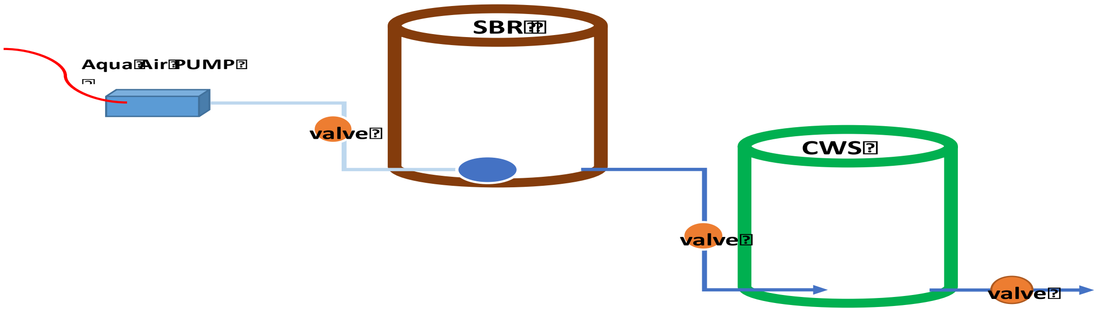

Figure 3.1: Schematic Diagram of Experimental Setup

Activated Sludge

Activated sludge for the seeding of the reactor was obtained from a MBR plant located at Galgotias university

Domestic Wastewater

The wastewater was collected from sewage pumping stations located at the disposal site at Galgotias University. The wastewater was collected in plastic cans daily. The influent characteristics are summarized in Table 3.1.

Table 3.1: Characteristics of Influent Wastewater

Parameter	Range	Range (Mean ± Std. Deviation)
pH	6.5 - 7.03	6.854 ± 0.180
Conductivity (µS/cm)	703 - 814	735.365 ± 32.601
Total Solids (mg/L)	656 - 956	796.822±140.614
COD (mg/L)	240 - 308	268.336± 30.654
BOD (mg/L)	150 - 200	183.34 ± 14.966
Total Nitrogen (mg/L)	12.3 - 13.7	12.94068 ± 0.754
Total Phosphorus (µg/L)	1108 - 1326	1205.231 ± 115.671

Reactor Operation and Sampling

3 L activated sludge was transferred to the SBR reactor column and the wastewater was added manually. The reactor was operated at 24 hr cycle for proper acclimatization of the sludge at room temperature. Thereafter, at a 6 hr cycle period with fixed intervals for filling, reaction, settling, and decanting. Characteristics of influent and effluent were determined for each cycle. Samples were collected and analyzed for COD, pH, conductivity, and BOD. Sludge properties MLSS and SVI were measured daily. Air was supplied at a rate of 1.3 L/min. The DO level was monitored to ensure aerobic conditions in the reactor. The cycle was continued till pseudo-

steady-state COD removal was observed. The whole procedure was repeated for 12 hr cycle period. The MLSS concentration was maintained between 2500-3000 mg/L throughout the study. The desired SRT was set as 3.5 days for 6 hr cycle and 7 days for 12 hr cycle.

Table 3.2 : Details of Operating Phases

Phase	**6 HrCycle**	**12 HrCycle**
Fill	Instantaneous	Instantaneous
React	4.5 hr	9.5 hr
Settle	1 hr	2 hr
Decant	0.5 hr	0.5 hr

3.3.3 Analytical Techniques

(a) Chemical Oxygen Demand (COD)

TheCOD was measured using closed reflux dichromate method (APHA, 2005).

(b) Biochemical Oxygen Demand (BOD)

The BOD was measured using dilution method (APHA, 2005).

(c) pH

The pH of samples were measured using ORION 5 Star analyzer.

(d) Electrical Conductivity

The pH of samples were measured using ORION 5 Star analyzer.

(e) Dissolved Oxygen

The dissolved oxygen concentration in mixed liquor was measured usingORION 5 Star analyzer.

(f) Total Solids

Total solids in the sample were determined by drying the sample volume in hot air oven for 24 hrs and then cooling in desiccator (APHA, 2005).

i) Total Nitrogen

Total Nitrogen (TN) was measured using a continuous flow auto analyzer.

(j) Total Phosphorus

Total Phosphorus (TP) was measured using a continuous flow auto analyzer

3.5 Instruments and Equipments Used

The details of instruments and equipments used in the present study are given in Table 3.3.

Table 3.3: List of Instruments and Equipments Used

Instrument/ Equipment	Make and Model
COD Digestor	HACH, DRB 200
Continuous Flow Auto Analyzer	Foss FIAstar, 5000 Analyser
pH meter	Thermo Scientific, Orion 5 Star
Incubator	Colton, Narang Scientific Works Pvt. Ltd.
Balance	Adair Dutt, ADGR 200
Peristaltic Pump	Ravel Hitcks Pvt. Ltd., RH – P 100 VS – 100
Digital Timer	TM – 619 H – 2, Frontier
Muffle Furnace	Microsil, Linco Scientific Instruments and Chemical (Pvt.) Ltd
Stirrer	Remi Motors, GCU 8405
Hot Air Oven	-
Aqua Air Pump	SOBO, SB-548A

RESULTS AND DISCUSSION

The main focus of present study was to Performance evaluation of SBR in combination with macrophyte for treating wastewater. The studies were carried out on laboratory scale SBR operating for 4hr and 120hr cycle The influent and effluent samples were collected and analyzed for pH, conductivity, total solids, COD, BOD, Total Nitrogen and Total Phosphorus. The results are presented in Tables A1.1 – A1.6 (Appendix-1). The results are discussed in following sections.

