COMPARATIVE STUDY OF SUBSURFACE FLOW CONSTRUCTED WETLAND METHOD AND COAGULATION METHOD FOR WASTE WATER TREATMENT

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PROJECT REPORT

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DECLARATION

We hereby declare that this project entitled **"COMPARATIVE STUDY OF SUBSURFACE FLOW CONSTRUCTED WETLAND METHOD AND COAGULATION METHOD FOR WASTE WATER TREATMENT"** 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 **"COMPARATIVE STUDY OF SUBSURFACE FLOW CONSTRUCTED WETLAND METHOD AND COAGULATION METHOD FOR WASTE WATER TREATMENT"** is a record of project work done jointly by **Ms. Athira P M, Ms. Chithra M R and Ms. Dibisha K Das** 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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SYMBOLS AND ABBREVIATIONS

%	Percentage
&	And
µ	Microns
Asst.	Assistant
/	Per
min	Minute
sec	Seconds
ºC	Degree Celsius
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
CW	Constructed wetland
Dept.	Department
E.g.	Example
Etc.	Etcetera
et. al.	And others
Fig.	Figure
GW	Grey water
h	Hour
HRT	Hydraulic retention time
i.e,	That is
KCAET	Kelappaji College of Agricultural Engineering And Technology

LH	Ladies' Hostel
L	Litre
m	Meter
cm	Centimetre
Mm	Millimetre
Mg	Magnesium
Pb	Lead
Zn	Zinc
Ca	Calcium
Al	Aluminium
ppm	Parts per million
WHO	World health organization
Lpcd	Litre Per Capital per Day
UASB	Upflow Aerobic Sludge Blanket
mg/l	Milligram/litre
N	Nitrogen
P	Phosphorous
HP	Horse Power
l/h	Litre per hour
dS/m	Deci Siemens per meter
$Al_2(SO_4)_3 .18\ H_2O$	Aluminium sulphate or Alum
$Al(OH)_3$	Aluminium hydroxide
$CaSO_4$	Calcium sulphate
H_2O	Water
CO_2	Carbon Dioxide
$Ca(HCO_3)_2$	Calcium Bicarbonate

Cr	Chromium
EC	Electrical Conductivity
SFCW	Subsurface flow constructed wetland
PVC	Poly vinyl chloride
Cl	Chlorine
Na	Sodium
Fe	Iron
TSS	total soluble solids
K	Potassium
O_2	Oxygen
Sl. No.	Serial number
HCl	Hydrochloric Acid
H_2SO_4	Sulphuric Acid

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ABSTRACT

Grey water is defined as wastewater generated from bathroom, laundry, kitchen, wash basin water etc. except water from toilets. So in order to overcome acute water shortage recycling of grey water is essential. With this recycling system, the water shortage can controlled to a limit by using these water for secondary activities like gardening, irrigation etc.

The main purpose of this project was to treat the grey water from the bathroom outlets of ladies hostel of KCAET, Tavanur. The main objective of this project was to compare the removal efficiencies two grey water treatment systems – subsurface flow constructed wetland and coagulation method. The subsurface flow constructed wetland consists of a settling tank, suitable filter media and an emergent type Macrophyte. The coagulation method consists of a coagulation tank and a suitable coagulation. The treated water coming through the outlet of both the tanks were analysed for BOD, COD, TSS, TN, TP, pH, oil and grease content.

CHAPTER 1

INTRODUCTION

Water is the most precious and prime element in the socio economic development of mankind and can be said as eco currency. In other words water is one of the most precious and important gift to mankind. For the sustenance of life on earth water is essential. Although 70 % of the earth's cover being water, only 3 % is regarded as fresh water. In that two thirds is seen in frozen glaciers or otherwise unavailable for use.

As the world population is increasing day by day, there is an acute water shortage as the demand for water is increasing at an alarming rate. An individual person requires around 340 l of water per day for various activities like bathing, laundry uses, domestic purposes etc. So the water resources around the world are depleting due to the lavish use of water. The rivers and aquifers are either over exploited or polluted. Many of the water systems that keep the ecosystem thriving and feed a growing human population have become stressed.More than half the world's wetlands have disappeared. Agriculture consumes more water than anyother 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 while floods in others.

Globally, most of the developing countries are located in those part of the world where there is a chance of facing water shortage in the near future. As most of the industries are located along the banks/shores of water bodies. So these sources are contaminated due to the discharge of untreated sewage and industrial waste to the water bodies resulting in the decreased level of water quality.

Fresh water can be defined as water with less than 500 ppm of dissolved salts. However most of the human activity causes degradation to water resources making it as waste water. Waste water is the by - product of domestic, industrial, commercial and agricultural activities. Hence in order to remove the pollutants, we adopt waste water treatment.

Literally the term waste can be of two types – liquid and solid. The liquid portion is termed as waste water, and generally comprises of discharges from domestic residences,offices and retail buildings, industrial or manufacturing plants and agricultural uses. According to the source of generation waste water can be generally classified as grey, brown, yellow, black, green and storm water. Grey water is defined as wastewater generated from bathroom, laundry, kitchen, wash basin water etc. except water from toilets. Yellow waste water is defined as the water collected with urine, but is not contaminated by black or grey water. Black water is defined as wastewater originating from toilet fissures, dishwaters and food preparation sinks. Black water is considered as the most contaminated ones with dissolved chemicals and particulate matters and highly pathogenic in nature.

As a result of acute water shortage, there is a need of reuse of waste water for secondary purposes. Due to rapid industrialization and development, grey water recycling has an immense scope in the developing countries. It is estimated that around 60% of domestic waste water is grey water, shooting its immense strength in recycling i.e. grey water producing capacity is nearly 200 litre/capita/day.

According to the researches of Jamrah,*et al.*, 2006; Al-Mughalles, *et al.*,2012; Ghaitidak and Yadav, 2013, 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.so this waste water section can be effectively recycled for other useful purposes.

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

The grey/waste water cannot be directly reused, it has some limitations. Direct handling of waste water can result in bacterial infection, anaemia and transmission of cholera (WHO, 2001). Also consumption of vegetables irrigated with raw waste water is harmful as bacterial infection can occur through this route also. Direct reuse of waste water for landscape irrigation can lead to saline soil conditions. Dissolved salts in waste water accumulate in the root zone leading to reduction in availability of water to crops. An excessive concentration of sodium, chloride and boron can lead to burning of leaves, leaf cupping, chlorosis, reduced growth and yield. Excessive nitrogen in irrigation water can lead to vigorous vegetative growth, delayed or uneven maturity and reduced crop quality. The excess concentration of phosphorous from washing activities and industrial effluents in water streams causes eutrophication. It leads to domination of the aquatic plants which results in obstruction of water flow, transport, flooding and transformation to marshy land.

To overcome the water scarcity problem and to reduce the pollution of the water bodies to some extent, some sort of water treatment is required. Waste water treatment is the process of converting waste water to water that is no longer needed or is no longer suitable for use- into bilge water that can be discharged back into the environment. It is formed by a number of activities including washing, bathing using the toilets and rain water runoff. Waste water is full of contaminates including bacteria, chemicals and other toxins. Its treatment aims at reducing the contaminants to acceptable levels to make the water safe for discharging back to environment.

Numerous waste water treating technologies are available like filtration techniques, trickling methods, anaerobic digestion etc. Generally there are two waste water treatment plants viz, chemical or physical treatment plant and biological waste water treatment plant. Physical waste treatment plant use chemical reactions as well as physical process to treat waste water.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 .

Constructed wetlands are engineered systems that use natural functions of wetland vegetation, soil and organism to treat waste water. Constructed wetland treats the sewage water using highly effective and ecologically sound, design principles that uses plants, microbes, sunlight and gravity to transform waste water into gardens and reusable water. The water treatment mechanisms are biological, chemical and physical, these include physical filtration and sedimentation, biological uptake, transformation of nutrients by bacteria that are anaerobic (bacteria that flourish in the absence of oxygen) and aerobic (oxygen-needing bacteria), plant roots and metabolism, as well as chemical processes (precipitation, absorption and decomposition) that purify and treat the wastewater.

Constructed wetland method comes under the physical water treatment plant. The main defect in this process is that it is a very slow process. It takes several days to treat the water. So one of the fastest method to treat the waste water is the chemical method. Coagulation is a prominent process in the chemical treatment plants.

Coagulation process is important in water treatment. It is used to separate suspended solid portion from the water. Suspended particle vary in source, charge, particle size, shape and density. Coagulants are the chemicals mainly used for separation of suspended particles from water. Mainly there are primary coagulant and coagulant aid. Primary coagulants neutralize the electrical charge of particles in the water which causes the particles to clump together. The main chemicals used for coagulation are Aluminium sulphate (Alum), Poly aluminium chloride (Liquid alum), Alum potash and Iron salts (Ferric sulphate or ferric chloride). A coagulant (typically a metallic salt) with the opposite charge is added to the water to overcome the repulsive charge and destabilize the suspension.

OBJECTIVES

- To evaluate the performance of subsurface flow constructed wetland by using Canna plant and filter media.
- To remove suspended solid portion from water by using coagulation.
- To compare performance of constructed wetland method and coagulation method.

CHAPTER 2

REVIEW OF LITERATURE

The increased industrialization and urbanization lead to the increased fresh water demand and hence further lead to the ground water exploitation. Since the available fresh water source is limited, some sort of waste water treatment is essential. Waste water treatment will have two major positive effects on environment. It will help to reduce the pollution level, bad odour etc from water bodies and also reduce the demand of fresh water. There are numerous method of water treatment. 2 cost effective, simple and reliable methods are constructed wetland and the coagulation method. Though latter is physical treatment plant and the other is chemical treatment method, both are easy to operate.

2.1 WASTE WATER TREATMENT TECHNOLOGIES

Waste water treatment is defined as any operation/process or a combination of these to reduce the objectionable properties of waste water and render it less dangerous. The main objective of the waste water treatment system is to allow the domestic and industrial effluents to dispose without danger to human health or those to the environment.

2.1.1 Conventional Waste Water Treatment Process

Conventional waste water treatment system consists of combination of physical, chemical and biological operations to remove the contaminants from the waste water.

