PERFORMANCE EVALUATION OF A
SUBSURFACE FLOW CONSTRUCTED WETLAND

By

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PROJECT REPORT

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Department of Land and Water Resources and Conservation Engineering

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DECLARATION

We hereby declare that this project entitled **"PERFORMANCE EVALUATION OF A SUBSURFACE FLOW CONSTRUCTED WETLAND"** is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of another university or society.

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CERTIFICATE

Certified that the project entitled **"PERFORMANCE EVALUATION OF A SUBSURFACE FLOW CONSTRUCTED WETLAND"** is a record of project work done jointly by **Ms. Nafla K** and **Mr. Navaneeth B S** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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Nafla K

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SYMBOLS AND ABBREVIATIONS

Asst.	Assistant
BOD	: Biological Oxygen Demand
CASP	: Carbon Activated Sludge Process
CBF	: Commercial Bio Filter
CPCB	: Central pollution control board
CW	: Constructed wetland
Dept.	: Department
E.g.	: Example
EC	: Electrical Conductivity
et al.	: And others
Etc.	: Etcetera
Fig.	: Figure
FWS	: Free water surface flow
GW	: Grey water
h	: Hour
HF	: Horizontal Flow
HP	: Horse power
HRT	: Hydraulic Retention Time
i.e	: That is
KCAET	: Kelappaji College of Agricultural Engineering And Technology
LH	: Ladies' Hostel
L	: liter
L/p/d	: Liter per person per day

Lpcd	: Liter Per Capital per Day
LWRCE	: Land and Water Resources and Conservation Engineering
m	: meter
MBBR	: Moving bed bio film reactor
Mg	: Magnesium
mg/l	: milligram per liter
mm	: millimeter
MNP	: Most Probable Number
N	: Nitrogen
Na	: Sodium
P	: Phosphorous
PBBR	: Packed Bed Biofilm Reactor
PVC	: Poly Vinyl Chloride
S	: Sulfur
S/cm	: Siemen per centimeter
SFCW	: Subsurface Flow Constructed Wetland
Sp.	: species
TC	: Total Carbon
TDS	: Total Dissolved Solid
TSS	: Total Soluble Solids
UASB	: Upflow Aerobic Sludge Blanket
VF	: Vertical Flow
WHO	: World Health Organisaton
%	: Percentage
&	: And

°C	: Degree Celsius
/	: Per
°	: Degree
‘	: Minutes(s)
“	: Second(s)

CHAPTER 1

INTRODUCTION

Water is the nature's most precious gifts to mankind. It is the most essential component of life and is vital for sustenance. About 70% of the earth's cover being water; it becomes one of our greatest resources and it is easy to think that it will always be plentiful. But water is becoming a rare resource in the world. However, freshwater- the stuff we drink, bathe in, and irrigate our farm fields is incredibly rare. Only 3% of the world's water is fresh water, and two-thirds of that is tucked away in frozen glaciers or otherwise unavailable for our use.

The water shortage is because world population increases day by day, improper usage water and lack of recycling. As a result, some 1.1 billion people worldwide lack access to water, and a total of 2.7 billion find water scarce for at least one month of the year. Inadequate sanitation is also a problem for 2.4 billion people who are exposed to diseases, such as cholera and typhoid fever, and other water-borne illnesses. Two million people, mostly children, die each year from diarrheal diseases alone.

Many of the water systems that keep ecosystems thriving and feed a growing human population have become stressed. Rivers, lakes and aquifers are drying up or becoming too polluted to use. More than half the world's wetlands have disappeared. Agriculture consumes more water than any other source and wastes much of that through inefficiencies. Climate change is altering patterns of weather and water around the world, causing shortages and droughts in some areas and floods in others.

At the current consumption rate, this situation will only get worse. By 2025, two-thirds of the world's population may face water shortages and ecosystems around the world will suffer even more.

Globally, most of the developing countries are geographically located in those parts of the world that are or will face water storage in near future. Moreover, the existing water sources are contaminated because untreated sewage and industrial waste water is discharged into surface waters resulting impairment of water quality. Therefore it is essential to reduce surface and ground water use in all sectors of consumption, to substitute fresh water with alternative water resources and to minimize water use efficiency through waste water treatment and reuse options.

Waste water term used for any water that has been adversely affected in quality by anthropogenic influences. It comprises liquid waste discharged by domestic residences, offices and retail buildings industrial or manufacturing plants and agricultural uses

The main alternative sources used for reuse options are rain water and gray water. Rain water harvesting and their treatment are mainly used in area where getting rainfall as a major water source.

Grey water is commonly defined as wastewater generated from bathroom, laundry and kitchen. Due to rapid industrialization and development, there is an increased opportunity for grey water reuse in developing countries generated from bathroom, laundry and kitchen. Due to rapid industrialization and development, there is an increased opportunity for grey water reuse in developing countries.

Some researches indicates that about 27% of grey water originates from the kitchen sink and dishwasher, 47% originates from the wash basin, bathroom, and shower, and 26% originates from laundry and the washing machine.(Jamrah,*et al.*, 2006; Al-Mughalles*et al.*,2012; Ghaitidak and Yadav, 2013).

1.1 Benefits of grey water recycling

- Lower fresh water extraction from river and aquifers

- Reduce strain in septic tank or treatment systems
- Indoor usage .E.g. .toilet flushing
- Irrigation and plant growth
- Less energy and chemical use
- Highly effective purification
- Ground water recharge
- Maintain soil fertility
- Enhance water quality

There are many types of methods for grey water treatment. It may be use of chemicals or any physical methods. Along with use of chemicals some environmental friendly methods also can be employed. We can utilize wet land that has been naturally occurred or manmade is an effective system for water treatment.

Wetlands are area that water covered with soil or is present at surface of soil or near the surface for varying period of time during a year. Wetlands support growth of both aquatic and terrestrial plants due to prolonged presence of water. The larger aquatic plants usually grown in wetlands are called macrophytes. Wetlands are also termed as 'nature's kidneys', because they cleans our environment. Wetlands are very sensitive eco systems; they are fully influenced by the hydrologic conditions of soils. Marshes, bogs, and swamps are all the examples of naturally occurring wetlands. The transportation and transformation of chemicals in an ecosystem is called biogeochemical cycling. Wetlands are influences these cycles prominently.

Some of the functions of wetlands are given below

- Wetlands can provide water quality improvements
- Recycling of nutrients and other materials
- Habitat fish and wild life
- Used for education and research purposes

- Support many of living organisms
- Flood storage and desychronisation of storm rainfall and surface runoff etc

The treatment of waste water using constructed wetland (CW) is one of the suitable treatment systems, used in many part of the world. A “constructed wetland” is defined as a wetland specifically constructed for purpose of pollution control and waste water management, at a location other than existing natural wetlands. Wetlands can be used for primary, secondary and tertiary treatment of domestic waste water, storm waste water, combined sewer overflows, overland runoff, and industrial waste water such as landfill leachate and petrochemical industrial wastewater.

A subsurface flow constructed wetlands (SFCW) are specially designed for waste water treatments are typically constructed as a bed or channel with appropriate media like coarse rock, gravel, sand and other soils etc. sometimes mediums are planted with emergent type of macrophytes.

The most common emergent plants in SFCWs include cattail (*typha*spp.) bulrush (*scirpus*spp.) and reeds (*phragmites*spp.). Many of small on site system in homes, uses water tolerant decorative plants as the planting crop in CWs. The submerged plants roots provide substrate for microbial process and most emergent plants can transmit oxygen from the leaves to their roots there are aerobic microsites on the rhizomes and root surface. SFCW systems are very effective for removal of BOD, TSS, metals and some priority water pollutants etc.

Horizontal subsurface flow constructed wetlands are most commonly used for aerobic post treatment of domestic waste water and takes a higher hydraulic load than of a surface flow CWs. When they are accurately designed provide an extremely reliable low cost treatment solution than other treatment systems.

In this project, we focus on grey water treatment by using subsurface constructed wetland and its use as an alternative water resource for irrigation purpose.

Objectives

1) To design and fabricate the subsurface flow wetland by using suitable filter media and vegetation.

2) To evaluate the performance of subsurface flow constructed wetland.

CHAPTER 2

REVIEW OF LITERATURE

2.1. Scope of waste water treatment

Wastewater recycling has been and continues to be practiced all over the world for a variety of reasons including; to increase water availability, combat water shortages and drought, and support environmental and public health protection. The increase in water demand is due mainly to the steady rise in the world's population which also generates an increase in wastewater production. Consequently wastewater, if recycled, becomes a significant source of water that could potentially cover for the lack of fresh water observed elsewhere. Worldwide, the most common application for wastewater recycling is agricultural irrigation. However, other options such as industrial, recreational, environmental and urban reuse have been practiced.

Central Pollution Control Board (CPCB) studies estimated that there are 269 sewage treatment plants in our India, of 231 are operational, thus the existing treatment capacity is about 21% of the present sewage water generation. The remaining untreated sewage water is the main cause in pollution in lakes, rivers and other natural water sources. The large number of sewage treatment plants created under central funding schemes such as Ganga Action Plan and Yamuna Action of Natural River Action Plans are not fully operated till now. (CPCB 2007)

2.2 Waste water treatment technologies

Waste water treatment plants are the facilities designed to receive the domestic, commercial and industrial waste water sources and to remove the materials, they effects the quality of water and compromise the public safety health when discharged into water receiving systems. The principal purpose of waste water treatment is generally to allow domestic and industrial effluents to dispose without danger to human health or unacceptable damage to the natural environment.

2.2.1 Conventional waste water treatment processes

Conventional waste water treatment processes consists of a combination of physical, chemical and biological operations to remove solid, organic matter and sometimes nutrients from waste water.

2.2.1.1 Preliminary treatment

The objective of preliminary treatment is the removal of solids and other coarse or larger materials often found in raw waste water. Removal of these materials is necessary to enhance the operation and maintenance of subsequent treatment units. Preliminary operations include screening, grit removal and in some cases comminution of large objects.

2.2.1.2 Primary treatments

The objective of primary treatment is the removal of organic and inorganic solids by sedimentation and the removal of material that will float (scum) by skimming.

2.2.1.3 Secondary treatment

Secondary treatment is the further treatment of the effluent that coming from primary treatment to remove the residual organics and suspended solids. In most cases, secondary treatment follows primary treatment and used to remove the bio degradable dissolved and colloidal organic matters using aerobic biological treatment processes. Aerobic biologic treatment processes is performed in the presence of oxygen by aerobic micro-organism that metabolize the organic matters in the waste water and thereby producing inorganic end product with more micro-organism. Common processes include the activated sludge process, tickling filter or bio filter, oxidation ditches and rotating biological contractors (RBCs)

2.2.1.4 Tertiary treatments

Tertiary treatment is the final cleaning process that improves waste water quality before it reused, recycled or discharged to the environment. Tertiary treatment is necessary in waste water treatment system, if secondary treatment cannot remove main contaminants.

2.3 Grey water treatment systems

Grey water (GW) is defined as wastewater that includes water from baths, showers, hand basins, washing machines, dishwashers, and kitchen sinks, but excludes streams from toilets (Jefferson,*et al.*, 2000; Eriksson,*et al.*, 2002; Friedler and Hadari, 2006; WHO-guidelines, 2006). Some authors exclude kitchen wastewater from the other grey water streams (Christova-Boal,*et al.*, 1996;Al-Jayyousi, 2003; Ghunmi, 2009). Wastewater from the bathroom, including showers and tubs, is termed light grey water (Friedler and Hadari, 2006). Grey water that includes more contaminated waste and from laundry facilities, dishwashers and, in some instances, kitchen sinks is called dark grey water (Birks and Hills, 2007).

The potential sources identified for urban reuse are sewage, greywater and rain water, where greywater is defined as domestic wastewater excluding toilet flush. In some cases, mixed rain and grey waters have been used as well as a ‘light greywater’ including only the sources from the bathroom, The advantage of recycling greywater is that it is a large source with a low organic content. To illustrate, greywater represents up to 70% of total consumed water but contains only 30% of the organic fraction and from 9 to 20% of the nutrients (ICCREST-2016).

Water consumption always depends on the quality of life standards and availability of resources. The quantity of grey water generation depends on the total water consumption, living standard, population structures (i.e., age, gender), resident habits, and water installations of a given population (Morel and Diener, 2006; Ghaitidak and Yadav, 2013).