Date: 04/02/2020								
DT 4 hr	**Parameters**	**pH**	**Conductivity (ms)**	**TS (mg/L)**	**TDS (mg/L)**	**DO**	**BOD**	**Rem**
	Influent	7.97	3.75	2478	2136			
	Effluent SBR	8.04	3.82	2460	2242			
	Effluent CWS	8.04	3.87					

Date: 05/02/2020								
DT 24 hr	**Parameters**	**pH**	**Conductivity (ms)**	**TS (mg/L)**	**TDS (mg/L)**	**DO**	**BOD**	**Rem**
	Influent	7.97	3.82	2673	2546			
	Effluent SBR	8.38	3.82	2328	2431			
	Effluent CWS							

Date: 06/02/2020								
DT 72hr	**Parameters**	**pH**	**Conductivity (ms)**	**TS**	**TDS**	**DO**	**BOD**	**Rema**
	Influent	8.42	3.98	2385	2319			
	Effluent SBR	8.74	3.88	2254	2271			
	Effluent CWS	8.35	3.93					

Date: 13/02/2020								
DT 96 hr	**Parameters**	**pH**	**Conductivity (ms)**	**TS**	**TDS**	**DO**	**BOD**	**Remar**
	Influent	8.47	4.44					
	Effluent SBR							
	Effluent CWS							

4.1 COD Removal

The results of COD removal at varying temperature of 30, 35, 40 ˚C for both 6 hr and 12 hr cycle are presented in Figure 4.1. As shown in Figure 4.1, the COD removal for 6 hrtreatment cycle at 30, 35 and 40˚C was found to be 73.1, 78.8 and 68.5%, respectively. The COD removal for 12 hr treatment cycle at 30, 35 and 40˚C was found to be 88.6, 93.2 and 85.3%, respectively. The COD removal increased with increase in cycle time. Similar trend had been reported in literature where the efficiency of COD removal at 6, 8, 12 hrs were 65%, 80%, 83%, respectively, and the highest removal was at cycle time 12 hrs.This was attributed to a complete oxidation of the refractory organic matters present in theincoming grey water (Sabri et al., 2013). Maximum removal at 35 ˚C may be attributed to the fact that optimum temperatures for bacterial activity have been reported from 25 to 35 °C and at temperature above 39 °C results in decreased activity of mesophilic organisms (Eckenfelder,2000; Metcalf and Eddy, 2003).

4.2 pH

The pH is extremely important in biological wastewater treatment, because the microorganisms remain sufficiently active only within a narrow range, generally between pH 6.5 and 8.5. Outside this range, pH can inhibit or completely stop biological activity. Nitrification reactions are especially pH-sensitive. Biological activity declines to near zero at a pH below 6.0 in unacclimated systems (Water Environment Federation, 2007).