2.1.1.1 *Primary Waste Water Treatment*

The primary waste water treatment aims at removing suspended solids, odour, and colour and to neutralise pH (in cases like industrial effluents)

- *Screening* – It is the removal of coarse and settleable solids by surface straining.
- *Comminution* – It is the grinding of coarse solids.
- *Flow equalization* – Equalization of flow and mass loadings of BOD suspended solids.
- *Flocculation* – Promotion of aggregation of smaller particles into bigger ones.
- *Sedimentation* – Removal of settleable solids and thickening of sludge.
- *Floatation* – Removal of finely divided suspended solids and particles. And thickens biological sludge.

- *Filtration* – Removal of fine residual suspended solids remaining after biological or chemical treatment.
- *Micro screening* – same as filtration. Also removes algae from stabilization pond effluents.
- *Skimming* – It is the process of removing oils, grease, etc from the wastewater.

2.1.1.2 *Secondary Wastewater Treatment*

Secondary treatment aims at removing the soluble and colloidal organic matter which remains after primary treatment. It concentrates mainly in the removal of BOD, COD etc. These are treated mainly using biological treatment methods. Biological unit operations includes removal of contaminants by biological activity. Biological processes are classified as

- Aerobic processes – These are treatment processes that occur in the presence of dissolved oxygen. The two main aerobic processes are activated sludge process and trickling filter process.
- Anaerobic process – These includes the decomposition of organic or inorganic matter in the absence of oxygen.

2.1.1.3 *Tertiary Wastewater Treatment*

Tertiary treatment includes all treatments and processes which are used to remove pollutants which are not removed in primary and secondary waste water treatment. Various process included are chemical clarification, recarbonation, filtration, activated carbon adsorption, disinfection, nitrogen removal, phosphorous removal, demineralisation.

2.2 GREY WATER TREATMENT SYSTEMS

Grey water is defined as wastewater generated from bathroom, laundry, kitchen, wash basin water etc. except water from toilets (WHO guidelines, 2006). Some authors excludes kitchen waste water from other grey water streams. Waste water from bathroom, including those from showers and tubs, is termed as light grey water (Friedler and Hadari, 2006). Grey water that includes more contaminated waste from laundries, dishwaters, kitchen sinks etc are called dark grey water (Birks and Hills, 2007).

Halalsheh. *et al.* (2008**)**conducted various treatment systems on grey water treatment. The average grey water generation was measured as 14 Lpcd. The examined treatment systems were septic tank followed by intermittent sand filter; septic tank followed by wetlands; and UASB-hybrid reactor. The study area was Um Alquttain in Mafraq governorate located inJordan. Family size ranges between 5 and 11 persons. Grey water was collected from six households from around 12 different places. Average COD, BOD and TSS values were 2568 mg/l, 1056 mg/l and 845 mg/l, respectively. They 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 as a low cost treatment option, which is affordable by households and also flexible in operation and maintenance.

Pidou*et al*. (2008) investigated about the use of coagulation/flocculation treatment system for shower grey water. They 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 pH, which required adjusting the pH after treatment.

Bhausaheb*et al*. (2010**)** implemented a grey water treatment system based on the hybrid treatment involving a combination of physical and natural systems of cascaded water flow, aeration, agitation and filtration. Laboratory scale grey water treatment plant was designed for 180 l/h capacity. Agitator of 0.18m diameter and 0.125 HP motor was used in the agitation operation. Locally 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 finalize. Further experiments were carried by placing a bed depth of each as 0.15m, o.1m, 0.2m for sand. A removal efficiency of 26% was observed. This involved a cost effective treatment without the chemical operations.

Ghaitidak and Yadav (2013) conducted experiments to study the potential of treating grey water and to reuse it. He characterised different grey water systems, its characteristics, methods to treat them, their proportions etc. Numerous treatment methods were implemented to test the obtained grey water. From that most efficient and economical method was constructed wetland and filtration. Generally 65 % grey water is obtained from households. And around 50 % of light grey water is obtained from the total grey water system.

Albalawneh and Chang (2015) designed an efficient grey water recycling systems mainly with the aim of using this treated water for agriculture irrigation use only. The amount of grey water varied from 50 – 80%. Based on their experiments, they designed a grey water recycling systems. Filtration and sedimentation are the two preliminary treatments done. For medium and high strength grey water, biological processes were implemented.

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

Albalawneh *et al.* (2016)studied the impact of long term irrigation of treated grey water on soil quality. They mainly considered the impact of electrical conductivity along with other soil quality parameters. In this case, they irrigated with treated grey water for almost 2 years. The electrical conductivity of soil before applying grey water is 0.97 dS/m and after applying grey water it decreased to 0.41 dS/m. Almost all parameters like concentration of organic matter, potassium, cadmium, lead, magnesium, chloride, sodium, ESP, and SAR after 2 year complete application of grey water was decreased drastically. But the concentration of Zinc was increased along with slight increase in soil pH.

Sibel and Turkay (2016) treated domestic grey water using electrocoagulation method. They used hybrid electrode combinations for removal of impurities. They used 18 different electrode combination for testing. They also studied about the effect of different parameters like current density, initial pH, and supporting electrolyte concentration on the grey water treatment. The optimum pH obtained was 7.62. When electrode combination of Al-Fe-Fe-Al was used, highest COD removal efficiency was obtained. A current density of $1mA/cm^2$ is obtained as the optimum. And when optimum conditions was provided the energy consumption was only $9.46\ kWh/m^3$.

2.3 COAGULATION METHOD

Coagulation method is used to separate suspended solid portion from the water. These suspended impurities will be in finely divided state. So it is difficult to remove those. So an easy way to remove these particles is by increasing their particle size. So the main purpose of coagulation is to make particles bigger in size and make it settleable; by the addition of certain chemicals known as coagulants. Coagulants are generally classified as primary coagulants and coagulant aid. Primary coagulants neutralize the electrical charge of particles in the water which causes the particles to clump together. The main chemicals used as coagulants are Aluminium sulphate (Alum), Poly aluminium chloride (Liquid alum), Alum potash and Iron salts (Ferric sulphate or ferric chloride).

2.3.1 Principle of Coagulation

2.3.1.1 Floc formation

When coagulants are dissolved in water and thoroughly mixed, they produce a gelatinous precipitate, known as floc. This floc arrest the suspended impurities and settle at the bottom.

2.3.1.2 Electric charge

The ions of floc are positively charged and the suspended impurities are of negatively charged. They tend to attract themselves form precipitate which settle down at the bottom.

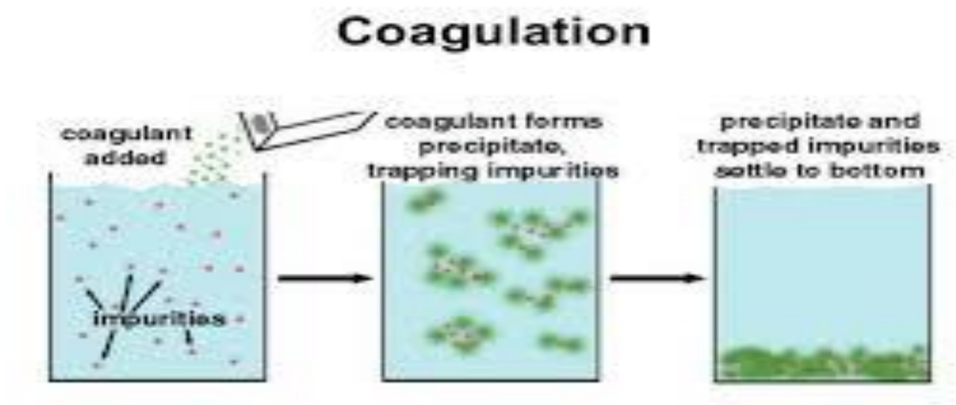


Fig 2.1 mechanism of coagulation

2.3.2 Factors Affecting Efficiency of Coagulation

- Dosage of coagulant
- Feeding
- Mixing
- pH value
- velocity

2.3.3 Aluminium Sulphate/alum

In this experiment, we chose aluminium sulphate as coagulant based on pH of the waste water. Aluminium Sulphate is commonly known as alum. Alum coagulation is generally effective within the pH limits of 6 to 7.

(Source: iwapublishers.org)

Fig 2.2 Alum block

2.3.3.1 Advantages of Alum

- Cheap
- Reduces taste, odour and turbidity.
- Simple in working, does not skilled supervision.
- Produces crystal clear water.
- Floc formed by alum is better than that formed from other coagulants.
- Floc formed is quite tough, i.e., not broken easily.

2.3.3.2 Chemical Reaction

The chemical reaction for alum is expressed as:

$$Al_2(SO_4)_3 .18\ H_2O + 3\ Ca(HCO_3)_2 = 2\ Al(OH)_3 + 3\ CaSO_4 + 18\ H_2O + 6\ CO_2$$

Zunan *et al.* (1995)researched on the efficiency of coagulation method in removing oil from concentrated wastewater using adsorption on pulverized attapulgite. They found that raw clay is better than clay-calcined product for better removal of oil. But in case of emulsified oil, they were not very effective. When 1 % attapulgite is used for 1 h an efficiency of above 90 % is obtained. When the concentration of attapulgite is changed to 2.5 % and treated for 15 min, 99 % of initial removal was observed. The main advantage of using clay is that the used clay can be regenerated.

Muhammad *et al.* (1996) treated domestic waste water using coagulation crossflow microfiltration method. The main aim of the experiment was to determine the effect of alum, polyaluminium silicate sulphate and lime which is used as the coagulants. The primary membrane used was made of woven polyester and dynamic membrane was made of magnesium dioxide precipitate. At pH 7, the coagulant dosage (alum) obtained was 20 – 120 mg/l. Polyaluminium silicate sulphate seem to behave as same as that of alum when used as coagulant. When in case of lime, it is not a suitable coagulant.

According to the studies conducted by International Water Association (2000) they mainly classified the chemical agents for coagulation process or coagulants into 2 categories

i. Those based on aluminium – these include aluminium sulphate, aluminium chloride and sodium aluminate.
ii. Those based on iron- these include ferrous sulphate, ferric sulphate, ferric chloride, ferrous chloride sulphate.

They found out that when metal coagulant are added to water, the metal hydrolyze rapidly but in a somewhat uncontrolled manner. The efficiency of rapid mixing, the pH and the coagulant dosage determine which coagulant is effective for the treatment.