Some grey water sources and their constituents are presented in fig 2.1

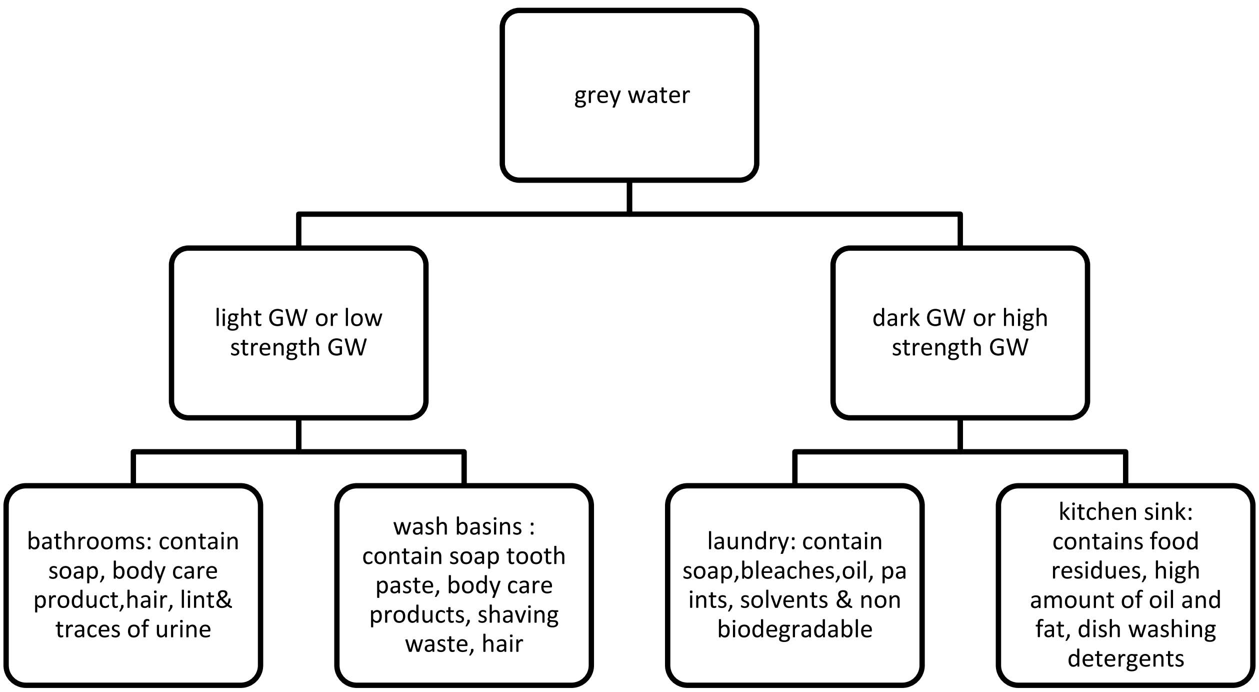
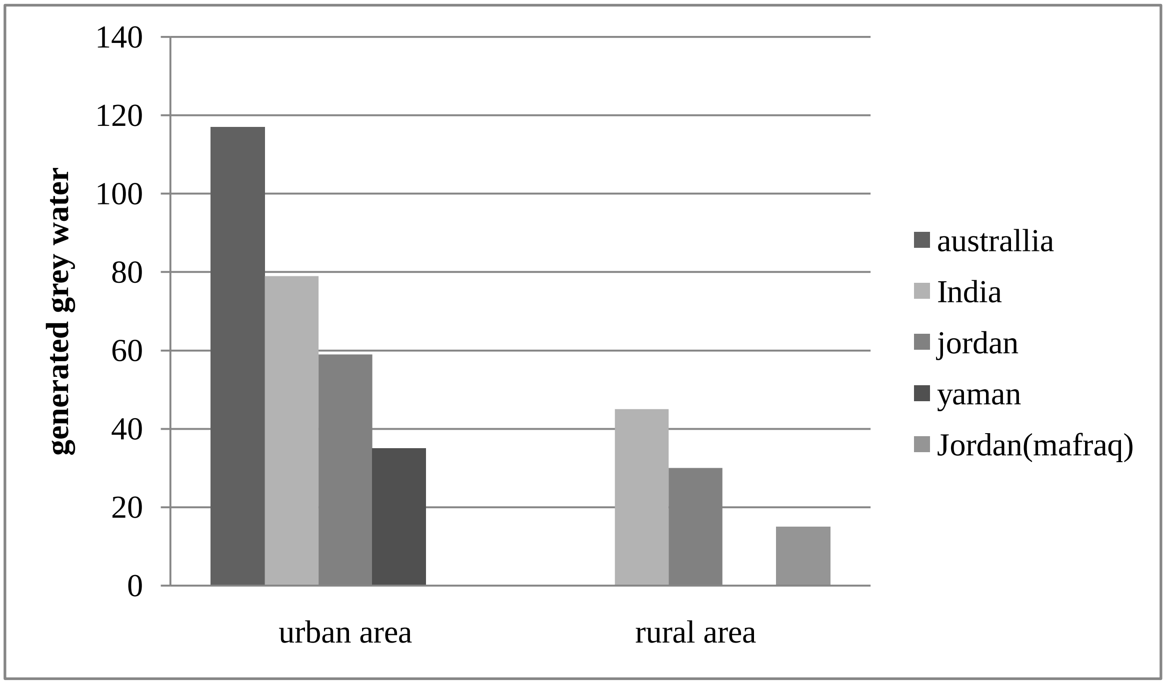


Fig2.1 Grey water sources and their constituents

Grey water varies from 50% to 80% of the wastewater volume produced by households (Jenssen and Vråle, 2003; Flowers, 2004), and over 90% if vacuum toilets are installed Leal et al. (2011). The typical volume of grey water varies from 90 to 120 l/p/d, however the volume of grey water in low income countries that experience chronic water shortages can be as low as 20–30 l/p/d (Morel and Diener, 2006). The quantity of grey water also varies between urban and rural area,as shown in Figure 2.2



(source:Al-Mughalles et al. (2012))

Fig 2.2 Variation of grey water generation between urban area and rural area

Halalsheh,*et al.* (2008**)** carried out various treatment systems on grey water treatment. The average grey water generation was measured to be 14 Lpcd. The examined treatment systems are septic tank followed by intermittent sand filter; septic tank followed by wetlands; and UASB-hybrid reactor (upflow anaerobic sludge blanket). The study area was Um Alquttain in Mafraq governorate located north east of Jordan. Family size ranges between 5 and 11 persons. Grey water was collected from six households and 12 different places. Average COD, BOD and TSS values were 2568 mg/l, 1056 mg/l and 845 mg/l, respectively. Concluded that UASB-hybrid reactor would be the most suitable treatment option in terms of compactness and simplicity in operation. The volume of UASB-hybrid reactor was calculated to be 0.268 m^3 with a surface area of 0.138 m^2 for each house having 10 inhabitants on average. The system is considered to be a low cost treatment option, which is affordable by households and flexible in operation and maintenance.

Pidou *et al*. (2008) investigated about the use of a coagulation/flocculation treatment system for shower grey water. There achieved sufficient levels of organics and coliforms removal but found poor in removal of total N; they achieved BOD removal of 85 to 89%,COD removal around 64 %, total N removal of up to 13%, TC removal greater than 99 %, and E-coli removal greater than 99 %. Furthermore, this system provided better results in acidic p^H, which requires adjusting the p^H after treatment.

Bhausaheb *et al*. (2010**)** implemented a grey water treatment based on the hybrid treatment involving a combination of physical and natural systems of cascaded water flow, aeration, agitation and filtration. Laboratory scale greywater treatment plant was designed for 180 l/h capacity restricted four stage physical operations such as primary settling with cascade flow of water has 20 litres capacity, aeration has 15 litres tank capacity, agitation has also 15 litres and filtration unit of 20 litres. The 0.18m diameter agitator and 0.125 HP motor was used in the agitation operation. The easily available and natural materials were used as filter beds in the filtration unit such as fine particles (equal size) sand bed, course size bricks bed, charcoal bed, wooden saw dust bed and bed of coconut shell covers. The bed height of each material was determined and finalized by the experimentation. The further experiments were carried by placing a bed depth of each as 0.15m, o.1m, 0.2m for sand. Soaps and detergents were carried out by agitation operation. A removal of 26% was observed. This involved a cost effective treatment without the chemical operations.

Grewal,*et al*. (2010**)** carried out greenhouse experiments and studied the effects of grey water irrigation on the growth of silver beet plants. The comparative studies were carried out by irrigating by 100% potable water and 100% with grey water and a mixture of grey and potable of ratio 1:1. The p^H and EC (Electrical conductivity) values of the grey water used in the study were 10.5 and 1358S/cm respectively. Results showed that grey water irrigation had no significant effect on soil total N and total P after plant harvest, but there were significant effects on the values of soil pH and EC.

Kariuki et al (2011**)** performed experiments on treatment of greywater by series of units comprising of Filtration, Flocculation, Sedimentation and Disinfection. Their main aim was to provide low cost technology and that led them to combine physical, physiochemical and biological. Greywater was collected from Kenyatta University kitchen and students` laundry uses from the two sources between 2008 and 2009. Initially pre-treatment was done to remove oil, grease and then led to filtration barrier. The capacity of each subsequent system was having a capacity of 200 L, alum was added for flocculation18. Screening of E-coli bacteria was done and BOD, EC, and COD were determined. p^H values of GW from kitchen and laundry sources were found out significantly different with kitchen GW having higher values than laundry GW.

Mandal *et al.*(2011**)** carried out the characteristic study by collection of grey water from recycling system was designed and implemented in an urban household having a water requirement 165 litre per capita per day and a grey water generation rate of 80 lpcd. Up flow and down flow treatment plant involves screening, sedimentation, disinfection and filtration. Nagpur is located at an altitude of 310m above sea level at latitude of 21°06'N and 79°03'E longitude. Nagpur experiences a climate that is mainly dry and slightly humid for major period of the year. Summer season in the city begins around in the month of March and lasts till June. Maximum temperature is recorded above 45◦C for about 30 days. Nagpur also experiences water scarcity in summer season despite annual rainfall of about 1200mm which predominately occurs in the months of monsoon, i.e. from July to September. Water requirement for bath and laundry (shower, hand wash basin, laundry tap and washing machine) was 96lpcd. Water requirement for kitchen (kitchen tap, dish washer, etc.) was 17lpcd. Water requirement for toilet flushing is equal to22lpcd. Design flow rate for filtration is equal to 0.1–0.2$m^3/m^2/h$ (0.15$m^3/m^2/h$ is considered in this study. Based on this study, it is estimated that about rupees 2, 80, 320 lakhs per year water charges can be saved, if treated recycled greywater is used for gardening, irrigation and for toilet flushing in NEERI (National environmental engineering research institute) colony. Recycling and conservation of water in urban areas is therefore an essential contribution to the future.

Parjane, *et al*. (2011) presents grey water reuse system is developed for the small college campus in rural areas. The finest design of laboratory scale grey water treatment plant, which is a combination of natural and physical operations such as primary settling with cascaded water flow, aeration, agitation and filtration, hence called as hybrid treatment process. Performance of the plant were investigated for treatment of bathrooms, basins and laundries grey water and recycled in residential hostel at college campus in rural Maharashtra.13 Laboratory scale grey water treatment plant was designed for 180 L/h capacity restricted four stages such as primary settling with cascade flow of water has 20 litres capacity, aeration has 15 litres tank capacity, agitation has also 15 litres and filtration unit of 20 litres. The sources of the grey water was collected from bathrooms, basins and laundries in residential rural area in a tank and sent to the primary settling unit by the 0.5 HP pump.13 from the performance of laboratory scale experiments studied that the average organic load in grey water found 327 mg COD/L. The solids in grey water were found to have about 76% dissolved and 24% suspended particles. All the parameters found in grey water were reduced and found the better performance of the natural system. The average 83 % of organic load was removed and the 46 % anions and 49 % cations were found to be adsorbed by the natural adsorbents used in filtration.