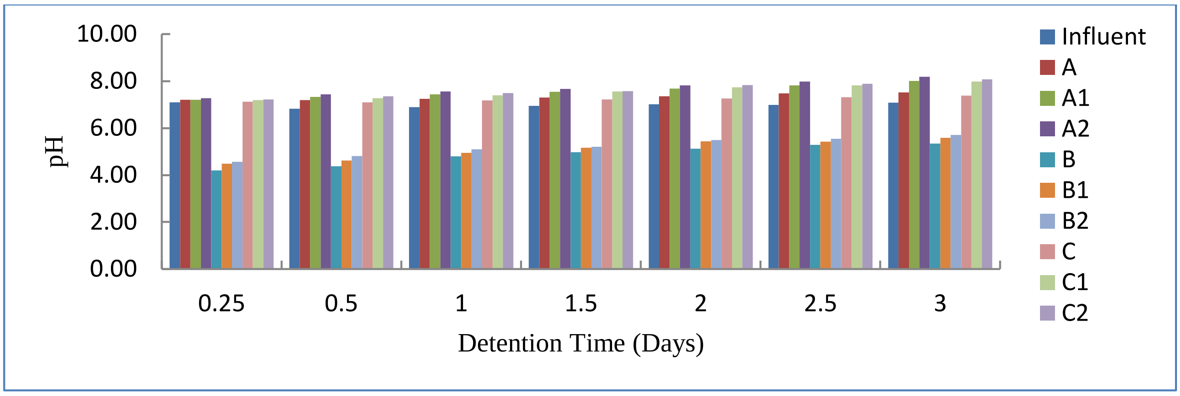

Figure 4.1 pH of Influent and Effluent from CWS in Cycle 1 of Phase I

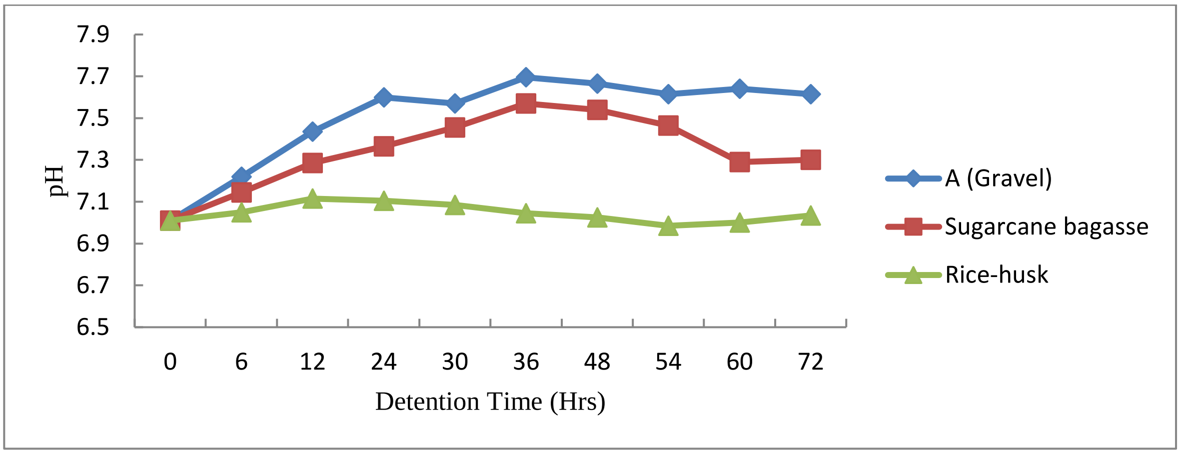

Figure 4.4 Variation in pH of Effluents from Unplanted CWS in Cycle 4 – 5 of Phase II

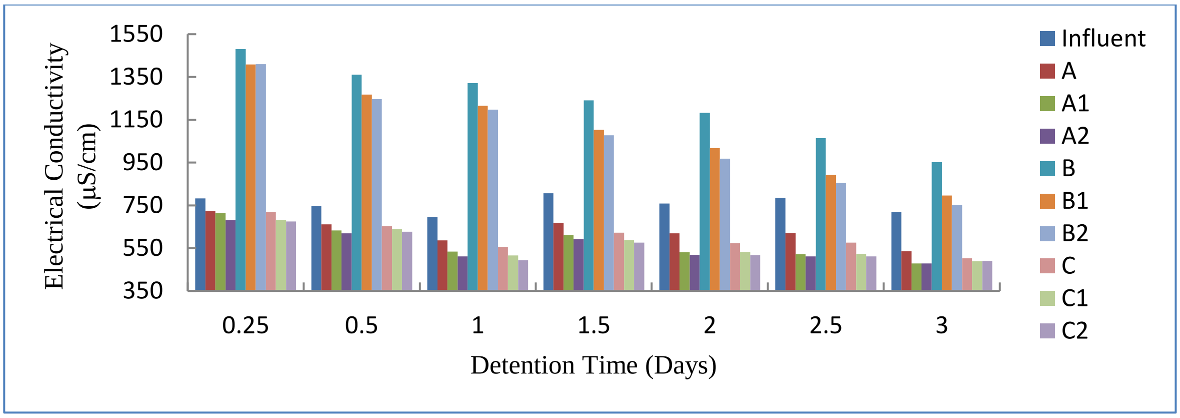

Figure 4.6 EC of Influent and Effluent from CWS in Cycle 1 of Phase I

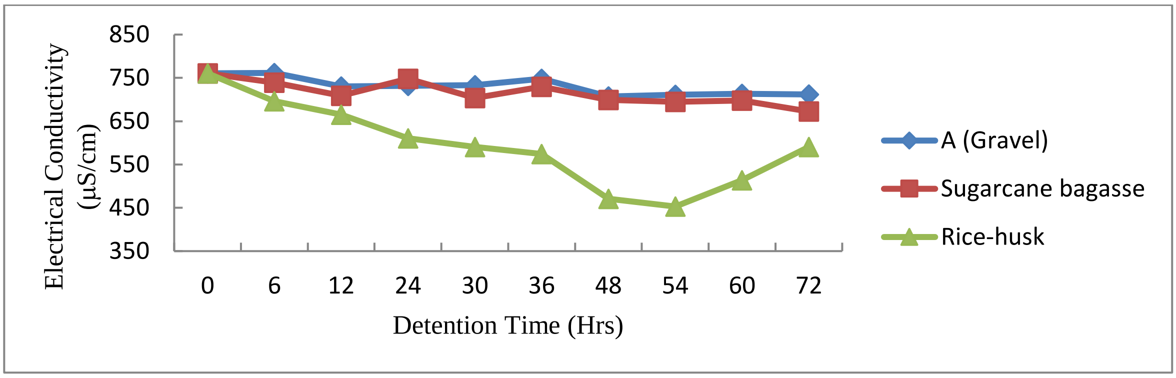

Figure 4.9 Variation in EC of Effluents from Unplanted CWS in Cycle 4 – 5 of Phase II