Bansode (2000) has done a detailed study on coagulation method and the types of coagulant used. According to his studies coagulation and flocculation is a combined process used to remove the turbidity, colour, and some microbes from the water. Coagulants are mainly primary coagulant and coagulant aid. Primary coagulants neutralize the electrical charge of particles in the water which causes the particles to clump together. Coagulant aids add density to slow settling flocs and add toughness to the flocs so that they will not break up during the mixing and settling process. Chemically coagulants are either metallic salts (such as alum) or polymers. Polymers are long chained man made organic compounds. They can be either cationic or anionic or non-ionic. Different sourced of water needs different coagulants, but the most commonly used are alum and ferric sulphate. Alum or aluminium sulphate is extensively used. When added to water alum reacts with water and form positively charged ions. Coagulant aid is an inorganic material, when used along with main coagulant, improves or accelerates the process of coagulation and flocculation by quick forming, dense and rapid settling flocs. The common coagulant aids used are bentonite, calcium carbonate, sodium silicate, anionic polymers and non-ionic polymers.

According to the studies conducted by Amescua (2001) on coagulation method, the procedure to potabilize water from soapy water consists of mainly:

1. Adding polymers of aluminium chlorohydroxide to coagulate soapy water flow.
2. Adding a base or alkaline salt to the soapy waste water.
3. Directing the mix to a tank where they are coagulated.
4. Filtering the water that comprises the coagulated particles at least through one diatomaceous earth filter.
5. Storing the water in storage or recycling tank.
6. Injecting hydrogen peroxide or ozone.
7. Recycling the water until desired quality is obtained

Jiang and Lloyd (2001), conducted a study to review the use of ferrate salt as coagulant and oxidant in waste water treatment methods. Ferrate salts have properties like strong oxidising potential, generation of ferric coagulating species simultaneously etc. due to which it can disinfect the micro-organisms, partially oxidise or degrade organic as well as inorganic impurities. When phosphate buffer, carbonate buffer and distilled water was applied, the removal efficiency of turbidity was 95 %, 79 % and 84 % respectively. The main demerits of using ferrate ions was that they have low yield, high toxicity was observed in the by-products and the instability of ferrate ions. On the other hand it has certain advantages like high treatment rate of micro-organisms, heavy metals, suspended particles, organic matter etc.

They concluded that water treatment for drinking water quality standards using ferrate salts needs to be conducted carefully as its effect on water quality is undefined.

Williams *et al,* (2004) conducted experiments to test the effectiveness of chemical coagulation in treating tannery waste water. The main objective of this experiment was to develop a treatment system which can be effectively used to treat the tannery waste water. The coagulants which were used was aluminium sulphate and ferric chloride. The prime constituents which got reduced was COD and chromium. Around 38 – 48 % of suspended solids, 30 37 % COD and 74 – 99 % chromium was removed when optimum coagulant dosage of 800 mg/l in an optimum pH of around 7.5. In his experiments, it can be seen that ferric chloride is a better coagulant than aluminium sulphate. Higher coagulant dosage will not render higher removal efficiency, also it is not economical. When coagulation is combined with centrifugation, there was an improved efficiency in removal of suspended solids. Also a higher clarification degree was obtained by an excess 85 – 86 % colour removal.

According to Bachir (2005) of university of Biskra, in water treatment coagulation and flocculation are treatments that aim to optimise the removal of particles by decantation and filtration. These treatments favour the aggregation of the colloidal particles into broad and dense aggregates. The two main stages include destabilization of the particles and collision of destabilized particles to form bulky aggregates. The destabilization of the particles can be achieved using addition of external agents or chemicals which reduce or eliminate the repulsive forces. The bulky aggregate thus formed after coagulation is undergone fine filtration process.

Golob *et al.* (2005) conducted experiments to determine the efficiency of coagulation flocculation method for the treatment of dye bath effluents. Textile industry is the most environment unfriendly industry, since they generate coloured waste waters heavily polluted with dyes, textile auxiliaries and chemicals. The coagulation/flocculation method was used to decolourise the dyes. A combination of aluminium sulphate and a cationic organic flocculent gives complete decolourisation of dyes, reduction in TSS, COD, BOD, anionic surfactants and biodegradability.

Aguilar *et al.* (2006) applied coagulation method to treat slaughterhouse waste water. They used anionic polyacrylamide as coagulant aid with ferric sulphate, alum and polyaluminium chloride as coagulants. They obtained 25 mg/l as the optimal dosage of anionic polyacrylamide and an optimum pH of around 5-7 when ferric sulphate is used, its optimum dosage is around 75 mg/l within a pH range of 6-7 when alum is used. When anionic polyacrylamide was used as the coagulation aid, it increased the settling speed, reduced the amount of coagulant required and thus decreasing the cost of coagulation flocculation process.

Badawy and Ali (2006) treated combined industrial and domestic waste water using Fenton's peroxidation ad coagulation processes. When conventional coagulation method was used, under various conditions, led to 63 % COD removal and 44 % colour removal by using ferric chloride. The efficiency was increased to 79 % when cationic polymer was added. And when anionic polymer was added efficiency was increased to 73 %. When bentonite was added efficiency was 84 % and 95 % for powdered activated carbon. When Fenton process was used, 100 % colour removal was observed and more than 90 % colour removal was achieved.

Katz and Dosoretz (2007) conducted experiments to completely remove phosphorous from domestic wastewater using chemical coagulation. It is considered as a pre-treatment for RO desalination. For efficient reduction in turbidity and phosphorous, 20 30 mg/l of sodium aluminate was considered. Phosphate removal was done in 2 ways; either the coagulant was added in the membrane bioreactor or, during the secondary treatment of effluents using activated sludge process. In either of the case, complete removal of phosphate was attained. Under these conditions, alkalinity was reduced by around 75 %. In general they concluded that chemical coagulation is technically feasible pre-treatment of domestic effluents with low organic matter content.

Banu *et al.* (2008) conducted experiments to test the effect of using ferrous sulphate as coagulant in removing phosphorous and nitrogen from domestic wastewater. In this case, anoxic/oxic reactor is used. Phosphorous and nitrogen are the main constituents which contribute towards eutrophication. Phosphorous was removed using coagulation and nitrogen was removed through biological treatments. The simultaneous precipitation will not affect COD removal, nitrification and denitrification rate. Also, they found that coagulation process is not affecting the denitrification process the nitrogen removal efficiency was in the range 78 – 85 %. COD removal efficiency was from 94 – 98 %.

Merzouk *et al.* (2008) conducted studies to determine the decolourization efficiencies and COD removing efficiency of textile dye wastewater by continuous electro coagulation process. The electrode used was aluminium. In order to find the effects of operating parameters like current density, pH, influent dye concentration and electrolyte concentration, a series of experiments was conducted. The results obtained were as follows: for an optimum influent concentration of 200mg/l having pH around 6, have a current density of 31.25 mA/ cm^2 with a residence time of 14 mins. Distance between electrodes was 1cm. removal efficiency was in the range of 85 – 95 %. When these conditions were fulfilled, the COD removal efficiency was higher than 80 %.

Sena *et al.* (2008) compared the coagulants and coagulant aids used in the column floatation method of treating meat processing wastewater. Here ferric salts were used as coagulants and 4 different polymers as coagulant aid. The effluent characteristics were pH = 6.5 – 6.7, turbidity = 1000 – 12000 NTU, total solids = 2300 – 7000 mg/l, oils and grease = 820 – 1050 mg/l, BOD = 1200 – 1260 mg/l, COD = 2800 – 3230 mg/l. They achieved removal efficiencies of up to 85 % for oils and grease and total solids. BOD removal was around 62 – 78% and COD removal as around 74 – 79 %. They also achieved high organic matter removal.

Suarez *et al.* (2009) had done a pre-treatment of hospital wastewater using coagulation-flocculation and floatation. The treatment included the removal of 13 pharmaceutical waste and personal care products waste (PPCPs). The dosage of coagulation was determined by jar test. TSS removal efficiency has reached 92 %. Musk fragrances were also reduced. The main PPCP constituents removed were diclofenac, naprogen and ibuprofen whose removal efficiencies were 46 %, 42 % and 23 % respectively. They also found that the rest of PPCP components was unaffected by coagulation process. The worst result was obtained by the floatation method, when it was combined with other method gives better results.

Ismail *et al.* (2011) has designed a combined coagulation flocculation pre-treatment unit for municipal wastewater using hydraulic mixing rather than mechanical mixing. The optimum dosage of coagulant was determined using jar test. All the coagulant types were tested namely alum, ferrous sulphate, ferric sulphate, ferric and ferrous sulphate mixture, lime and ferrous sulphate mixture. Based on various experiments conducted, an optimum dosage of alum was obtained as 60 mg/l. When alum was used, removal efficiency of TSS was 83 % that of COD was 65 %, that of BOD was 55 % and finally that of phosphorous was 76 %. The optimum retained obtained was 2.5 h to 3.5 h. These units can be effectively used for the sewage treatment plant in small villages and camps.

Parmer *et al.* (2011) conducted experiments to determine the effective use of ferrous sulphate and alum as coagulants in the treatment of dairy waste water. From his experiments an optimum dosage of alum was found to be 100mg/l and that of ferrous sulphate was found to be 200mg/l. Both the coagulants showed high removal efficiencies ranging from 20% to 97 %.

Rattanapan *et al.* (2011) devised a new method to enhance the efficiency of biodiesel wastewater treatment using acidification and coagulation processes. When acidification was employed with pure HCl and H_2SO_4, the removal efficiencies of grease and oil and COD at pH = 3 and with retention time of 1 day was observed as 80 and 50 % respectively. When coagulation was used with alum, polyaluminium chloride and ferric chloride as coagulants, the removal efficiencies of more than 90 and 30 % was obtained. But dissolved air floatation alone and dissolved air floatation with acidification were not very much effective in treating biodiesel wastewater. But it can be said that efficiency of grease and oil removal is 10 % higher for dissolved air floatation with acidification and coagulation.

Turk *et al.* (2011) had done a comparative study of laundry wastewater treatment using coagulation and membrane filtration. The membrane filtration units include ultrafiltration and reverse osmosis. They concluded that better treatment option was available using conventional methods along with less sludge production. The COD was reduced up to 98 % and BOD up to 99 % in membrane filtration method, along with complete colour removal. But the cost of installation and operation of using membrane filtration was very high. As in case of coagulation alone, the cost is low, along with its removal efficiencies. The removal efficiency of COD was only 36 % and BOD only 51 %. So to increase the removal efficiency they incorporated the activated carbon adsorption and GAC method. After this, the removal efficiency of CAD was 93 % and BOD was 95 %. In case of coagulation method, the sludge production was slightly higher.