Pawskar *et al.* (2012) investigated the effectiveness and techno economic feasibility for Root zone treatment system(RZTS) along with its modification and he made the study on COD, BOD and TSS removal efficiency of modified RZTS and tickling model. The modification was carried out in a conventional RZTS to minimize the area requirement which is major constraint while using conventional RZTS. Lower 0.5 m bed will be acting as constructed wetland (RZTS), as anaerobic treatment and upper 1.5 m depth bed will be designed as trickling bed, act as aerobic treatment. Design and cost analysis of RZTS application with modification so as to treat waste water incoming to various nallahs of Kolhapur (Maharashtra, India) city throughout the nallah area which will also prove multiple point waste water treatment.15 The experimental results shown that average BOD removal efficiency of designed unit (modified design of RZTS and trickling bed) is about 85.25%upto 0.5m root zone bed depth, and is of average 79.45% for total 1.5m combined bed depth. COD removal efficiency of designed unit (modified design of RZTS and trickling bed) was 85.25%upto 0.5m root zone bed depth, and is of average 79.45% for total 1.5m combined bed depth. The average TSS removal efficiency of designed unit (modified design of RZTS and trickling bed) is 91.83% up to 0.5m root zone bed depth, and is of average of83.07% for total 1.5m combined bed depth. The result indicated that RZTS have provided the low cost system and can be built by both centralized and decentralized manner and with efficient removal of pathogens by providing a long life span.

Azizi, *et al.* (2013) evaluation was done by the different waste water treatment process and the development of modified attached growth bioreactor as a decentralized approach for small communities. The evaluation was done based on three biological process namely activated sludge process (CASP), moving bed bio film reactor (MBBR) and packed bed bio film reactor (PBBR) (Figure 5) The laboratory scale result revealed that the overall reduction of 87% COD, 92% BOD_5, 82% TSS, 79% NH_3-N, 43% PO_4-P, 95% MPN (most probable number), and 97% TVC at a HRT of 2 h was achieved in

PBBR. This study illustrated that the present PBBR with a specific modified internal arrangement could be an ideal practice for promoting sustainable decentralization and therefore providing a low wastage sludge biomass concentration. The results obtained from the study suggest that the conventional activated sludge has low degree of flexibility and treatment efficiency; however, the attached growth technologies are remarkably superior in pollutant elimination even at low hydraulic retention time from residential wastewater The present packed bed bio film reactor under modified internal arrangement provided a better treatment efficiency and lower wastage of bio solids in comparison to the other two processes.

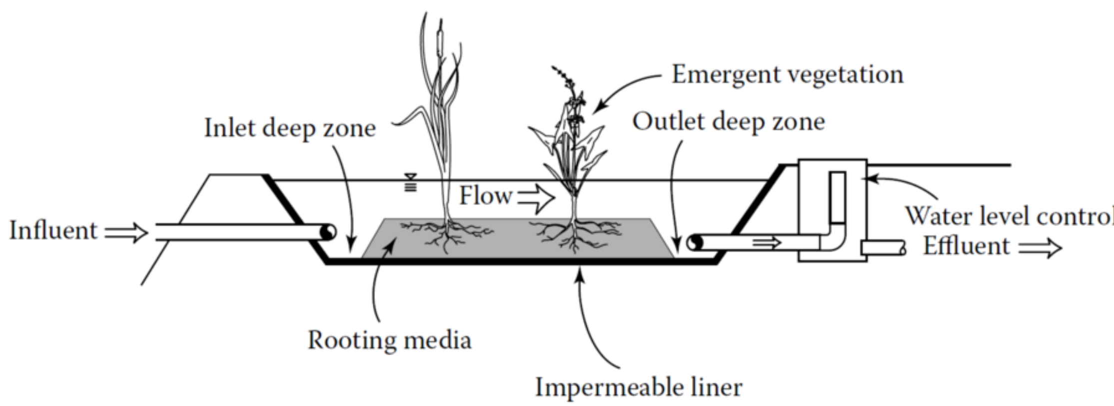
Sameer *et al*. (2015**)** evaluated and implemented the integrated treatment of grey water from household ‘and a small scale experiments were conducted on greywater. The sample was collected from 100 households from Maharashtra mainly to deal with water crisis problem. The experiment involves 100 L/h capacity restricted five components such as storage tank with 100 litres capacity, sedimentation tank has 40 L capacity, Filter-I (Gravel + Sand) has 40 litres Filter-II (Coconut shell coal + Charcoal) unit of 40 L capacity and Disinfection Tank has also 40 litres capacity. Various parameters like P^H, TSS, TDS, COD, turbidity and chloride content were determined for each sample, the analysis was done. There was observed a drastic change between after and before treatment.

2.4. Constructed wetland

Constructed wetlands can be defined as an ‘‘engineered systems, designed and constructed to utilize the natural functions of wetland vegetation, soils and their microbial populations to treat contaminants in surface water, groundwater or waste streams” (ITRC, 2003). A constructed wetland consists of a properly designed basin that contains filter substrates, water and appropriate cultivated plants. These components can be manipulated or altered based on the needs.

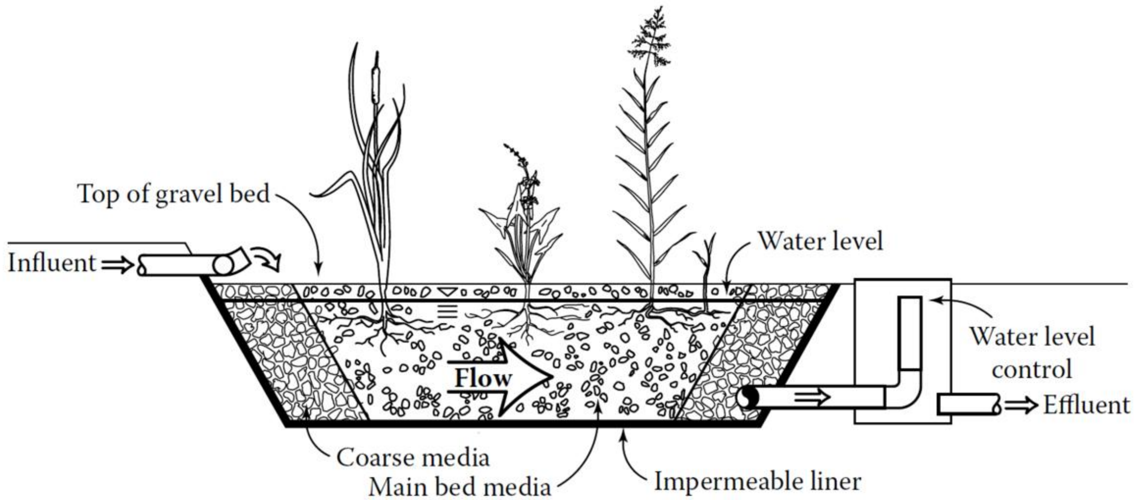
Constructed wetlands for waste water treatment are classified according to types of dominating macrophytes in the system as free floating, floating leaved, emergent and submerged macrophytes.

Constructed wetlands can be classified based on their water flow regimes (or hydrology) as free water surface flow constructed wetland (FWS CWs) and subsurface flow constructed wetland (SFCWs). And subsurface flow CWs further classified according to flow direction into horizontal flow and vertical flow.



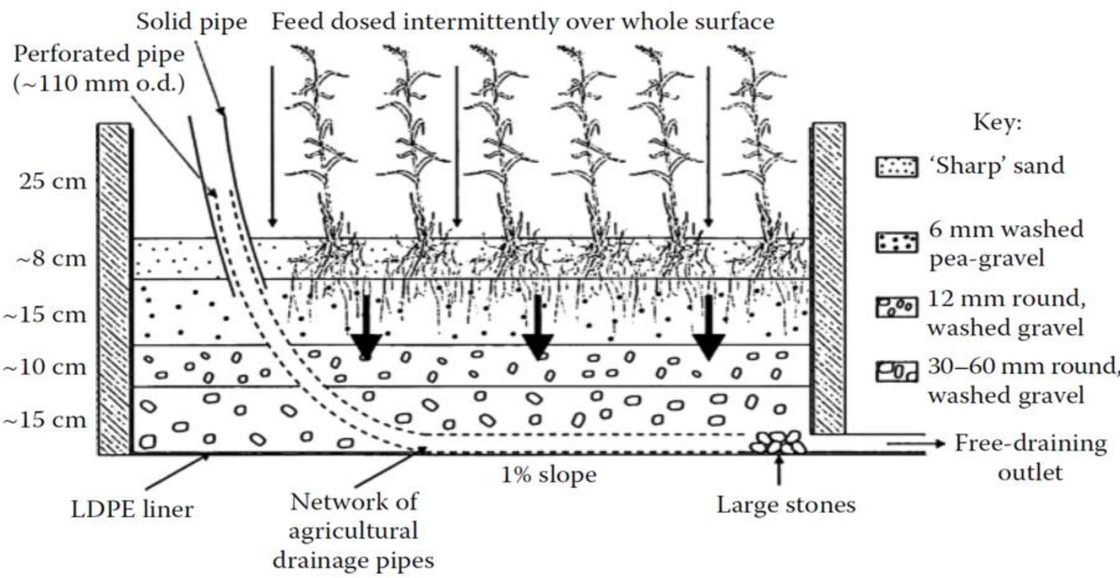
(source: Kadlec& Wallace, 2009)

Fig.2.3 Typical configuration of a free water surface flow constructed wetland



(source: Kadlec& Wallace, 2009)

Fig.2.4 Typical configuration of a horizontal subsurface flow constructed wetland



(source: Kadlec& Wallace, 2009)

Fig.2.5 Typical configuration of a vertical subsurface flow constructed wetland

Various types of constructed wetlands differ in their operation, design characteristics as well as efficiency in treatments. A hybrid system of constructed wetland comprises all type of CWs combined in order to achieve more treatment efficiency. Most of hybrid systems consist of frequently arranged VF and HF systems of CWs in a staged manner

Yang *et al.* (1995**)** studied the removal efficiency of a constructed wetland. After their three years study on constructed wetland wastewater treatment system they reported that wetland system under study occupied an area of 8400m^2, with a design flow of 3100m^3/d. Parameters such as BOD, COD, suspended solids, total nitrogen, and total phosphorous in influent and effluent of wetland system were examined, and their removal rates were determined. It was found that the system was very effective in removing organic pollutants and suspended solids.

Surve (2007) conducted treatment performance of recycled grey water collected from the bathroom outlets of men's hostel KCAET, Tavanur, by subsurface flow constructed wetland. It was evaluated removal efficiency of various parameters. The parameters analysed for the study were pH, BOD_5, TSS, sulphate , phosphate etc. done for both influent effluent. The yield and growth of vegetation irrigated by both recycled and untreated grey water were studied.

Halalsheh*et al.* (2008) carried out various treatment systems on grey water treatment. The average grey water generation was measured to be 14 Lpcd. The examined treatment systems are septic tank followed by intermittent sand filter; septic tank followed by wetlands; and UASB-hybrid reactor (upflow anaerobic sludge blanket). The study area was Um Alquttain in Mafraq governorate located north east of Jordan. Family size ranges between 5 and 11 persons.6 Grey water was collected from six households and 12 different places. Average COD, BOD and TSS values were 2568 mg/l, 1056 mg/l and 845 mg/l, respectively. Concluded that UASB-hybrid reactor would be the most suitable treatment option in terms of compactness and simplicity in operation. The volume of UASB-hybrid reactor was calculated to be 0.268 m^3 with a surface area of 0.138 m^2 for each house having 10 inhabitants on average. The system is considered to be a low cost treatment option, which is affordable by households and flexible in operation and maintenance.

Khaldoon*et al*. (2011) evaluated the potential for potable water saving in Syrian city where the Swedia city has been focused. Two treatment systems were analyzed by constructed wetlands and a commercial bio filters (CBF).The CW is composed of Biological filter composed of gravel and wetlands plants. For a block system consisting of one residential building (50 inhabitants) the saved drinking water may reach about 600 m^3/year. The CW can be designed especially for new buildings. The economic analysis showed that, within the current water tariff, the payback period of this system is about 7 years. CBF can also be installed in block systems; however, the payback period was estimated to about 52 years and thus unfeasible. The payback period of a small household of five members reach 20 and 139 years for CW and CBF, respectively.

CHAPTER 3

MATERIALS AND METHODS

Constructed wetlands have been used for treatment of municipal and industrial waste water and are considered as more cost effective than advanced waste water treatment systems. It is easily operated and maintained and has a strong potential for application in developing countries like India, where cheaper and economical methods of water treatment systems are not available at present. Therefore, CW for filtration and reuse of wastewater has major applications in areas facing shortage of water for domestic uses. To study this environment friendly technology, a small pilot scale SFCW system designed, developed and short term evaluation was carried out through the present study.

This chapter broadly explain the steps to be adopted to achieve the set of objectives

3.1.Site selection

Surface methods of CWs are not advised in areas of denser populations where it may cause breeding of mosquitoes as well as become habitat for rodents and rats which spread epidemic diseases. So, to use an efficient filtering unit as well as a disposal system for grey water in household areas, SFCWs are used rather than surface wetland construction. The choice of SFCWs in premises of Ladies' Hostel, KCAET was also made with the above said reasons.