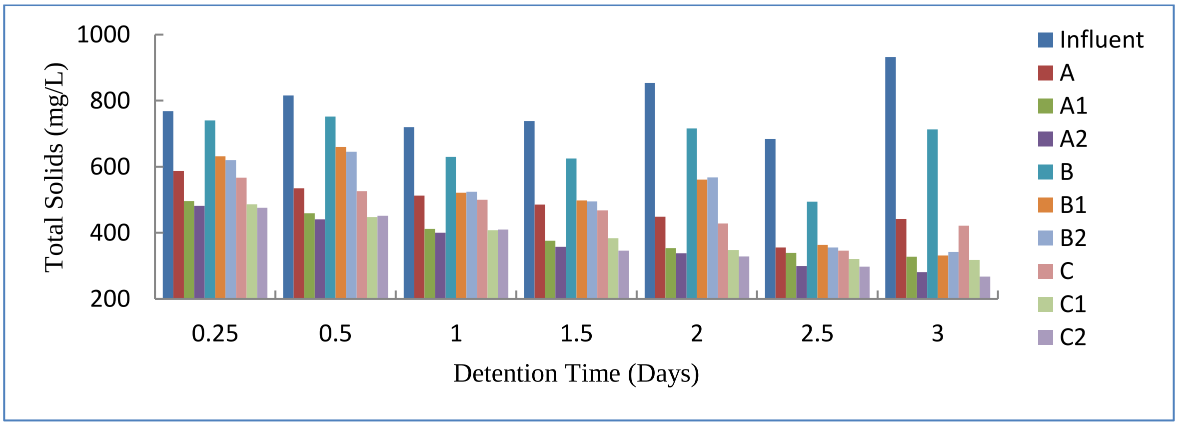

Figure 4.11 TS of Influent and Effluent from CWS in Cycle 1 of Phase I

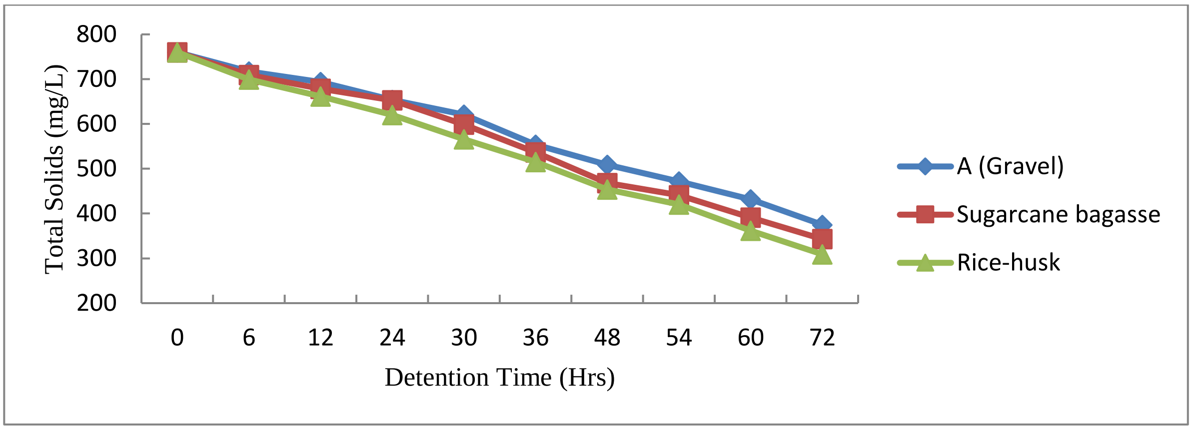

Figure 4.14 Variation in TS of Effluents from Unplanted CWS in Cycle 4 – 5 of Phase II