Verma *et al.* (2012) conducted experiments to determine the efficiency of chemical coagulation method to treat coloured textile effluents. Textile industry is considered as one of the most chemically intensive industry. It generates large quantities of chemically impure water. In this experiment they used pre-hydrolysed coagulants such as polyaluminium chloride, polyaluminium ferric chloride, polyferrous sulphate and polyferric chloride. They concluded that rather than chemical coagulants, pre-hydrolysed coagulants and natural coagulants was more effective in removing colour.

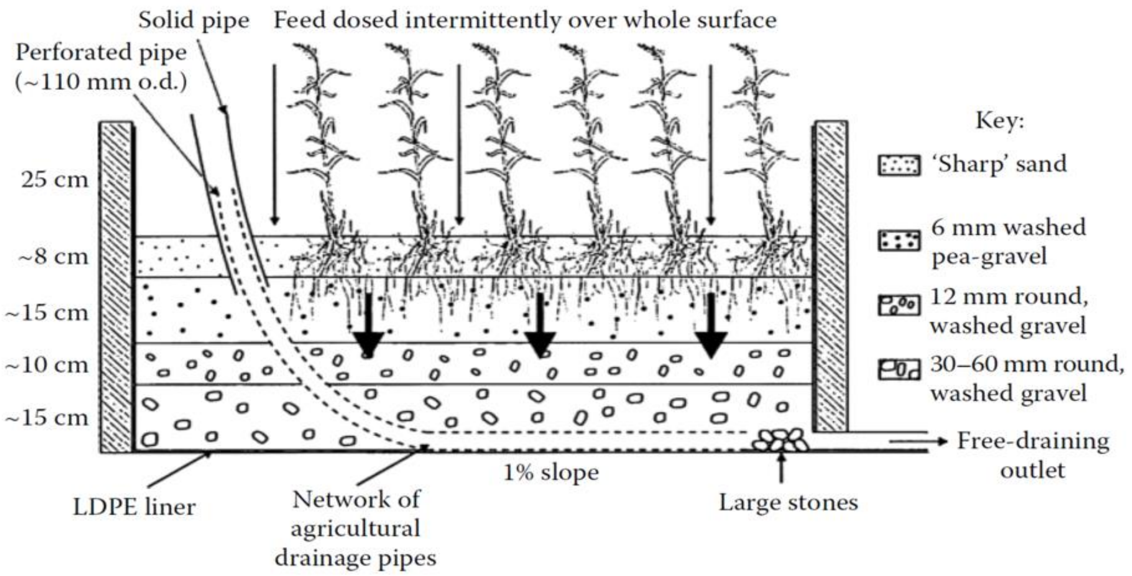
Nawaz *et al.* (2013) applied the coagulation/flocculation method to remove lignin from wastewater. Lignin is found mainly in the wastewaters from paper and pulp industry. The conventional method to remove the lignin from wastewater is not economical, it has certain drawbacks. So this method is an effective method and cost effective method in removing lignin. In case of aluminium based, iron based and copper sulphate coagulants are positively charged whereas titanium based coagulants are negatively charged. When aluminium sulphate is used, 80 % lignin removal is observed and when a mixture of oxititanium and aluminium sulphate was used, 90 % lignin removal was seen.

Zueva *et al*,(2013) conducted experiments to test the effectiveness of coagulation method in treating waste water from meat industry. The wastewater from meat industry is a suspension liquid. Here, aluminium sulphate was used as the coagulant. Based on the results obtained, the average particle size of the powder absorbent was 5.22 µm with an optimum range pH of 6-7. Aluminium sulphate is twice more effective than alumina powder.

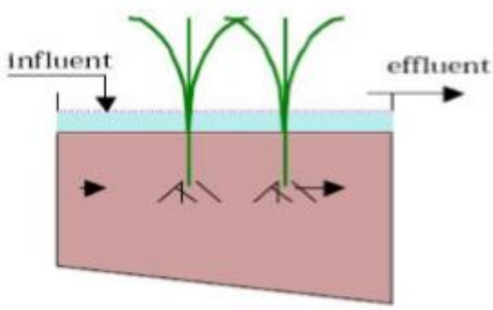
2.4 Constructed wetland

Constructed wetland is an engineered system that uses natural functions of wetland vegetation, soil and organism to treat waste water. Constructed wetland treats the sewage water using highly effective and ecologically sound, design principles that uses plants, microbes, sunlight and gravity to transform waste water into gardens and reusable water. The water treatment mechanisms are biological, chemical and physical, these include physical filtration and sedimentation, biological uptake, transformation of nutrients by bacteria that are anaerobic (bacteria that flourish in the absence of oxygen) and aerobic (oxygen-needing bacteria), plant roots and metabolism, as well as chemical processes (precipitation, absorption and decomposition) that purify and treat the wastewater.

The treatment of waste water within a constructed wetland occurs as the water passes through the rhizosphere zone of plant. Due to the leakage of O_2 from rhizomes, roots and rootlets, there is thin aerobic layer around each root hair. So this aerobic condition helps in the decomposition of organic matter. Nitrogen present in water is released as atmospheric nitrogen by the microbial nitrification and denitrification. Phosphorous is precipitated along with the aluminium, iron and calcium compounds located in the root medium. The suspended impurities are separated by the filtration unit attached. Harmful bacteria and viruses are reduced by filtration and adsorption by the biological film present in the rock media. The constructed wetland can be classified as



- Free water surface constructed wetland
- Subsurface flow constructed wetland



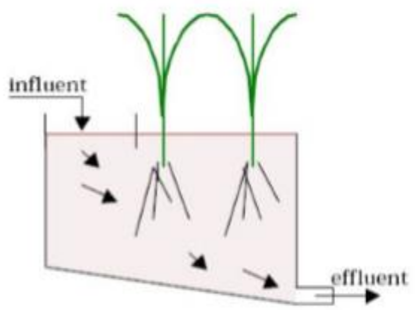


Fig 2.3 Free water surface constructed wetland **Fig 2.4 Subsurface flow CW**

The Subsurface flow constructed wetland is further classified as horizontal SFCW and vertical SFCW based on flow direction.

(Source: Kadlec& Wallace, 2009)

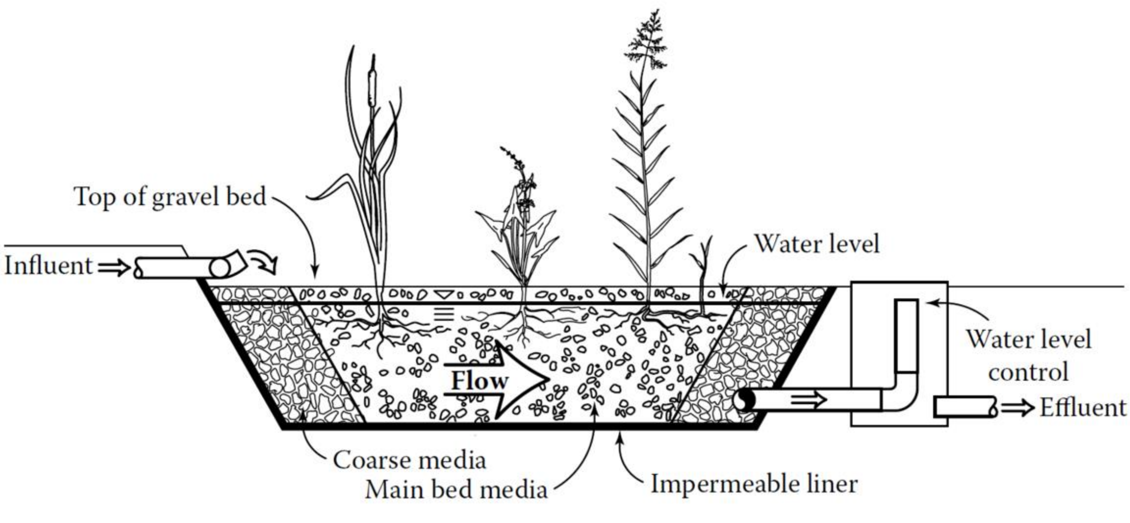
Fig.2.5 Typical configuration of a vertical subsurface flow constructed wetland

(Source: Kadlec& Wallace, 2009)

Fig.2.6 Typical configuration of a horizontal subsurface flow constructed wetland

Seidel undertook the first experiments to be aimed at the possibility of wastewater treatment by wetland plants in the early 1950s at the Max Planck Institute in Plön. Seidel then carried out numerous experiments aimed at the use of wetland plants for treatment of various types of wastewater, including phenol wastewaters, dairy wastewaters or livestock wastewater. Most of her experiments were carried out in constructed wetlands with either horizontal (HF CWs) or vertical (VF CWs) subsurface flow, but the first fully constructed wetland was built with free water surface (FWS) in the Netherlands in 1967

Bevis (1989) of grand valley university, Michigan has undertook a project on reuse of municipal wastewater by freshwater wetland at Vermontville, Michigan. This municipal waste water system consists of 2 facultative stabilization ponds of 10.9 acres and 4 diked surfaces. This system was intended to provide phosphorous removal both by harvesting terrestrial grasses and by soil-water contact as wastewater seeps. The overflow from the final



wetland fields contains a fairly constant volume of effluent, which has seeped from the higher elevation wetlands. This treated effluent is of high quality. The outflow when monitored weekly has confirmed the TSS range well within the limits. Carbonaceous BOD was also within the permissible limits. Total phosphorous in the surface discharge was also well within the permissible limit with an average value of 0.24 mg/L compared to the permit level of 1 mg/L. ammonium nitrogen was also within the limits with an average of 0.86 mg/L compared to the 2.2 mg/L. With this system they could achieve phosphorous removal up to the extent of 97%. Levels of nitrogen nitrate increased approximately 60%.

Vereen (1990) conducted a 5 year intensive study on open type constructed wetland on Carolina bay. The carefully planned and monitored use of the bay for tertiary water treatment facilitates surface water quality management while maintaining the natural character of the bays. After undergoing conventional primary and secondary treatment at the treatment plant, the waste water is slowly released to the wetland for tertiary treatment. The plants along with the purification of water, gives high productivity also. The treated effluent can be distributed to 700 acres within the Carolina bay through a series of pipe network. After this natural treatment of waste water they could achieve a monthly average BOD rate of 12mg/L and TSS of 30 mg/L

According to Bavor and Adcock(1994) Wetland can effectively remove or convert large quantities of pollutants from point sources and non-point sources including organic matter, suspended solids, metals and nutrients. The focus on wastewater treatment by constructed wetlands is to optimize the contact of microbial species with substrate, the final objective being the bioconversion to carbon dioxide, biomass and water. Wetlands are characterized by a range of properties that make them attractive for managing pollutants in water. These properties include high plant productivity, large adsorptive capacity of the sediments, high rates of oxidation by micro flora associated with plant biomass, and a large buffering capacity for nutrients and pollutants.