In the process of assessing the suitability of sites for constructing SFCW for grey water treatment, important consideration as follows:

- Availability and easy conveyance of greywater
- Approximate size of 4-5 m^2 land in ladies hostel for treatment system has been considered
- Topography of the site. The slope of site is an important factor in controlling surface ponding, runoff and erosion. A minimum 2% slope of area is recommended.

3.2.General description of study area

Site selected on basis of easy availability and conveyance of grey water to the area. The project site, premises of Ladies' Hostel, KCAET, located at Tavanur village, Malappuram district, Kerala. The site is located at 10°51'12.4" North latitude and 75°59'9.3" longitude. Average annual normal rainfall of 2952mm is received in this region from both south-west (SW) and north-east (NE) monsoon. The south-west (SW) monsoon occurs during June to September and north-east (NE) monsoon occurs during October to December. The minimum and maximum temperature prevails between 22°C

And 32 °C while average annual relative humidity is about 83%.

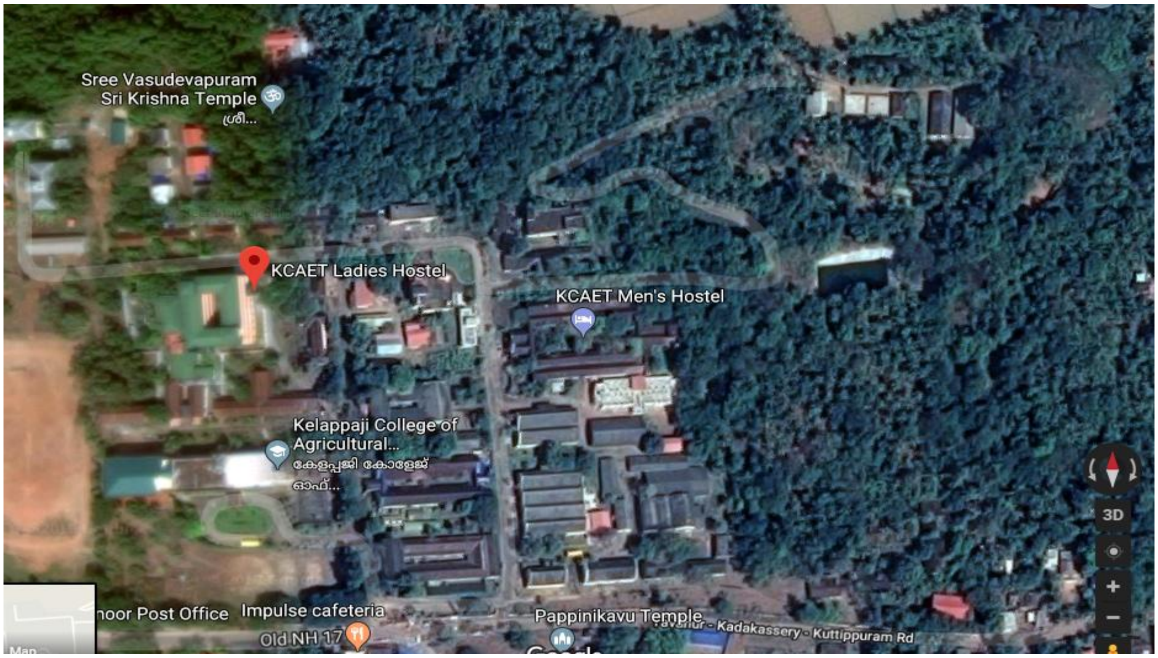


Plate 3.1 Google map location of project site

The outlet coming from ladies hostel bathroom was taken source of grey water used treatment system. The water coming from the bathroom was diverted to the study area. The grey water coming from bathroom outlet contain hair, soap and detergent contents, some mineral (Na, Mg, P, S and N) compounds and small quantity of dust, oil and lint particle along with bacteria.

3.3.Characterisation of grey water

Samples of grey water are collected from suitable outlets. To design as suitable treatment system, a detailed analysis of quality of influent is very important. The characterisation of grey water was carried out by identifying influent concentration through chemical analysis. The sample was collected and tested for quality to know the distribution of pollutant concentration. The sampling techniques, sampling site, sampling interval or time used in a waste water survey must assure that representative samples are obtained, because data from analysis of sample will ultimately serve as a basis for designing treatment facilities. GW characterisations in this project include the analysis of waste water characteristics like p^H, EC, BOD, TSS, COD, oil and grease content etc.

The samples were collected from diverted outlet of ladies hostel bathrooms at peak use time (7.30 AM to 8.30AM). Three samples were collected in different days. These samples were tested for water characteristic p^H, TSS, $BOD_{5,}$ COD, EC, oil and grease etc, at Water Quality Division located at the Centre for Water Resources Development & management (CWRDM), Kozhikode.

3.4.Experimental set up

The experimental set up includes space consideration, pre treatment, vegetation, subsurface flow constructed wetland and conveying systems etc.

3.4.1. Space consideration

The project site conditions that can limits potential size of a constructed wet land are the property boundary, volume of influent and site topography.

In this study the experimental SFCW were constructed on ladies' hostel premises. The outlets of 3 bathrooms are diverted towards the project site. The size of experiment is designed on the basis of quantity of inflow and size available for to achieve particular performance goal.

3.4.2. Pre treatment requirements

Constructed wetlands are the biological system that can exist only in a certain envelope of potential concentrations of certain contaminants. The better functioning of ecosystem requires pre treatment of inflows. Pre treatment ensures the survival of the constructed wetland and thereby increasing the life of system.

The main requirement for experimental constructed wetland maintenance is sediment accumulation. The sludge through the inflow may clog the inlet, clogging of filter bed and killing the vegetation. The necessary of pre-treatment in grey water purification system are sludge and other solid removal. The overloading of solids accumulation was avoided by these pre-treatment processes. Pre-treatment arrangements used in this study are mesh filter and sedimentation tank.

3.4.2.1. Mesh filter

It is a type of filter using a rigid or flexible screen to separate solid and some semi solid particles. These are generally made up of the materials such as stainless steel, polypropylene, nylon and polyester. The mesh size of less than10mm size was used in this study. It is the first stage of filtration in this study. The mesh size of less than10mm size can be place at the inlet to the piping system of grey water outlet to filter out the solid and semisolid particles such as hair, soap cover and other constituent, which blocks the inflow. The screens were cleaned manually.

3.4.2.2. Sedimentation tank

Sedimentation tank also called settling tank, which separate sediment particles, oils and grease from the grey water. The inflow coming to the system was allowed to settle in the sedimentation tank, the solid particles were settle down at the bottom of the tank and the oily and grease portion of the grey water was float on the upper side the water level. So the inflow taken to the SFCW was taken from the middle portion of the sedimentation tank.

3.4.1. Subsurface flow constructed wetland (SFCW)

The efficiency reduction performance of SFCW has already been proved by many researchers around the world. So, the SFCW has been chosen to analyze the performance in tropical climate. Apart from reduction performance, the reasons for selecting the subsurface option over the surface flow option are concern about human health via contact with untreated wastewater, mosquito control and odour control. Because the experimental constructed wetland system was located at hostel premises as well as the near the hostel mess, consideration of the students' health was one of the prime factors for designing the constructed wetland

The main components of the SFCW system namely basin, filter substrata and vegetation are explained below.

3.4.1.1.Basin

A constructed wetland is an impervious basin, shaped artificially; act as a land filled with soil, gravel or other natural material. A constructed wetland collect the surface waste water and by sealing the basin to retain the water for sufficient period of time without seepage and percolation. The basin usually consist of three compartments namely inlet section, filtering section and outlet section. These three sections are filled with appropriate substrate for the effective working of the system. The grey water from the sedimentation tank is enter into the inlet section and slowly flows to the filtering section and last to the outlet section of the SFCW. The majority of suspended solids and some micro organisms are physically got consumed in the filtering section. The macrophytes are available in filtering section removes some chemical contaminants and mineral trough absorption by the plant roots. The selected macrophytes are planted over the filtering section of the basin.

3.4.1.2.Substrate

The type of substrate media used in the constructed wetland has to be decided based on adsorption rate, filtration quality and surface area to increase retention time. The substrates used here were gravel, sand and crushed stone, charcoal and sea shell which was available locally. The bed material should have good absorption and filtration quality. The more surface area of filter material result increase the retention constant, which essential for chemical decay of pollutants.

Charcoal and crushed stone are used at the inlet section. Charcoalin a filter is more effective at removing chlorine, volatile organic compounds, sediments, taste and odor from water. Sand and soil is used in the filtering section. The porosity of filter material was found out by standard procedure. Gravel of 3mm diameter with a layer of sea shell at the bottom was used at the outlet section. Sea shell or lime stone cleanup heavy metals, increase water p^H and it can also reduce odour and colour of water.

Plate 3.2Typical representation of cross-sectional view of basin

3.4.1.3.Vegetation

Vegetation is the principal component of a wetland system. The ability of the plants to stay healthy and therefore to continue to grow is an important factor in the choice of plants for experiment. The common plants in wetlands are common reed (Phragmites sp.), rush (Juncus sp.), cattail (Typha sp.)and bulrush (Scirpus sp.). The contamination in the selected grey water source is low as compared other industrial grey water, a locally available water tolerant emergent plant Heliconia was selected for this study.

The stems of heliconia each minimum 0.2 m length were collected from the nursery and were transplanted from the polythene bags to a SFCW bed open to atmosphere and freshwater was applied daily for a period of half month for establishment of plant.

Plate 3.3Different stages of plant growth in SFCW

3.4.2. Collection tank

It was the final unit in the grey water treatment system, which collect the out flow from the SFCW. The effluent sampling is taken from the collecting tank and can be analysed for water characteristics. The treated water in the collecting tank can be stored in it and can be used for the irrigation purposes.

3.5.Allowable inflow

The allowable inflow was determined by hydraulic residence time (HRT) and mode of operation (batch or continuous). For the present study the mode of operation was taken continuous. But the inflow rate from the source was very large, which difficult to handle in a small scale SFCW. So an arbitrarily selected quantity was diverted to the outlet. Consider 10% of losses due to evapo-transpiration. In this study a 110 l of grey water was diverted to the SFCW. The settling tank has provided with three outlets, the outlet through the middle was diverted to the SFCW by the use of ball valve. While the top and bottom outlets were used for over flow and to flush the tank respectively.

3.6.Design of SFCW

Similar to all other designs, constructed wetland design include hydrologic design and hydraulic design. Hydrologic design comprises of site selection and determination of volume of water diverted to the treatment system. Dimension of SFCW is decided by hydraulic design

3.6.1. Design procedure

Steps followed for the design of a SFCW suggested by the EPA are as follows

1. Determine the existing condition of influent (BOD,TSS and COD etc) , average waste water temperature , average influent flow diverted.
2. Determine the desired quality of effluent parameters (BOD and TSS)
3. Select bed depth, media type and size of media
4. Find out the porosity of the media
5. An initial aspect ratio (length (L) to width (W) ratio) of SFCW must be selected based on the area calculated to achieve the desired BOD retention. It is suggested that an aspect ratio of 2:1 can be selected initially. the final overall L:W ratio depends on the hydraulic considerations
6. Calculate the required surface area of SFCW using the first order BOD removal equation

$$A_S = (L) \text{x} (W) = \frac{Q_1 \text{x} \ ln\left(\frac{C_I}{C_e}\right)}{K_t \text{ x } d \text{ x } n} \quad \text{….(3.1)}$$

$$K_t = K_{20} \text{ x } \theta^{T-20} \quad \text{….(3.2)}$$

$$K_{20} = 1.10 \quad \text{….(3.3)}$$

$$\theta = 1.046 \quad \text{….(3.4)}$$

Where :

A_s= Surface area of SFCW, (m^2)

L = Length, (m)

W = Width, (m)

Q_i = Inflow, (m^3/day)

C_i= Influent BOD (mg/l)

C_e = Effluent BOD (mg/l)

K_t= Rate constant at waste water temperature T°C

K_{20}=Rate constant at waste water temperature T=20°C

d= Average depth of water in filter (m)

n= Porosity of filter media

7. After determining the surface area and the corresponding dimensions based on the initial L:W ratio, use Darcy's equation to determine capacity of design to conduct the flow through the SFCW.

$$Q_d = K_s \text{ x } A \text{ x } i \quad \text{…. (3.5)}$$

Where;

Q_d= flow capacity of SFCW (m^3/day)

K_s= hydraulic conductivity of media (m/day)

i= hydraulic gradient of water surface in the system [d/L]

A= cross sectional area of SFCW (m^2)

If Q in equation 2 does not equal to or exceed the design flow, the L:W ratio must be adjusted to decrease length while increasing the width to maintain the surface area determined in equation 1. This process is repeated until the design is safe.