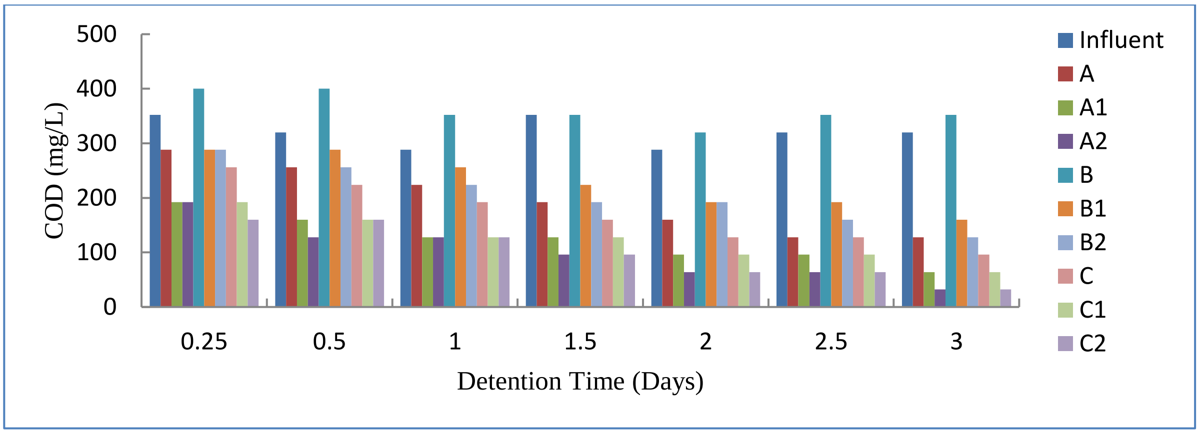

Figure 4.16 COD of Influent and Effluent from CWS in Cycle 1 of Phase I

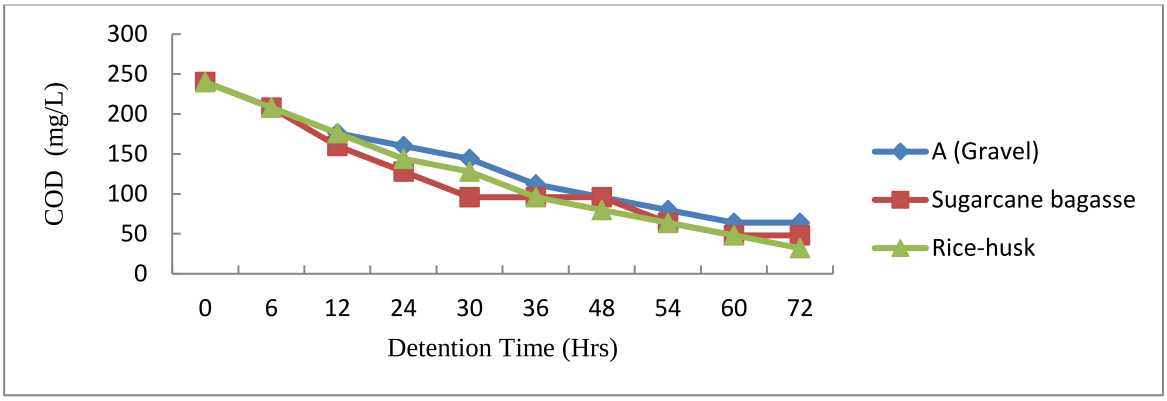

Figure 4.19 Variation in COD of Effluents from Unplanted CWS in Cycle 4 – 5 of Phase II