Adams (1995) has set up a natural wetland for waste water polishing in houghton lake, Michigan. He devised this wetand treatment method to support the peatland farming systems in the country. The clear water from the wetland is passed on to the farm for their use. According to the reports and results from his study some substances in the waste water do not interact as strongly with the wetland as do nutrients. Chloride, calcium, magnesium, sodium and potassium all displayed elevated values. Chloride, especially, moves freely through the wetland to the outer streams. Oxygen level in the pumped water are good, approximately 6 mg/L average.

Tanner (1995) compared different emergent plants for an artificially constructed wetland system. Their nutrient uptake, pollution removal level, growth – above and below the ground etc. were the parameters of comparison.8 emergent plant varieties were chosen like

Schoenoplectus validus, Glyceria maxima, Bolboschoenus fluviatilis,Juncus effuses, Zizania latifolia, Phragmites australis, Baumea articulate and Cyperus involucratus. Relatively poor growth was seen in Baumea and Juncus. Highest biomass value above ground was seen in Zizania and Glyceria. Nitrogen removal ranges from 65 – 92 %, suspended solids was 76 – 88 % and phosphorous removal of 79 – 93 % was achieved.

According to Mitchell (1996) there are six major biological reactions involved in the performance of constructed wetlands, including photosynthesis, respiration, fermentation, nitrification, denitrification and microbial phosphorus removal.

Knight (1999) has constructed a wooded wetland for waste water treatment in cannon beach. The objective of this wetland treatment is to meet water quality requirements with minimal disturbance to the existing wildlife habitat. The 15 acres of wetland are primarily red alder, slough sedge and twinberry. These wetlands act as natural filter to complete the treatment process, and the wildlife is not disturbed. The average monthly limitations were 10 mg/L BOD and TSS of 50 mg/L over dry season. The system was initially operated with aerated lagoon effluent flowing in series to the three facultative lagoon. The discharge from the system is approximately 25-50% of the influent flow with a remainder loss through evapotranspiration and seepage. The lagoon average BOD and TSS were 27 mg/L and 51 mg/L while that of wetland effluent were 6 mg/L and 11 mg/L.

Kivaisi (2001) conducted experiments to determine the potential of constructed wetland foe the treatment of wastewater and its reuse in developing countries. They according to him, constructed wetland are one of the recently proven efficient technology. The constructed wetland are a low cost technology. According to his studies, constructed wetland can be implemented as a wastewater treatment facility in almost all conditions. It can be adapted to all environment parameters and all plant species.

Hadad *et al.* (2006) constructed a pilot scale wetland to determine the feasibility of treating wastewater from tool industry. High conductivity and pH was observed along with Cr, Ni and Zn. They induced an available inflow rate of 1000 l/day with an HRT of 7 days. They selected different species of pants for treating wastewater. And each species react differently towards pollutant.

Harikumar *et.al*. (2006) conducted a study on treatment of wastewater using artificial wetland. An artificial wetland was constructed in The Centre for Water Resource Development and Management (CWRDM), Calicut to treat wastewater from the canteen. The wastewater was allowed to pass through six different tanks viz, sedimentation tank, skimming tank, filtration tank, storage tank, constructed wetland and finally the treated water is collected in another storage tank. The analysis of treated samples indicated that BOD is reduced to 84%. The TKN values decreased to 90 % in the final out flowing water. The total coliform is reduced to 210 MPN/100 ml from a value of greater than 2400 MPN/100ml in the inflow water fromthe canteen. The oil and grease is reduced from a value of 144 mg/l to 1.6 mg/l. the COD value is decreased to 60 % in the out flow water.

Halalsheh (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 (up flow 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.

Khan *et al.* (2009) conducted study to investigate the efficiency of treating industrial wastewater for removing heavy metals using constructed wetland. The heavy metals include lead, cadmium, iron, nickel, chromium and copper. The constructed wetland employed was continuous free surface flow wetland. The removal efficiency of lead = 50 %, cadmium = 91.9 %, iron = 74.1 %, nickel = 40.9 %, chromium = 89 % and copper = 48.3 %. They also found that the efficiency of removing heavy metals can be increased by proper vegetation and increasing area of wetland.

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 grey water 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.

According to the studies conducted by Farooqui*et al.* (2010), the constructed wetland system mimics natural wetland systems utilizing wetland plants, soils and associated micro-organisms to remove contaminants from waste water by filtration, settling and bacterial decomposition in a natural looking lined mash. a properly operating constructed wetland system should produce an effluent with less than 30mg/L BOD, less than 25mg/L total suspended solids less than 10,000 cfu/100 mL.

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.

Albold *et al.* (2011) conducted a case study on Sustainable Wastewater Treatment for Rural and Peri-Urban Communities in Bulgaria. The scope of this case study is to provide information about the principles and guidance for the design of subsurface flow constructed wetlands as a sustainable wastewater treatment option, especially for small communities in Bulgaria, based on German national guidelines. This case study only deals with subsurface flow CW and with coarse sand as filter bed material. Their constructed wetland system could achieve more than 80% COD removal which is similar to the other systems. Pathogenic indicators are also removed by 2 – 3 log orders. Their two-step constructed wetland can provide an efficient nitrogen removal if adequately designed and can achieve requirements for discharge into sensitive areas. The reduction in phosphorus depends on the adsorption capacity of the media and the age of the plant but is usually limit.

Kariuki *et al*. (2011**)** performed experiments on treatment of grey water 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. Grey water 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. PH 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 and 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 grey water 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 which was 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 of 83.07% 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.

Saeed and sun (2012) conducted experiments to study the organic and nitrogen removal mechanisms in subsurface flow constructed wetland and to determine other parameters influencing it’s functioning like environment parameters, operating conditions and supporting media. The major environmental parameters considered are, dissolved oxygen and temperature, operational parameters include organic carbon availability, loading, feed mode, retention time etc. these parameters had major impacts on the nitrogen removal mechanism. In organic removal, anaerobic and anaerobic heterotrophic degradation was an important mechanism.

Vyamzal (2013) has done a detailed study on the types of emergent plants used in free water surface constructed wetland. These plants are commonly known as emergent macrophytes. The main functions of emergent macrophytes include reducing wind speed which support sedimentation and prevent resuspension, they also provide substrate for bacteria and periphyton, take up nutrients and provide carbon for denitrification in carbon limited system. Generally there are 150 species of plants found in and around 43 countries and the most commonly used species were Typha, Scripus, Phragmites, Juncus and Eleocharis.

Sameer *et al*. (2015**)** evaluated and implemented the integrated treatment of grey water from household 'and a small scale experiments were conducted on grey water. 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.

Navaneeth and Nafla (2017) has conducted an experiment on subsurface flow constructed wetland in the ladies hostel premises of KCAET using helicornia as the emergent plant. Their main objective was to design and fabricate the subsurface flow wetland by using suitable filter media and vegetation and to evaluate the performance of subsurface flow constructed wetland. They could achieve an efficiency of 97% in BOD removal and 50 % in COD removal. Their constructed wetland system consists of conveying system, sedimentation tank, SFCW and a collecting tank. They evaluated the change in water quality after passing through the treatment system (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.

CHAPTER 3

MATERIALS AND METHODS

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

3.1 SITE SELECTION

Surface methods of constructed wetlands are not advised in areas of denser populations where it may cause breeding of mosquitoes as well as become habitat for rodents and rats. 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. In our experiment we decided to opt for considering the ladies hostel premises. The outlet coming from ladies hostel bathroom has been decided to be taken as the source of grey water used treatment system.

Important considerations in assessing a suitable site for constructing SFCW are 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 witha minimum 2% slope.

3.2 GENERAL DESCRIPTION OF STUDY 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 is 2952mm. The minimum and maximum temperature prevails between 22°C and 36°C while average annual relative humidity is about 85 %.

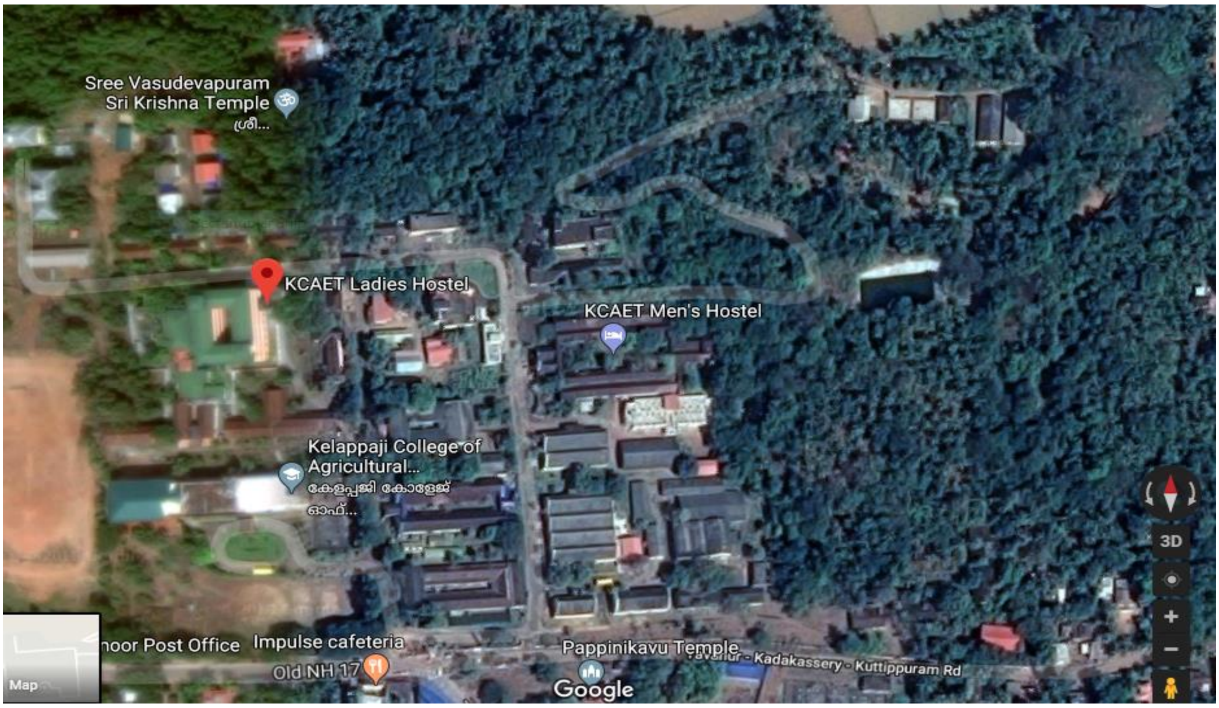


Plate 3.1 Google map location of project site

The outlet coming from ladies hostel bathroom was taken as the source of grey water used treatment system. The water coming from the bathroom was being diverted to the study area. The grey water coming from bathroom outlet consists of 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 bacterial population.