8. Theoretical detention time calculated as follows:

$$\text{Detention time or HRT} = \frac{(Volume \text{ x } Porosity)}{Flow} \quad \ldots.(3.6)$$

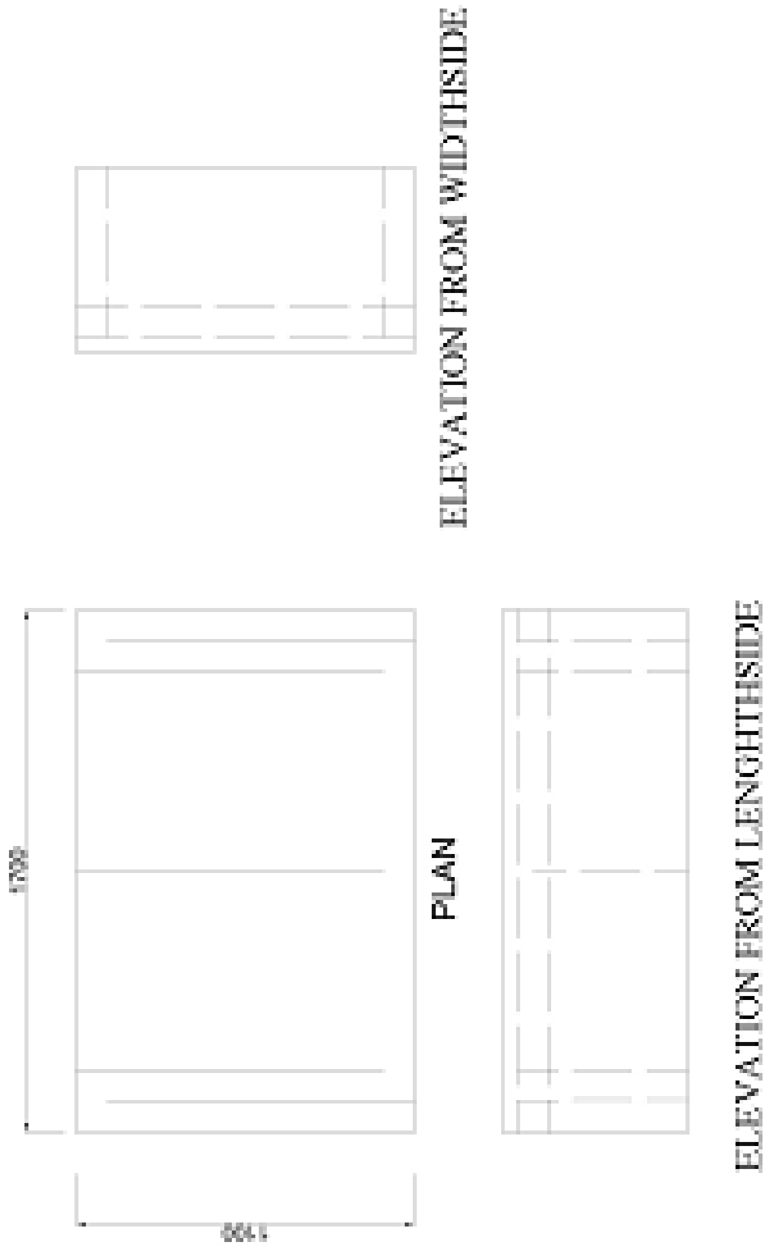


Fig.3.1 Plan and elevation of designed SFCW

3.7.Determination of porosity of filter media

Standard procedure for measuring porosity of filter media is as follows:

1. Measure out 100 ml of water in graduated cylinder.
2. Pour 100ml of water in a beaker and mark the level using a marker
3. Pour the water back to the graduated cylinder
4. Fill the same beaker with filter material up to the mark level.
5. Pour the 100 ml of water slowly into the beaker. Stop when the water level just reaches the top of filter material.
6. Record the amount of water left in the graduated cylinder.
7. Calculate the pore space by subtracting water left in the graduated cylinder from the 100ml
8. Calculate the porosity of filter media by using the formula

Error! Reference source not found. …. (3.7)

3.8.Aspect ratio

The hydraulic gradient defines the total head available in the system to overcome the resistance to horizontal flow in the porous media. The important consideration in the hydraulic design of SFCW is the aspect ratio (L:W). In Darcy's law the maximum potential hydraulic gradient (i) is related to the available depth of the bed divided by the length of the flow path. To avoid surface flow in subsurface flow constructed wetland, an aspect ratio less than 10:1 has to be provided. The system will designed with an aspect ratio of 1.5:1

3.9.Bed slope

An acceptable hydraulic gradient needs very little slope on the bottom of the bed to ensure drainage. EPA has recommended a bed slope SFCW as 0.5 to 1% bed slope. But practically it is very difficult to precisely design and construct a system with specified bed slope. For the present study the bed slope was kept nearly flat with an adjustable outlet.

3.10. Detention time/ hydraulic retention time (HRT)

Performance of constructed wetlands is a function of detention time, among other factors like bed slope and aspect ratio. Shorter detention time does not provide adequate time for pollutant degradation to occur; longer detention times can lead to stagnant, anaerobic conditions. The climatic factors that are significantly affect the detention time at a constant hydraulic loading rate, are evapo-transpiration in summer and ice formation in winter. In summer evapo-transpiration can significantly increase the detention time, while ice formation in winter can significantly decrease the detention time. Theoretical detention time is calculated by the equation (3.6)

3.11. Construction

The designed subsurface flow constructed wetland systems were constructed at the project site. The SFCW system was made with 12 gauge MS sheet for the present study. The SFCW tank was designed as per the standard procedures and the dimensions were fixed. The sheets of required dimensions were cut and jointed by welding. The basin of the tank separated to having distinct section and provided as baffles for water flow and thereby increasing the detention time.

In the inlet section, a PVC pipe having perforation fitted along the width to spread the waste water. The inlet section was filled with crushed stone of average 3cm diameter and above which a layer of charcoal was added. The filtering section consist of sand at a depth of 45cm and soil layer of 10cm to provide better root growth for vegetation. The outlet section consists of PVC pipe with holes to collect drainage and an adjustable outlet to convey the treated water and also to adjust the water level in the tank. The outlet section was filled with crushed stones of average diameter 8mm with a layer of sea shell at the bottom. The sea shells are calcium rich resources and that can be used to produce lime.

Plate 3.4Experimental set-up

3.12. Operation and monitoring

Each plant was fed with freshwater daily before the plants were established. Wastewater addition began after all the plants were well established. The wastewater was fed in to the system once in a day as the desired inflow. Allow the water to remain in the tank for hydraulic detention time. The micro organisms were monitored per week, and invasive seedlings like ordinary grass were immediately removed.

3.13. Sampling and analysis

The water quality in the SFCW was monitored monthly for influent and effluent basis. The system has an inlet port and outlet port to collect samples. The sampling was done at both inlet section and outlet section. The samples were analyzed for BOD, COD, TSS TN and TP etc. according to Standard Methods for Water and Wastewater analysis.

CHAPTER 4
RESULT AND DISCUSSION

The experimental subsurface flow constructed wetland unit was designed and constructed at the project site. The operation and monitoring of the unit was initiated after transplantation and establishment of wetland plant. The treatment performance was evaluated by examining the results of sampling both at the inlet and outlet of the experimental sub surface constructed wetland unit**.**

4.1.Waste water characterization

Wastewater characterization is important for designing a wastewater treatment plant. To design a treatment process or treatment plant properly, characterization of wastewater is the most critical step. Published information on domestic wastewater characteristics based on actual data is very limited. But literature concerning design parameters and values for varying-strength wastewater that can be used for the design of modern treatment systems are virtually nonexistent

The important contaminants in wastewater treatment, considered for present study, are listed in Table 4.1.

Table 4.1: Waste water characteristic concern

Constituent	**Unit**	**Test method**
Biochemical Oxygen Demand (BOD)	Mg /l	APHA,2012
Chemical oxygen demand (COD)	Mg/l	APHA,2012
Total dissolved solids (TSS)	Mg/l	APHA,2012
Oil & grease	Mg/l	APHA,2012
Ph	None	APHA,2012
Total Nitrogen (TN)	Mg/l	Kjeldahl Standard Methods
Total phosphorus (TP)	Mg/l	Standards methods
Total sulfer (TS)	Mg/l	Standard methods

4.2.Design

Design was done according to the contaminant consideration and the present waste water situation. The design of a subsurface constructed wetland to recycle the grey water that coming from the three outlet bathrooms in KCAET ladies' hostel was done. EPA recommended design procedures were adopted for the design of SFCW.

Existing condition of influent

Average influent flow diverted = Q_i = $0.11 m^3/day$

Influent BOD = C_i = 50 mg/l

Average waste water temperature = t = 17°C

Desired quality of effluent

Effluent BOD_5 = Ce = 5mg/l

Properties of filter media

Average porosity = n = 0.35(plants are used in wetland)

Bed depth = d = 0.45m

hydraulic conductivity of media = K_s = 0.865 m/day

K_{20} =1.104

Therefore;

K_t $=1.104\times(1.046)^{(t-20)}$

=0.964

Surface area A_s = (0.11m^3/day × ln(50/5)) ÷ (0.964 × 0.35 ×0.45m)

=1.67 m^2

Aspect ratio L:W = 1.5 : 1

Then, A_s = 1.5 W×W = 1.67 m^2

W = 1.055 m ; L = 1.6

Taking W = 1.1m

$$L = 1.7m$$

The design capacity calculated using Darcy's equation

$$Q_d = 0.865 \text{ m/day} \times 0.265 \times 1.1 \text{ m} \times 0.45 \text{ m}$$

$$= 0.113 \text{ m}^3\text{/day}$$

Since design capacity is greater than inflow, the design is safe.

4.3.Experimental set-up

Table 4.2 Experimental set-up – design hydraulics, structural dimensions, substrate and plant physical parameters

Hydraulics		**Structural dimensions**		**Vegetation- Physical parameters**	
Type	Subsurface	Size	1.7m ×1.1m	Plant type	Emergent plant
Flow regime	Horizontal	Longitudinal slope	<1%	Common name	Heliconia
Operation mode	Batch	Aspect ratio	1.5 : 1	Scientific name	*Heliconialatis patha*
Free board	0.1m	Inlet structure	500 ltr storage tank	Numbers	20
HRT	3 days	Outlet	500 ltr collecting tank	Density	12 plant/m^2

Substrate – Physical parameters				Waste water	
Section	**Media type**	**Depth**	**Size**	Type	Grey water
Inlet	Crushed stone Charcoal	0.45m 0.1m	3cm	Source	Domestic / bathroom
Filter	Sand Soil	0.45m 0.1m	1mm	Primary treatment	Sedimentation
Outlet	Sea shell Crushed stone	0.1m 0.45	 8mm		

4.4.Operation and monitoring of SFCW

The subsurface flow constructed wet land was operated after all the establishment of plants. The system was operated by diverting approximately 110 l of grey water per day. The valves were calibrated before the operation. The waste water discharged through the valve per time was calculated. Then the valve opened for 6 min per day for getting the desired inflow. The plant growth was measured regularly and grasses or weeds were uprooted and removed periodically.

4.5.Sampling and analysis of SFCW

Sampling is an extremely important consideration in characterizing wastewater for pollutant removal. Flow rate and wastewater quality are changing continuously, and these changes affect the ability of a wastewater treatment plant to achieve consistent removal efficiency. Obtaining samples that will actually represent accurate parameters in the wastewater flow through the SFCW was difficult. Diurnal fluctuations and seasonal fluctuations affect concentration, flow volume, and temperature. Therefore waste water characteristics fluctuations were related to water usage of students and time.

Water samples were collected from the collecting portion of inlet chamber and outlet chamber of SFCW unit. The samples were analyzed for COD, BOD, TSS, p^H, EC, TN, TP and S according to standard procedures of waste water analysis.

Plate 4.1 Samples; left bottle-influent,right bottle-effluent

Once a sample is taken, the constituents of the sample should be maintained in the same condition as when collected. The samples were collected in plastic bottles. When it is not possible to analyze collected samples immediately, samples were preserved properly. Biological activity such as microbial respiration, chemical activity such as precipitation or pH change, and physical activity such as aeration or high temperature should be kept to a minimum.