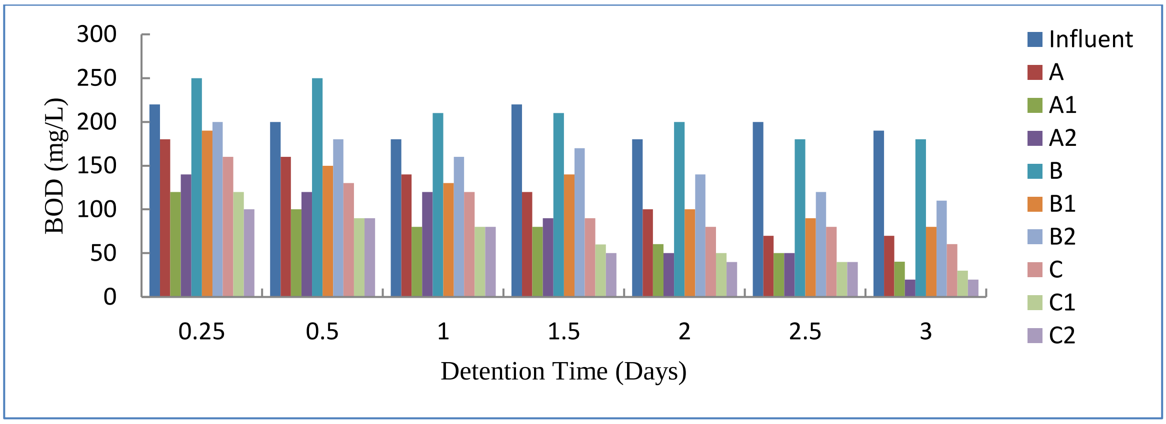

Figure 4.21 BOD of Influent and Effluent from CWS in Cycle 1 of Phase I

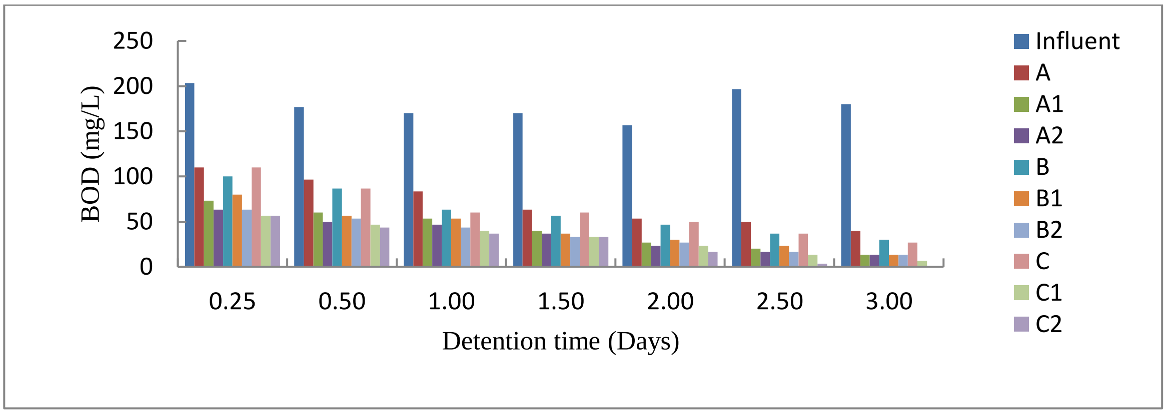

Figure 4.23Mean BOD of Influent and Effluent from CWS in Cycle 1– 3 of Phase II

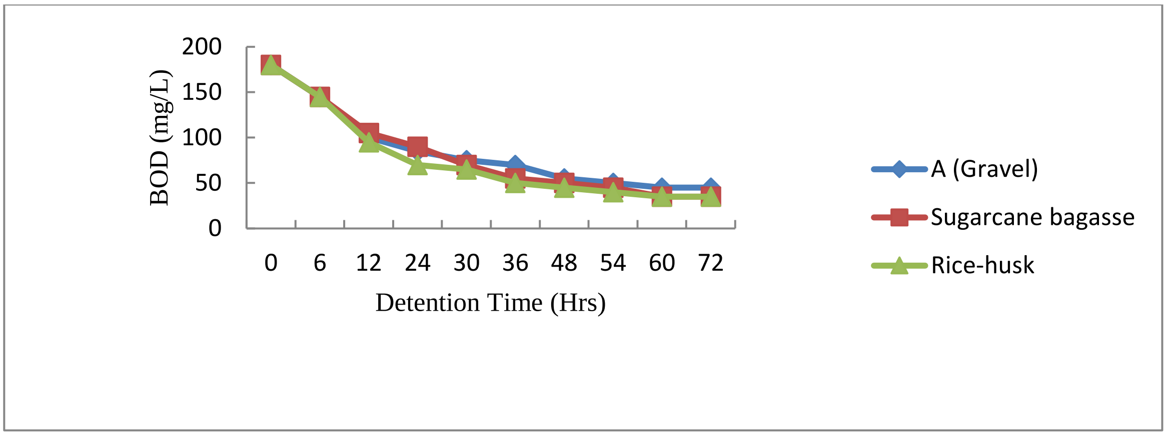

Figure 4.24 Variation in BOD of Effluents from Unplanted CWS in Cycle 4 – 5 of Phase I

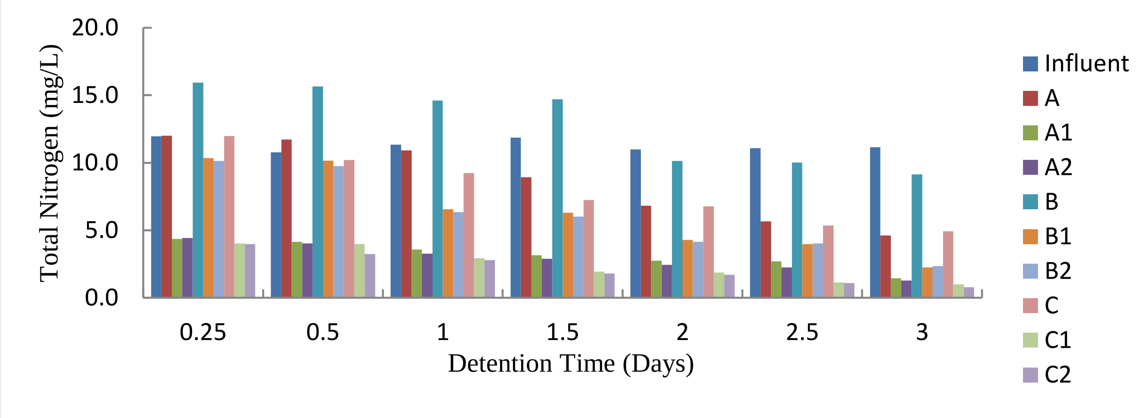

Figure 2.26 TN of Influent and Effluent from CWS in Cycle 1 of Phase I

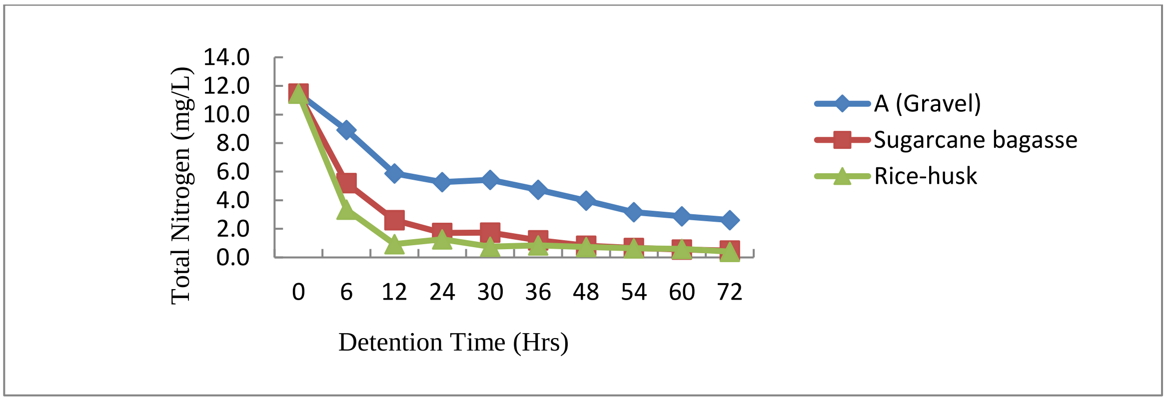

Figure 4.29Variation in TN of Effluents from Unplanted CWS in Cycle 4 – 5 of Phase II