3.3 CHARACTERISATION OF GREY WATER

Samples of grey water were collected from suitable outlets. 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 pH, BOD, TSS, COD, oil and grease content, total phosphorous and total nitrogen.

The samples were collected from the diverted outlet of ladies hostel bathrooms usually during peak usage time means in the morning. These samples were tested for water characteristic including pH, TSS, $BOD_{5,}$ COD, EC, oil and grease etc, atWater Quality Division located at the Centre for Water Resources Development & management (CWRDM), Calicut.

3.4 EXPERIMENTAL SET UP OF SFCW

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

- Property boundary
- Volume of influent
- Site topography.

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

3.4.2 Pre-Treatment

Pre-treatment ensures the survival of the constructed wetland and thereby increasing the life of the system. The necessary pre-treatments in grey water purification system are sludge and other solid removal. The overloading of solids or its accumulation was avoided by these pre-treatment processes. Pre-treatment arrangements used in this study include mesh filter and sedimentation tank.

3.4.2.1. Mesh Filter

It is a type of filter using a flexible or rigid screen to separate solid and some semi solid particles. They are generally made up of materials like stainless steel, polypropylene, nylon and polyester. In this study the mesh filter has a size less than 10 mm. It is the first stage of filtration. This mesh was placed at the inlet portion, before the inlet tank to avoid particles like hair, soap etc. The screens were cleaned manually.

3.4.2.2. Sedimentation Tank

Sedimentation tank also called as settling tank, 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 particleswill settle down at the bottom of the tank and the oily and grease portion of the grey water will float on top. So the inflow taken to the SFCW was from the middle portion of the sedimentation tank.

3.4.3 Subsurface Flow Constructed Wetland (SFCW)

The SFCW has been chosen to analyse the performance in tropical climate, as its efficiency has been proved by many scientists worldwide.

3.4.3.1Components

a) Basin: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 will enter into the inlet section and slowly flows to the filtering section and last to the outlet section of the SFCW *b) 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 which has been decided to use here are gravel, sand and crushed stone, charcoal and sea shell which are available locally. Charcoal and crushed stone can be used at the inlet section. Sand and soil is used in the filtering section

Plate 3.2 Typical representation of cross-sectional view of basin

*c) Vegetation***:** It 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. Commonly water tolerant emergent plants are used for this study. We have decided to take the canna plant for this purpose.

Plate 3.3 Different stages of plant growth in SFCW

3.4.4 Collection Tank

It is 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 is needed for the analysed for water characteristics. This water is stored for irrigation purpose.

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 was difficult to handle in a small scale SFCW. So an arbitrarily selected quantity was diverted to the outlet. Also 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 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

$$\text{porosity} = \frac{\text{pore space volume}}{\text{total volume}} \times 100 \quad \ldots.(7)$$

3.7 DETERMINATION OF PARTICLE SIZE DISTRIBUTION OF FILTER MEDIA

- Weigh the required amount of sand and keep it in a tray. Mix it thoroughly.
- Sieve the mixtures thoroughly through the following set of sieves: 2mm, 1mm, 600 micron, 425 micron, 300 micron, 212 micron, 150 micron and 75 micron. The set of sieves should be arranged in the following order and then fitted to a mechanical sieve shaker such that 2 mm sieve is at the top and 75 micron sieve is at the bottom.
- The soil fraction is retained on each sieve should be carefully collected on a container and the mass of each fraction is determined and recorded.

3.8 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.

3.9 DETENTION TIME/ HYDRAULIC RETENTION TIME (HRT)

Performance of constructed wetlands is a function of detention time, among other factors including 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 summerand 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 calculated as follows:

$$\text{detention time or HRT} = \frac{(\text{volume}\times\text{porocity})}{\text{flow}} \quad \ldots. (8)$$

3.10 CONSTRUCTION

The designed subsurface flow constructed wetland systems need to be constructed at the project site. The SFCW system was made with 12 gauge MS sheet. The basin of the tank is separated for having distinct section and provided as baffles for water flow and thereby increasing the detention time.

In the inlet section, PVC pipe having perforation should be fitted along the width to spread the waste water. The inlet section should be filled with crushed stone of average 3cm diameter and above which a layer of charcoal is to be added. The filtering section should consist of sand at a depth of 30 cm and soil layer of 8 cm to provide better root growth for vegetation. The outlet section consists of a 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 should be 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.

Pl

ate 3.4 construction stages of SFCW

3.11 OPERATION AND MONITORING

Each plant should be 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 should be monitored per week, and invasive seedlings like ordinary grass should be immediately removed.

3.12 SAMPLING AND ANALYSIS

The water quality in the SFCW should be 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 analysed for BOD, COD, TSS TN and TP etc. according to Standard Methods for Water and Wastewater analysis.

3.13 COAGULATION METHOD

3.13.1 Components

a) Coagulants**:** These are the chemicals agents added for the process of removal of suspended solids in water. Coagulation method is a type of method for the filtration and purification of water. A coagulant (typically a metallic salt) with the opposite charge is added to the water to overcome the repulsive charge and destabilize the suspension. For example, the colloidal particles are negatively charged and alum is added as a coagulant to create positively charged ions. The optimal pH range for coagulation is 6 to 7 when using alum and 5.5 to 6.5 when using iron. For proper coagulation process to occur the correct coagulant must be selected. Here we have selected alum as our coagulant. Aluminium sulphate or alum when added to raw water reacts with the bicarbonate alkalinities present in water and forms a gelatinous precipitate. This floc attracts other fine particles and suspended material in raw water, and settles down at the bottom of the container.

Determination of amount of coagulant to be added (jar test):

Take adequate amount of measurable glass jars in which the waste water is filled to certain amount/standard amount. Then add different quantities of coagulant in each jar and check to see the floc produced. The amount of which maximum floc will be formed is selected.

Plate 3.5 Jar test

b) Coagulation Basin**:** These are basin in which coagulation process are carried out. That means the coagulants are added in this section.

c) Fine filter**:** The water after coagulation still consists of minute particles which should be removed. These are removed either through fine filter like disc filter or fine mesh of less than 50 micron size. The water which is collected from the coagulation basin is filtered and then given to collecting tank.

d)Collection Tank*:*It is the final unit which collect the out flow from the coagulation basin. The effluent sampling is taken from the collecting tank and is needed for the analysed for water characteristics.

3.13.2*Chemical Reactions*

For alum:

$$Al_2(SO_4)_3 .18\ H_2O + 3\ Ca(HCO_3)_2 = 2\ Al(OH)_3 + 3\ CaSO_4 + 18\ H_2O + 6\ CO_2$$

3.13.3 Construction

A PVC pipe having perforation should fitted to coagulation basin for giving waste water. A fine filter is fitted at the outlet opening and outlet is connected to collection tank.The effluent sampling is taken from the collecting tank and is needed for the analysed for water characteristics.

Coagulation basin

Plate 3.6 construction of coagulation basin

3.13.4 Sampling and Analysis

The water quality in the coagulation system should be 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 analysed for BOD, COD, TSS TN and TP etc. according to Standard Methods for Water and Wastewater analysis.

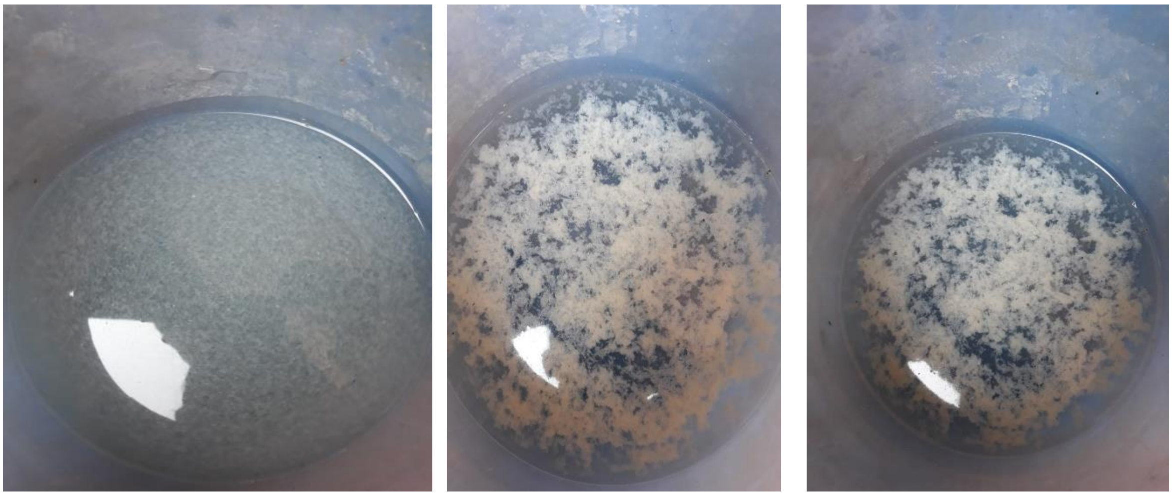


Plate 3.7 stages of coagulation process

CHAPTER 4

RESULT AND DISCUSSION

The subsurface flow constructed wetland was installed at the project site. After transplantation and establishment of the wetland plant, the operation and monitoring of the unit was initiated. The removal efficiency or the treatment performance was evaluated by examining the water quality at both inlet and the outlet.