Table 4.3 Variation of different parameters in influent and effluent samples from experimental SFCW

TARGET CONSTITUENT	SAMPLE LOCATION	SAMPLE NUMBER		
		1	2	3
BOD_5, mg/l	Influent	24.04	50.00	48.20
	Effluent	1	5	3
COD, mg/l	Influent	80.05	79.73	78.94
	Effluent	49.28	44	48.43
TSS, mg/l	Influent	108.0	110.02	98.44
	Effluent	2	2	3
p^H	Influent	5.5	5.98	5.6
	Effluent	6.24	6.53	6.31
TN, mg/l	Influent	100	24	76
	Effluent	82	18	69
TS, mg/l	Influent	130	108	118
	Effluent	103	94.3	97
TP, mg/l	Influent	6.25	7.1	6.36
	Effluent	4.23	5.76	5.31
Salinity	Influent	28.4	30.6	31.3
	Effluent	0.56	0.18	0.96
Oil and grease	Influent	15.20	13.60	11.20

	Effluent	8.64	7.22	5.14

4.6.Organic removal

The concentrations of BOD in the influent were 24.04, 50.00 and 48.20. So, the observed range in the BOD of the source wastewater was from 24 to 50 mg/l with an average of 40.74 mg/l..When the concentration of raw wastewater is diluted, thus lowering BOD concentration. The effluent concentrations were 1, 5 and 3. BOD was reduced to very low concentration. There is a reduction of 95.8%, 90% and 93.8% in BOD in different samples by using SFCW.

Table 4.4 BOD analysis

Sample no	**Influent**	**Effluent**
1	24.04	1
2	50	5
3	48.2	3

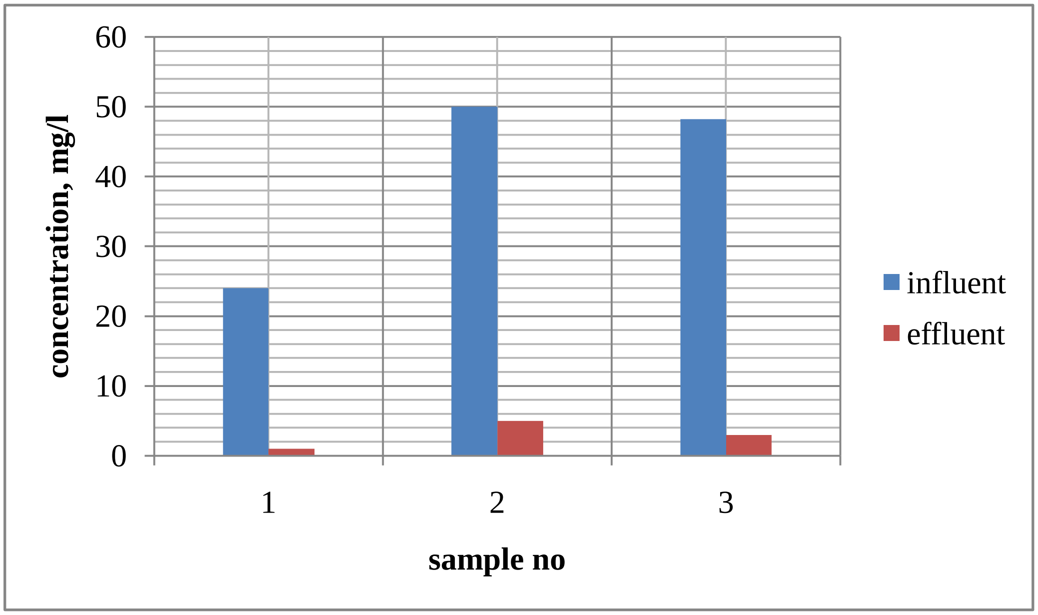


Fig.4.1 Variation of BOD in influent and effluent samples using SFCW

The concentrations of COD in the influent were 108.00, 110.02 and 98.44. So, the observed range in the COD of the source wastewater was from 98 to 110 mg/l with an average 105.48 of mg/l. The effluent COD were 49.28, 44 and 48.43 mg/l. the average concentration of COD was 47.24 mg/l. There is 54.3%,60.2 % and 50.8% reduction in COD by using different samples in SFCW

Table 4.5 COD analysis

Sample no	**Influent COD, mg/l**	**Effluent COD, mg/l**
1	108	49.28
2	110.02	44
3	98.44	48.43

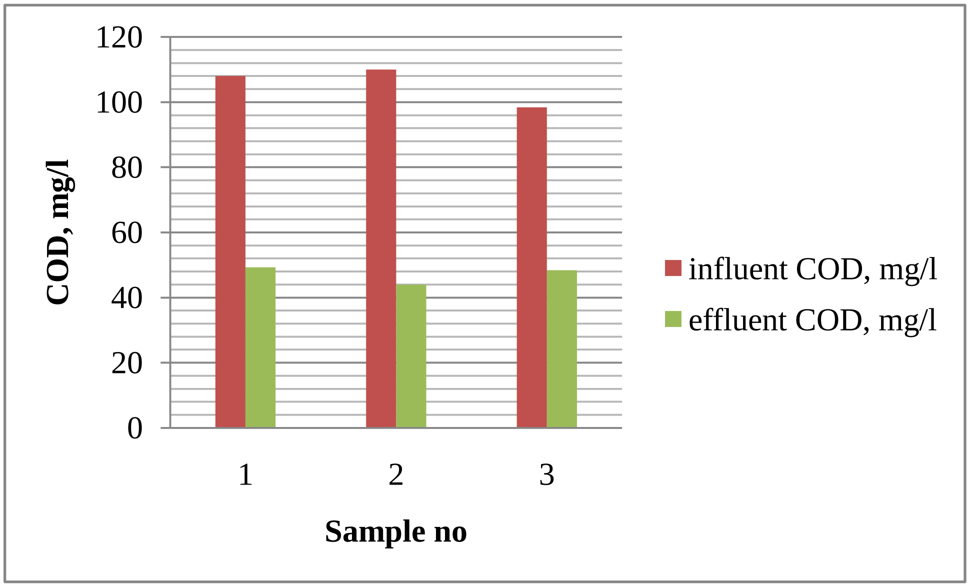


Fig.4.2 Variation of COD in influent and effluent samples using SFCW

The efficiency of organic removal was 90% to 95.84 for BOD_5,it was 50.8% to 60% for COD

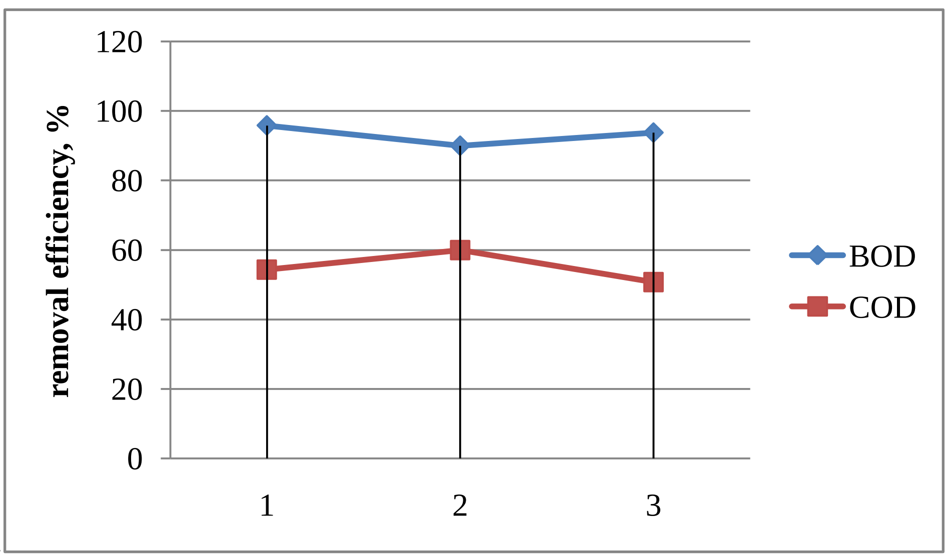


Figure 4.3 Organic removal efficiency of SFCW

In most of cases wastewaters COD is higher than BOD_5. The ratio of COD to BOD_5 indicates the biodegradability of wastewater and the higher the ratio the less the biodegradability of the wastewater. In this study COD to BOD ratio of influent is less, thus biodegradability influent is high and that off effluent is less.

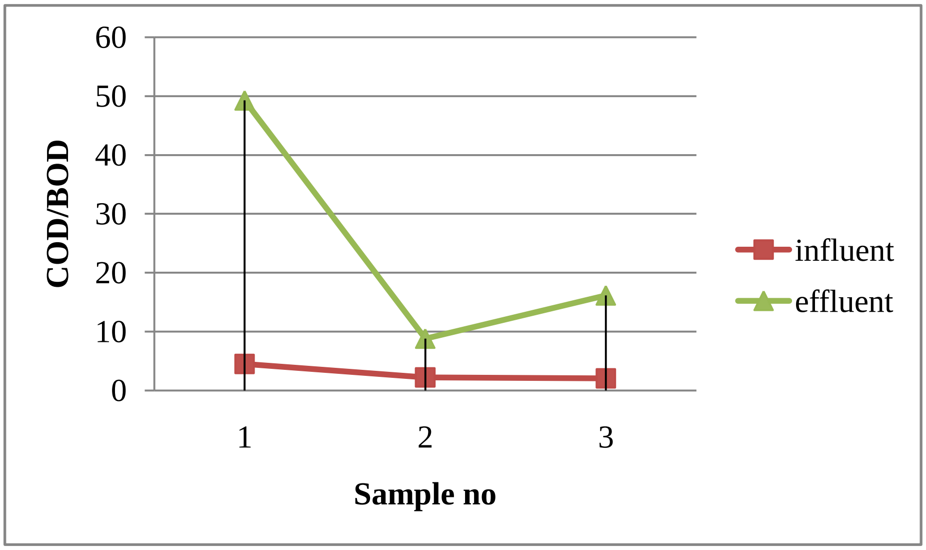


Fig.4.4 COD to BOD ratio of influent and effluent

BOD_5 is often 70–90% of the COD, depending on the substance or waste stream, since not all COD can be biologically oxidizable. In theory, the maximum the BOD can be is COD×0.9, since about 10% of the original organic material is part of a non-biodegradable residue. In this study, it is found that the maximum BOD was 0.49times COD for influent. However average BOD of influent was 0.386 times COD.

Similarly the maximum BOD of effluent was 0.113 times COD with an average of 0.065 times COD.

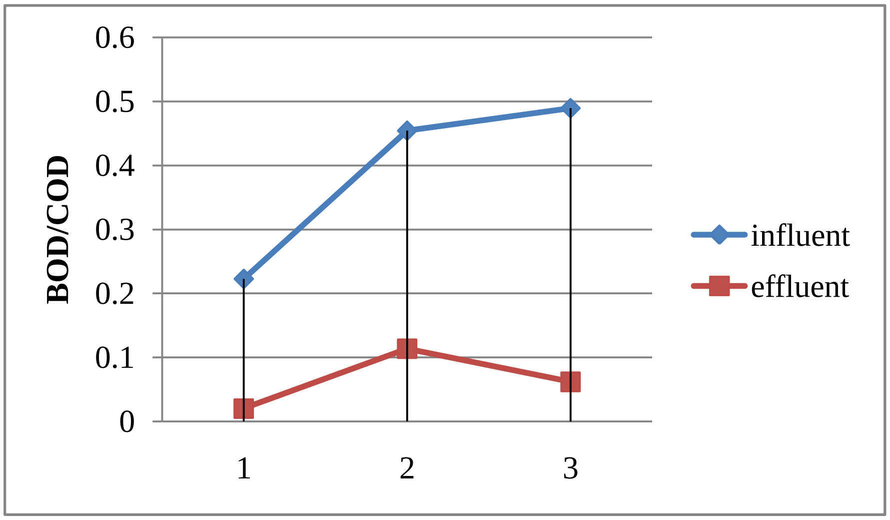


Fig.4.5 BOD to COD ratio of influent and effluent

4.7.Nutrient removal

In SFCW, the influent TN concentration ranged from 24 to 100 mg/l and the effluent TN concentration varied between 18 and 82 mg/l. The mean TN concentrations of the influent and effluent were 66.67 mg/l and 56.3 mg/l respectively.