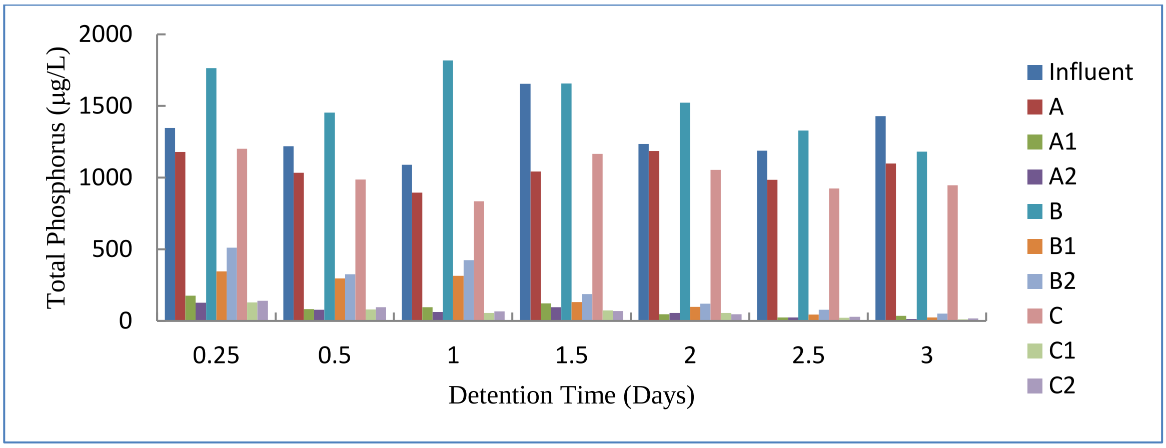

Figure 4.31 TP of Influent and Effluent from CWS in Cycle 1 of Phase I

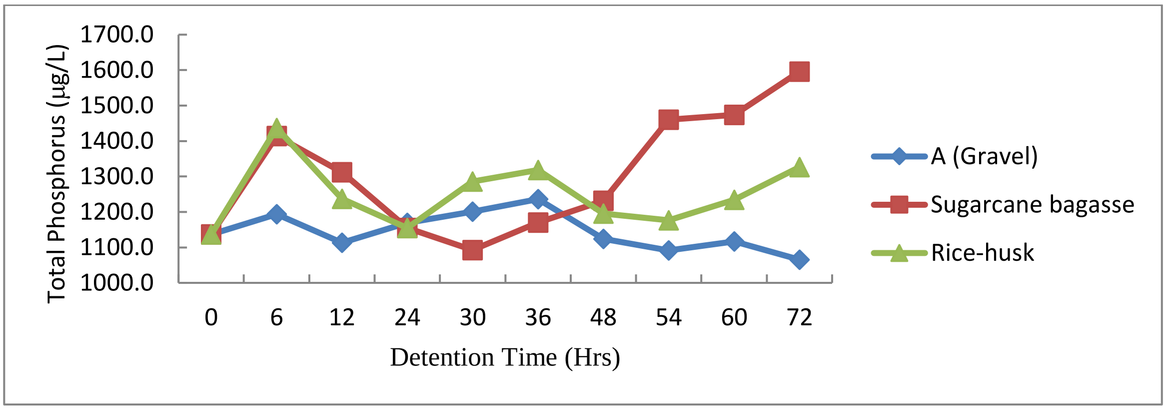

Figure 4.34 Variation in TP of Effluents from Unplanted CWS in Cycle 4 – 5 of Phase II

CHAPTER – 5

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

5.1 Conclusions

The present study was carried out to treat domestic wastewater using constructed wetland system (CWs). Artificial aeration was shown to enhance the unplanted wetland ability to remove COD, BOD and total nitrogen. Substrate in CWs i.e gravel, sugarcane bagasse and rice-husk adsorbed organic as well inorganic matter and provided surface for the growth of microorganisms. Macrophyerhizosphere helps in degradation of pollutants, uptake of nutrients, and adsorption of pollutants present in the domestic wastewater. The following findings/conclusions emerged from the present study.