4.1 WASTE WATER CHARACTERISATION

Waste water characterisation is an important aspect in designing a wastewater treatment plant. It is considered as one of the most critical step in designing of treatment plant. The important contaminants considered in the present study is enlisted in table 4.1:

Table 4.1: Waste water characteristics

Constituent	Unit	Test method
Biochemical Oxygen Demand (BOD)	Mg /l	APHA,2017 (part 5210)
Chemical oxygen demand (COD)	Mg/l	APHA,2017 (part 5220)
Total dissolved solids (TSS)	Mg/l	APHA,2017 (part 2540)
Oil & grease	Mg/l	APHA,2017 (part 5520
PH	None	APHA,2017 (part 4500 H+)
Total Kjeldahl Nitrogen (TN)	Mg/l	APHA,2017 (part 4500 – N)
Phosphate - P	Mg/l	APHA,2017 (part 4500 – P)

4.2 EXPERIMENTAL SET-UP OF CONSTRUCTED WETLAND

Table 4.2 Experimental set-up – design hydraulics andstructural dimensions

Hydraulics		**Structural dimensions**	
Type	Subsurface	Size	1.7m ×1.1m
Flow regime	Horizontal	Longitudinal slope	<1%
Operation mode	Batch	Aspect ratio	1.5 : 1
Free board	0.1m	Inlet structure	500L storage tank
HRT	5days	Outlet	500L collecting tank

Table 4.3 Experimental set-up – substrate physical parameters.

Substrate – Physical parameters			
Section	**Media type**	**Depth**	**Size**
Inlet	Crushed stone Charcoal	0.30m 0.1m	3cm
Filter	Sand Soil	0.30m 0.1m	1mm

Outlet	Sea shell Crushed stone	0.1m 0.30m	8mm

Table 4.4 Experimental set-up - Vegetation- Physical parameters

Vegetation- Physical parameters	
Plant type	Emergent plant
Common name	Canna
Scientific name	*Canna indica*
Numbers	30
Density	15 plant/m^2

Table 4.5 Experimental set-up - Waste water

Waste water	
Type	Grey water
Source	Domestic / bathroom
Primary treatment	Sedimentation

4.2.1 Operation and Monitoring Of SFCW

After the establishment of plant species, the subsurface flow constructed wetland was operated. Approximately 110 L of grey water per day. The valves were calibrated before starting of the operation. The time needed to discharge a particular quantity of wastewater was calculated. Then according to these calculations, the valve was opened for 9 mins a day for getting the desired inflow. The plant growth was regularly measured. Uproot weed and unnecessary plant growth.

4.2.2 Sampling and Analysis of SFCW

Water samples were collected from the collecting portion of the inlet chamber for influent analysis and from the outlet chamber for the effluent analysis. The samples were analysed for pH, BOD, COD, total suspended solids, oil & grease, phosphate and nitrogen. The samples were collected in translucent white sampling cans and given for water quality analysis.

Table 4.6 Result of SFCW

Sl. No.	Parameter	Influent	Effluent
1	pH	7.68	7.58
2	BOD (mg/l)	1280	1.0
3	COD (mg/l)	1738	15.26
4	Total suspended solids (mg/l)	1170	6.0
5	Oil & grease (mg/l)	151	1.47
6	Phosphate – P	2.6	Below detection level
7	Total Kjeldahl Nitrogen	28	13.78

Fig 4.1 Influent **Fig 4.2 Effluent of SFCW**

4.2.3 Organic Removal

The concentration of BOD in the influent is 1280 mg/l. and the concentration in effluent is 1 mg/l. So the BOD removal efficiency is 99.99 %.

Table 4.7 BOD analysis

Sample no.	Influent (mg/l)	Effluent (mg/l)	Efficiency (%)

1	1280	1	99.99

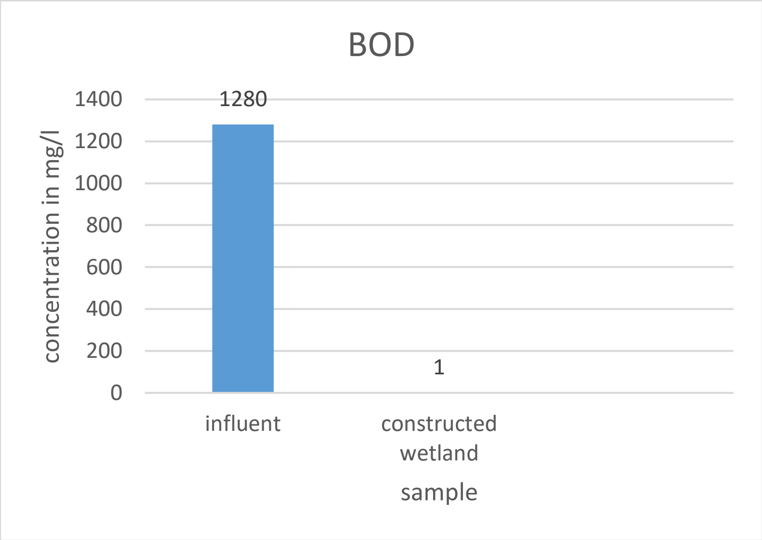


Fig 4.3Variation of BOD in influent and effluent samples using SFCW

The concentration of COD in the influent is 1738 mg/l and in the effluent is 15.26 mg/l. so COD removal efficiency is 99.12 %.

Table 4.8 COD analysis

Sample no.	Influent (mg/l)	Effluent (mg/l)	Efficiency (%)
1	1738	15.26	99.12

BOD_5 is often 70–90% of the COD, depending on the substance or waste water, since not all COD is biologically oxidizable. In theory, maximum BOD can be COD×0.9, since about 10% of the original organic material is part of a non-biodegradable residue.

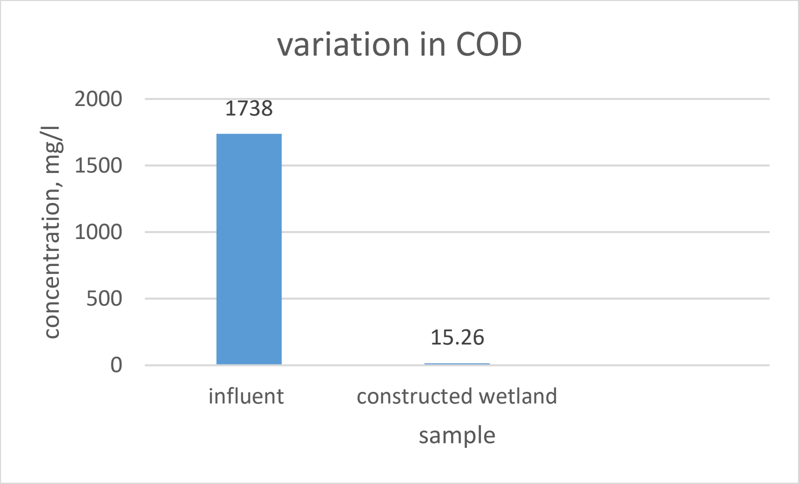


Fig 4.4Variation of COD in influent and effluent samples using SFCW

4.2.4 Nutrient Removal

In SFCW total nitrogen obtained was 28 mg/l. and after the treatment it was reduced to 13.78 mg/l. So the nitrogen removal efficiency is 40.3 %.

The phosphorous content the influent was 2.6 mg/l. and after the treatment the phosphorous content was so low that it was not able to determine chemically that means it was below detection level.

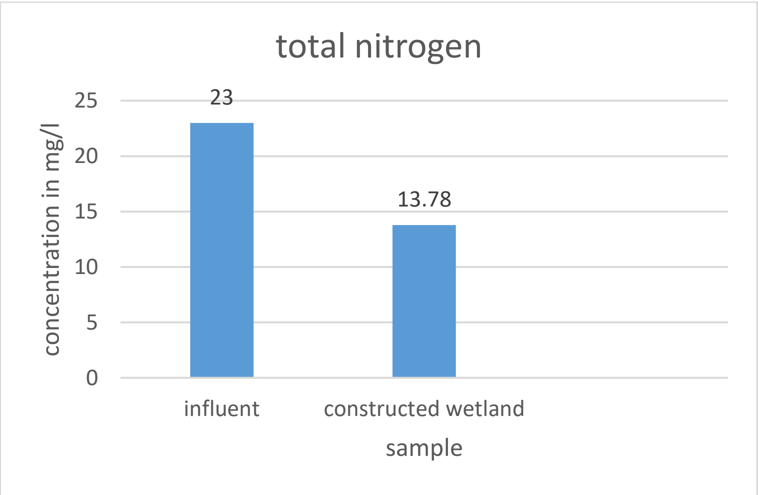


Fig 4.5 Variation of nitrogen

4.2.5 Solids removal

The total suspended solids concentration of the influent was1170 mg/l and in the effluent was 6 mg/l. So its removal efficiency is 99.48 %.

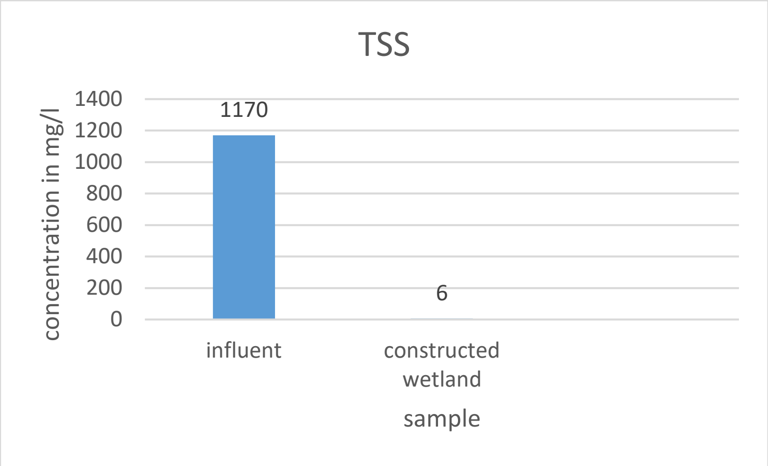


Fig4.6 variation of TSS in influent and effluent

4.2.6 pH Variation

The pH of the influent sample was 7.68 and after the treatment it was reduced to 7.58. Still it can be considered in the normal range.