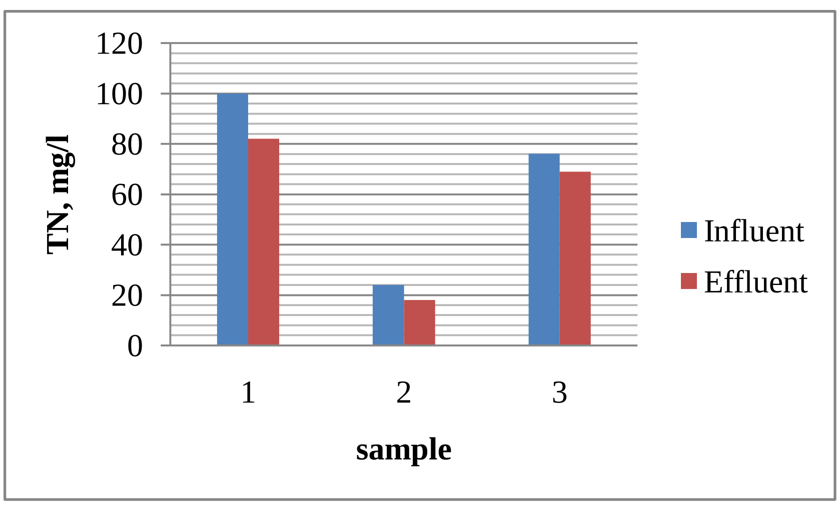


Fig.4.6 Variation of TN concentration in influent and effluent samples

The TP concentration influent grey water ranged from 6.25 to 7.1 mg/l and the effluent TP concentration varied between 4.23 and 5.75 mg/l. The average TP concentrations of the influent and effluent were 6.57 mg/l and 5.1 mg/l respectively.

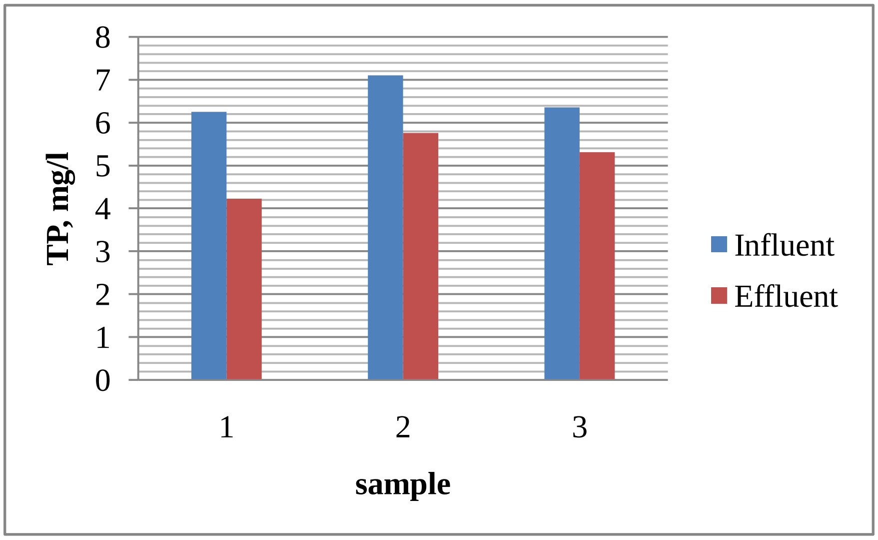


Fig.4.7 Variation of TP concentration in influent and effluent samples

The TS concentration influent grey water ranged from 108 to 130 mg/l and the effluent TS concentration varied between 94.2 and 103 mg/l. The average TS concentrations of the influent and effluent were 118.67 mg/l and 98.1 mg/l respectively.

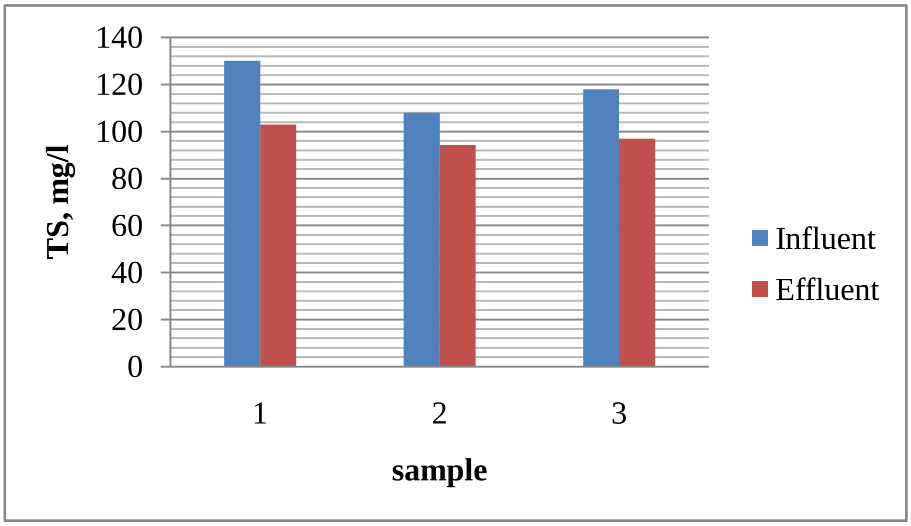


Fig. 4.8 Variation of TS concentration in influent and effluent samples

The average TN removal efficiency of SFCW was 17.67%, where as the average TS removal efficiency was 17.3% and TP removal efficiency was 22.5%

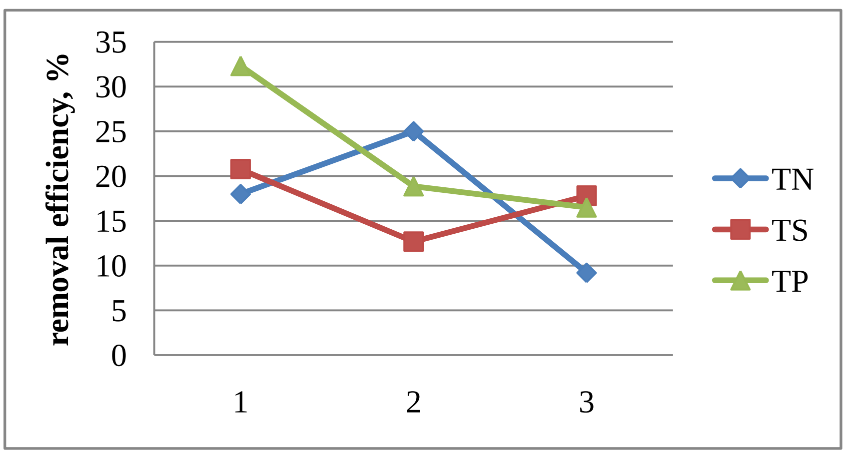


Fig.4.9 Nutrients removal efficiency of SFCW

4.8.Solids removal

In SFCW, the influent TSS concentration ranged from 98.44 to 110.02 mg/l and the effluent TSS concentration varied between 2 and 3 mg/l. The mean TSS concentrations of the influent and effluent were 105.49 mg/l and 2.33 mg/l respectively. The highest TSS removal efficiency achieved in SFCW was 98.18, while the least was 96.95 with mean 97.75.

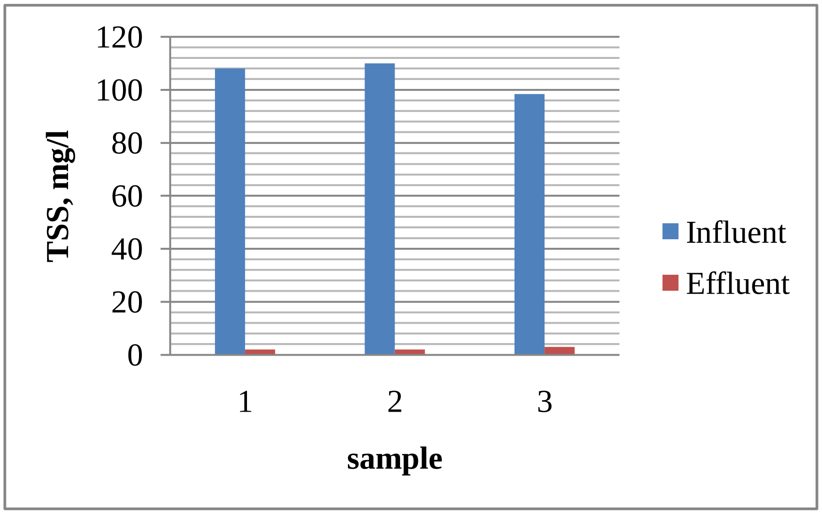


Fig.4.10 Variation of TSS concentration in influent and effluent samples

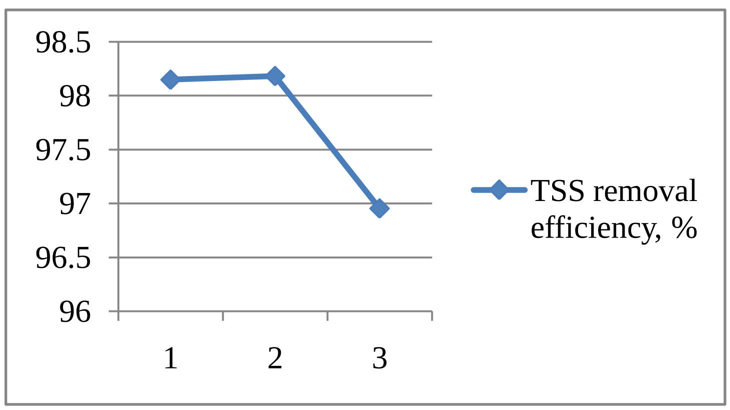


Fig.4.11 Solid removal efficiency of SFCW

4.9.Hydrogen iron (p^H)

The pH of grey water ranges from 5.5 to 5.98 with an average of 5.69 and median of 6.7. So, the source influent is slightly acidic in nature. Wastewater with an extreme concentration of hydrogen ion is difficult to treat by biological means. In the case of effluent from SFCW p^H vary from 6.25 to 6.53.

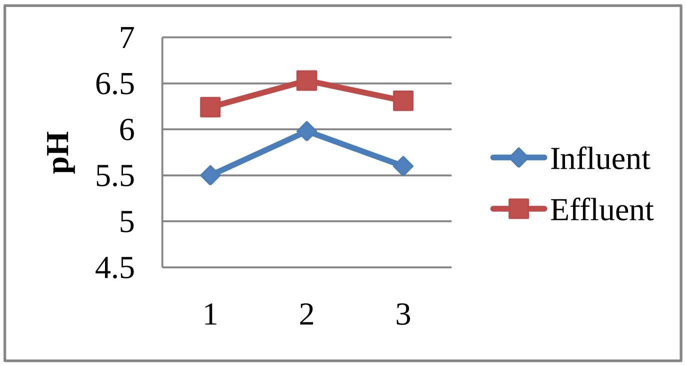


Fig.4.12 Variation of p^H in influent and effluent samples using SFCW

4.10. Salinity

Salinity of grey water source was between 28.4 and 31.3 with an average of 30.1 when the grey water delivered to the SFCW it was changed to the range of 0.18 to 0.96 with an average of 0.566.

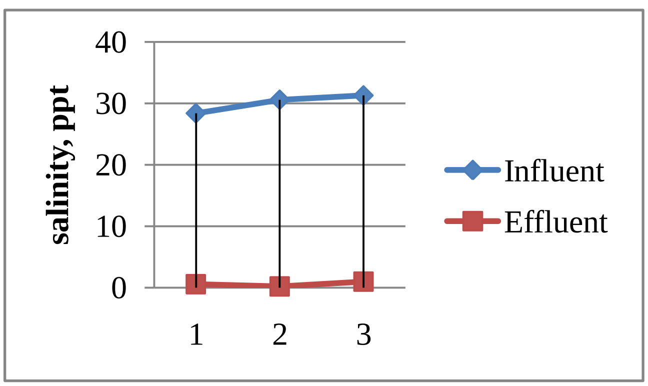


Fig.4.13 Change of salinity of SFCW

4.11. Scum removal

Scum or oil and greases present in the waste water were removed by the SFCW treatment. The concentration of oil and grease in the grey water were15.20, 13.60 and 11.20 mg/l. the concentration of oil and grease at the outlet were changed to 8.64, 7.22 and 5.14 mg/l.