- The total solids in the domestic wastewater were effectively removed by unplanted CWs containing rice-husk followed by planted CWs with *Ranunculussceleratus*or E*ichhorniacrassipes*or*Veronica anagallis-aquatica*. The maximum total solids removal was 89%.
- Average COD of the domestic wastewater was 287.2 mg/L. The maximum COD removal were 73, 81 and 85% in unplanted CWS A, B and C, respectively. The COD removal was 85% in two stage CWS B-B1, 88% in A-A1, A-A2, B-B2, 89% in C-C1 and 100% in C-C2.
- Average BOD of the domestic wastewater was 183.9 mg/L. The maximum BOD removal were 79%, 83% and 85% in unplanted CWS A, B and C, respectively. The BOD removal were 95% in two stage CWS A-A1, 93% in A-A2, B-B1, B-B2, 96% in CC1 and 100% in C-C2.
- Average influent total nitrogen concentration of 11.5 mg/L were reduced to 4.6, 9.1 and 4.9 mg/L in unplanted CWS A, B and C, respectively when no bacterial consortium was introduced. When bacterial consortium was added TN reduced to 3, 3 and 2.3 mg/L in unplanted CWS A, B and C, respectively.
- Rice-husk followed by macrophyte species i.e. *Ranunculussceleratus*or E*ichhorniacrassipes*or*Veronica anagallis-aquatica* reduced the total nitrogen to zero whereas gravel and sugarcane bagasse followed by the *Ranunculussceleratus*or E*ichhorniacrassipes*or*Veronica anagallis-aquatica* reduced total nitrogen to very low value of 0.6 – 1.1 mg/L.

- Average influent total phosphorus concentration was 1.27 mg/L. There was no significant removal of total phosphorus in system A, B and C. The system A showed maximum TP removal i.e. 37% (DT 1.5 days) and 23% (DT 3 days) during the Cycle1 of Phase I. There was no TP removal when bacterial consortium was introduced externally.
- Unplanted CWs shown high removal of bacteria. The maximum bacterial removal in unplanted CWS A, B and C were 97.72 (DT 2.5 day), 89.65 (DT 1.5 day) and 95.52 (DT 1.5 day), respectively. In two stage CWS maximum bacterial removal observed at 6 day overall detention were 99.57, 99.79, 99.26, 99.47, 99.13 and 99.63 in A-A1, A-A2, B-B1, B-B2, C-C1 and C-C2, respectively.

5.2 Suggestions for Future Work

Based on the experience of present study and related information reported in literature, future efforts may involve following suggestions:

- Study of TN and TP retained in the rizhosphere of *Veronicaanagallis-aquatica*and *Eichhorniacrassipes.*
- Study on capability of *Veronica anagallis-aquatica*and *Ranunculussceleratus in* phytoextraction of heavy metals may be carried out.
- Studies may be carried out using Ranunculussceleratus, Eichhorniacrassipes, Veronica anagallis-aquatica for continuous flow condition.

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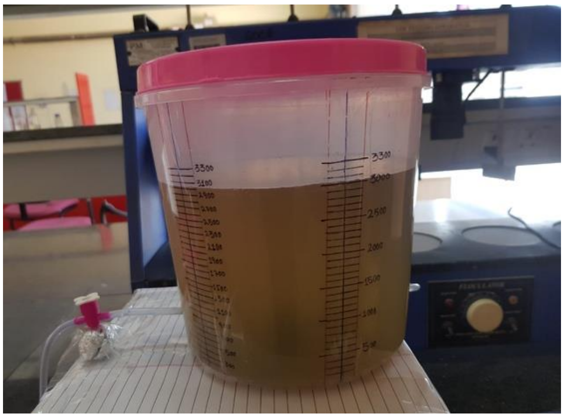

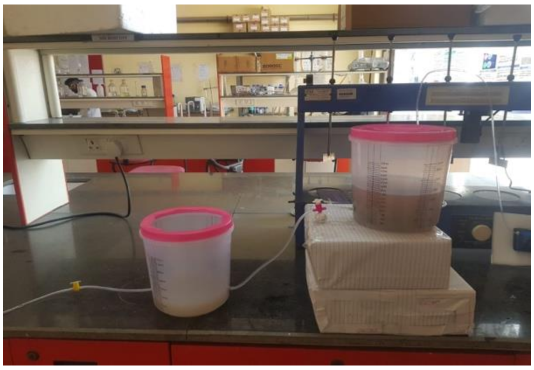


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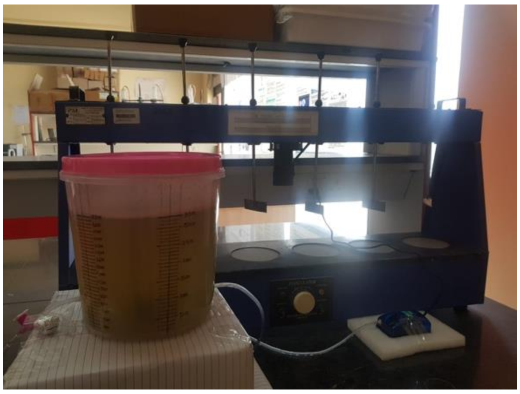

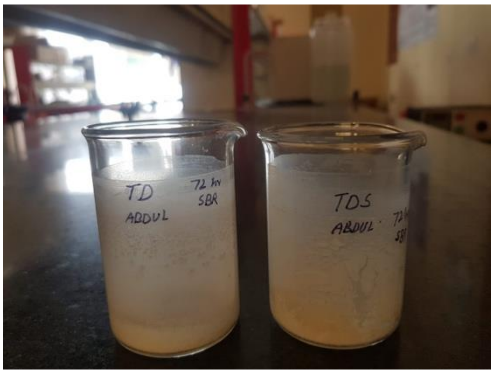
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