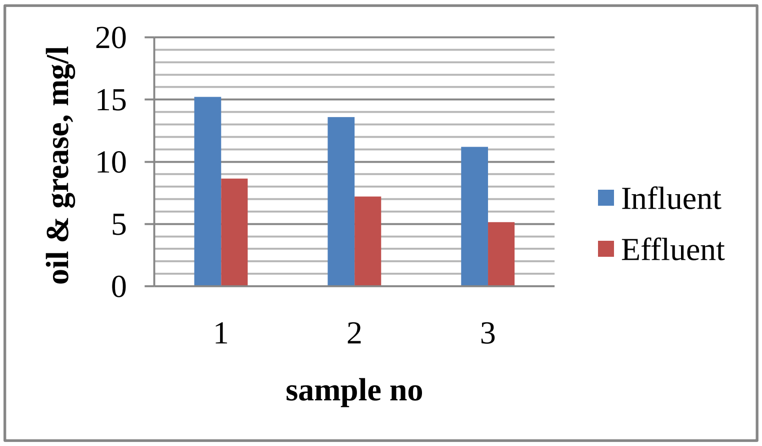


Fig.4.14 Scum removal in SFCW

Oil and grease removal efficiency changes from 43% to 54% with an average of 48.05%

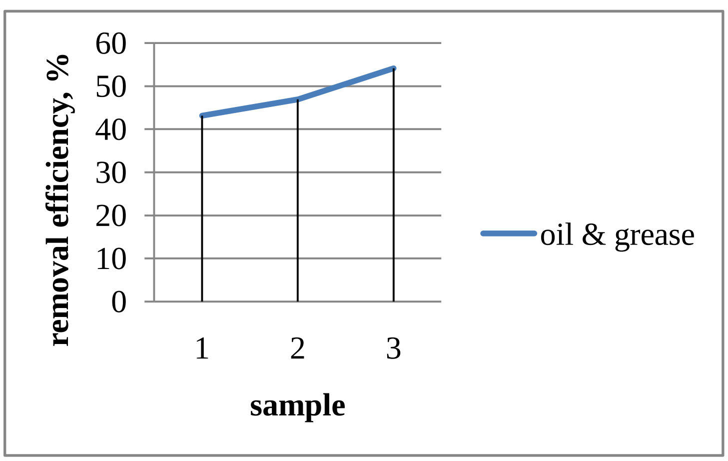


Fig.4.15 Oil and grease removal efficiency of SFCW

4.12. HRT studies

The efficiency of waste water treatment increases as the HRT of the treatment increases. For continues treatment plant HRT can be varied by changing inflow and depth of flow. Theoretical HRT can be calculated by the HRT equation given in chapter 3.Actual HRT was always greater than theoretical value. It is due the topographic property and the substrate property.

In this study we varied the daily inflow by adjusting the depth of flow to a constant value. And the HRT is observed. HRT decreases with increase in flow.

Table 4.6 hydraulic retention time with flow change

Depth, m	**Flow, m3/day**	**Theoretical HRT, day**	**Actual HRT, day**
0.45	0.05	5.8905	8
0.45	0.075	3.927	5.5
0.45	0.1	2.94525	4.5
0.45	0.125	2.3562	3.5
0.45	0.15	1.9635	3
0.45	0.2	1.472625	2.5

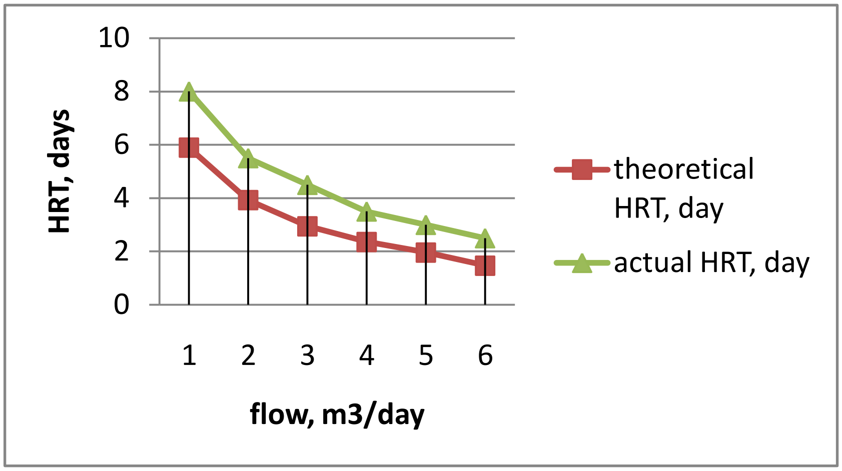


Fig.4.16 Hydraulic retention time VS flow graph

Similarly the rate of inflow fixed as constant and depth of flow is varied. The HRT was observed. HRT was increased with increase in flow depth

Table 4.7: hydraulic retention time with change in flow depth

Flow, m3/day	Depth, m	Theoretical HRT ,day	Actual HRT, day
0.1	0.25	1.63625	2
0.1	0.3	1.9635	2.5
0.1	0.35	2.29075	3.5
0.1	0.4	2.618	4
0.1	0.45	2.94525	5

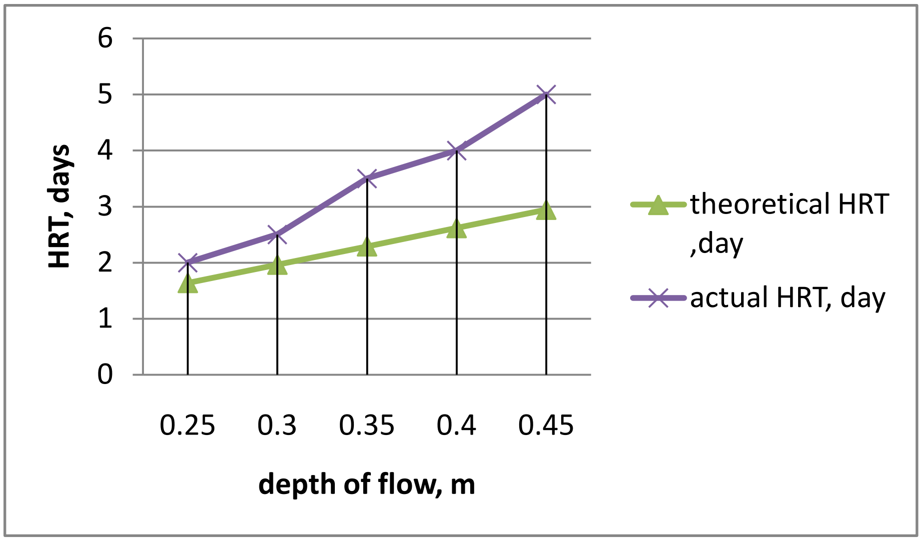


Fig.4.17 hydraulic retention time VS flow depth graph

CHAPTER 5

SUMMARY AND CONCLUSION

Population growth and industrialization has caused considerable amount of waste water generation. There are many methods to treat the waste water and to reuse for further use mainly irrigation. If the waste water is discharged to the natural water resources without proper treatment, it will cause pollution and also cause diseases for human beings. However we need to protect our land and conserve water by the proper treatment method. Various studies shown that constructed wetland is an effective and eco friendly water recycling system. This project was an application of subsurface constructed wetland for waste water treating system.

This research included the SFCW system with *Heliconialatispatha*was used for domestic grey water treatment. The treated grey water is found to be good quality and can therefore be used for irrigation purposes. The waste water characteristics after the treatment are noticed a significant change from the inlet.

BOD is a measure of the degree of contamination of water by measuring the oxygen required for the oxidation of organic matter by the aerobic metabolism of the microbial flora. The BOD test gives a measure of the oxygen utilized by bacteria during the oxidation of organic material contained in a wastewater sample. BOD5 means a 5-day biochemical oxygen demand. TheBOD_5 of the influent ranges in between 24.04 and 50 mg/l, where as the maximum BOD_5 of effluent was 5mg/l. The average BOD_5 removal efficiency was 95.84%.

COD estimates the oxygen equivalent of organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. The COD of the influent ranges in from 98.44 to 110 mg/l, for effluent it ranges in between 44 to 49.8mg/l. The maximum removal efficiency obtained was 60%.

N,S and P are of environmental concern because they are nutrients, and if present in excess they may cause algal bloom and affect the rest of the wildlife in a water body. Amount of S and P in grey water is due to soaps and detergents. N and P are essential elements for the growth of microorganisms, plants and animals. It is found that the plants in the SFCW are removes N, P and S.

The most important physical characteristic of wastewater is its total solids content. TSS of 110.02 ppt of influent changes to 2 ppt in effluent. The maximum TSS removal efficiency was 98.18%

The power of hydrogen ion is p^H. p^H is the negative logarithm of the hydrogen ion concentration. The p^H of influent was below 6.5. I.e. the influent grey water was slightly acidic. But when it is passed through SFCW, p^H value was increased considerably and close to 7.

Water quality is increases with increase in HRT. HRT can be varied by change of flow and change of flow depth. HRT decreases with increase of flow rate. Also HRT increase with increasing flow depth. Actual HRT was greater than theoretical HRT. It is because of temperature variation, elevation difference and substrate property etc.

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APPENDIX I

Valve calibration

Time(sec)	Volume of water (l)	Discharge rate (l/sec)	Discharge (l/min)
30	7.8	0.26	15.6
30	10.26	0.342	20.52
30	11.55	0.385	23.1

Average discharge,l/min = 19.74

Time required for 110 l inflow, min = 110 ÷ 19.74

= 5.572 taking as 6 min

The valve was opened for 6 min in a day for supplying 110 litre of grey water to the SFCW.

APPENDIX II

Determination of porosity of filter media

SI no	Total volume (mL)	Volume left in cylinder (mL)	Pore space volume (mL)	Porosity (%)
1	100	65	35	35
2	100	64	36	36
3	100	66	34	34

Sample calculations:

Total volume, mL = 100

Volume left in the cylinder, mL = 65

Pore space volume, mL = Total volume – Volume left in cylinder

= 100 – 65

= 35

Porosity, % $= \frac{Pore\ space\ volume}{Total\ Volume}$

= 35

APPENDIX III

Determination of theoretical HRT

Depth, m	Flow, m^3/day	Theoretical HRT, day
0.45	0.05	5.8905
0.45	0.075	3.927
0.45	0.1	2.94525
0.45	0.125	2.3562
0.45	0.15	1.9635
0.45	0.2	1.472625

Sample calculations:

Depth of flow, m = 0.45

Flow volume, m^3/day = 0.1

Void space = 0.35

$$\text{Detention time or HRT, days} = \frac{(\text{volume} \times \text{porocity})}{\text{flow}}$$

= 1.1575

APPENDIX IV

Calculation of efficiency

SI NO	Parameter	influent	effluent	Efficiency (%)
1	BOD_5, mg/L	48.20	3	93.77
2	COD, mg/L	78.94	48.43	50.80
3	TSS, mg/L	110.2	2	98.185
4	TN, mg/L	24	18	25
5	TS, mg/L	118	97	17.8
6	TP, mg/L	6.25	4.23	32.32
7	Salinity	28.4	0.56	98
8	Oil and grease, mg/L	13.60	7.22	46.91

Sample calculation:

Influent BOD_5, mg/L = 48.20

Effluent BOD_5, mg/L = 3

BOD_5 removal efficiency, % $= \frac{(Influent - effluent)}{Influent}$

= 93.77

PERFORMANCE EVALUATION OF A SUBSURFACE FLOW CONSTRUCTED WETLAND

By

NAFLA K

NAVANEETH B S

ABSTRACT

Submitted in partial fulfillment of the requirement for the degree

Bachelor of Technology

In

Agricultural Engineering

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Land and Water Resources and Conservation Engineering

Kelappaji College of Agricultural Engineering and Technology

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ABSTRACT

Grey water is the waste water, obtained from outlets of bathroom kitchen wash basins etc. Recycling of grey water is a best solution for water shortage and by improving water availability. Students residing in Ladies' Hostel of KCAET deal with plenty of water for bathing and other sanitation purposes.

The purpose of this project was a grey water recycling system by using subsurface flow constructed wetland that will provide water specifically for irrigation purposes. The objectives of the project were to design and construct a subsurface flow constructed wetland for grey water treatment and to evaluate performance parameters of the system. The system consists of conveying system, sedimentation tank, SFCW and a collecting tank. Suitable filter medium were selected and used in SFCW. The emerging plants, that are locally available in the area was selected for planting in constructed wetland. Change in water quality after passing through the treatment system evaluated for BOD_5, COD, TSS, TN, TP, TS, salinity, p^H, oil and grease content. Variation of hydraulic retention time with change in flow depth and change in flow volume was also evaluated.