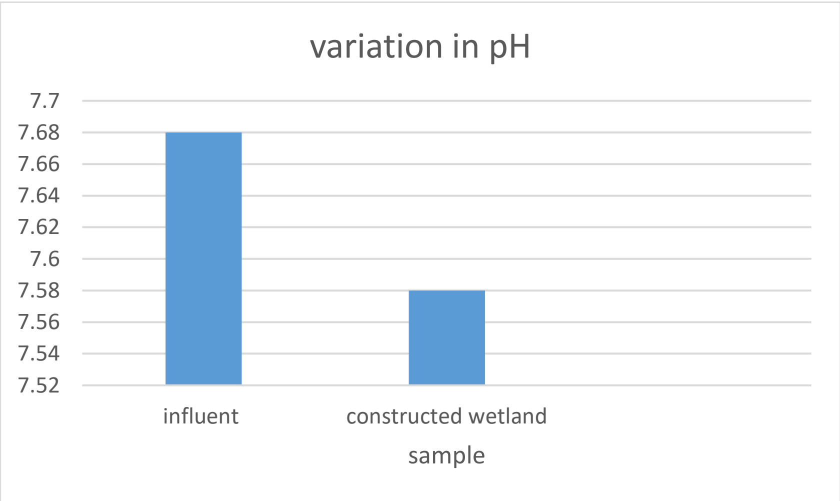


Fig 4.7 variation in pH

4.2.7 Scum Removal

Scum or oil and greases present in the water was removed through constructed wetland to a greater extent. The initial concentration of oil and grease is 151 mg/l and it was reduced to 1.47 mg/l. and its removal efficiency is 99.02 %

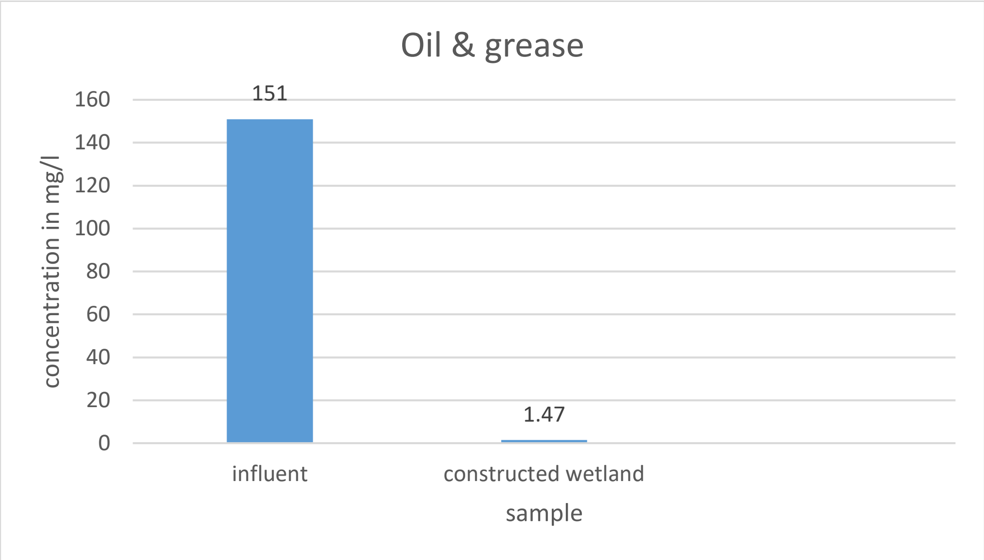


Fig 4.8 variation of scum removal

4.3 EXPERIMENTAL SETUP OF COAGULATION METHOD

Table 4.9 Experimental setup of coagulation method

Waste water	
Type	Grey water
Source	Domestic / bathroom
Treatment	Coagulation
Coagulant used	Alum
Optimum coagulant dosage	17 g/L

4.3.1 Operation

Collect the required amount grey water to the coagulation tank. Measure the amount of coagulant accurately using weighing balance. The amount of coagulant required is 17g/litre of grey water. Mix the coagulant and grey water thoroughly and leave it aside for the floc formed to settle down. Using very fine sieve (that means sieve of size 50 microns), filter the water carefully.

4.3.2 Sampling and Analysis

Water samples were collected and sent for analysis at CWRDM, Calicut.

Table 4.10 Result of coagulation method

Sl. No.	Parameter	Influent	Effluent
1	pH	7.68	3.48
2	BOD (mg/l)	1280	13.32
3	COD (mg/l)	1738	83.95
4	Total suspended solids (mg/l)	1170	58
5	Oil & grease (mg/l)	151	1.79
6	Phosphate – P	2.6	Below detection level
7	Total Kjeldahl Nitrogen	23.12	23.12

Fig 4.9

Influent

Fig 4.10 effluent

4.3.3 BOD Analysis

The initial BOD content was 1280 mg/l and it was reduced to 13.32 mg/l. so the removal efficiency was 98.95 %. It is slightly less when compared to constructed wetland.

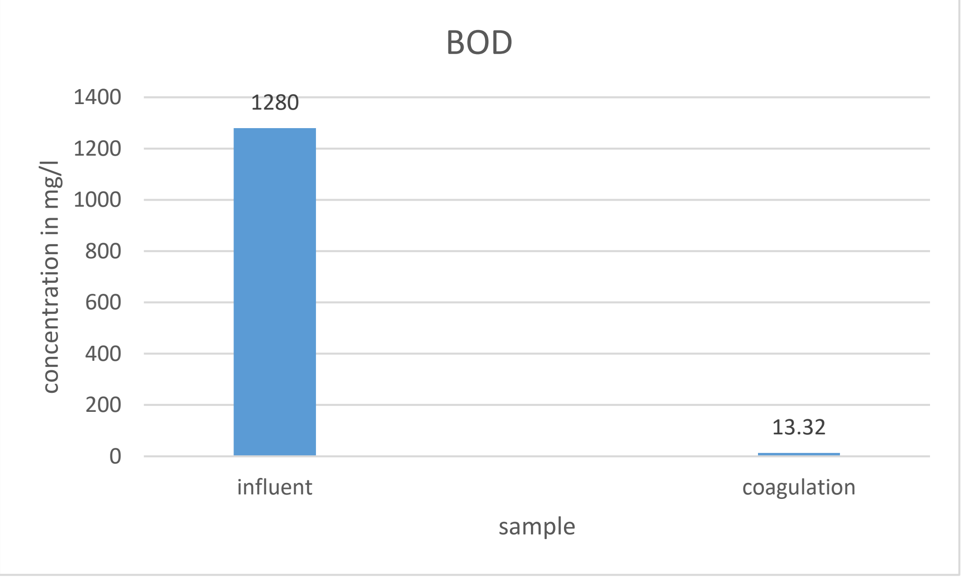


Fig 4.11 variation in BOD (Coagulation method)

4.3.4 COD Analysis

The initial COD content was 1738 mg/l and it was reduced to 83.95 mg/l. so its removal efficiency is 95.16 %.

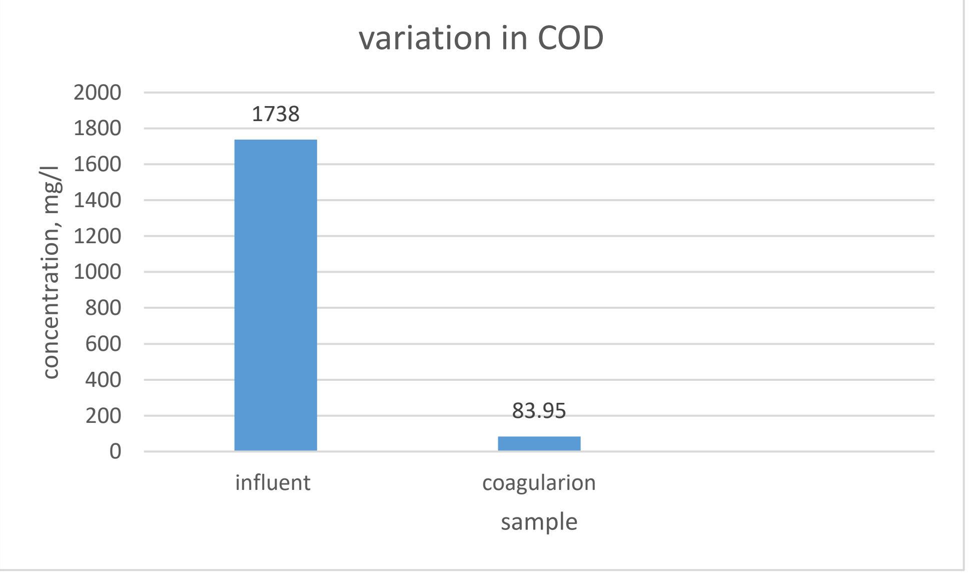


Fig 4.12 variation in COD

4.3.5 Total Suspended Solids

The initial concentration was 1170 mg/l and the effluent concentration was around 58 mg/l. so the removal efficiency is 95.05 % which slightly lesser than constructed wetland.

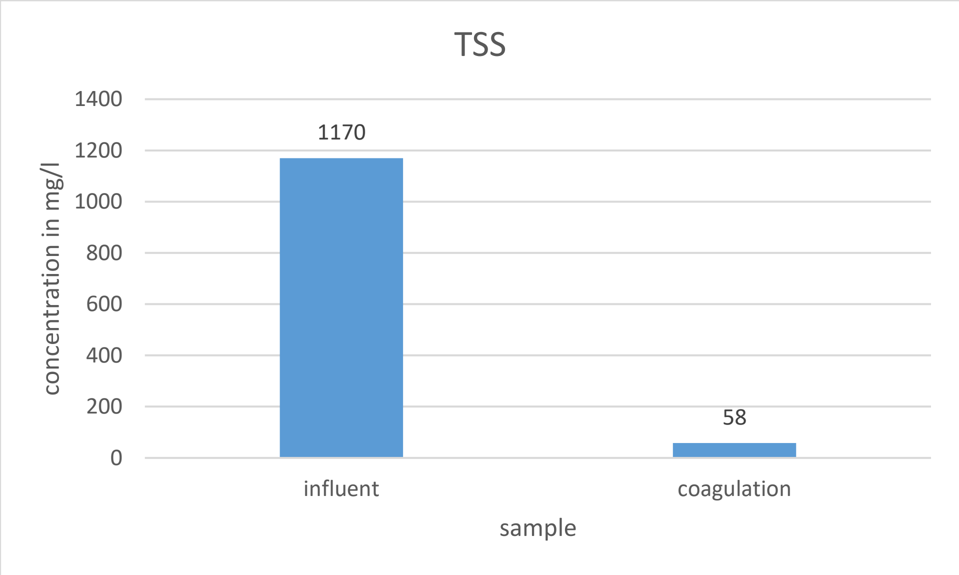


Fig 4.13 variation in TSS

4.3.6 Scum Removal

Oil and grease present in grey water are removed to a greater extent by the coagulation method. Their initial concentration was 151 mg/l and it got reduced to 1.79 mg/l. so it can be said that its removal efficiency is 98.81 %.

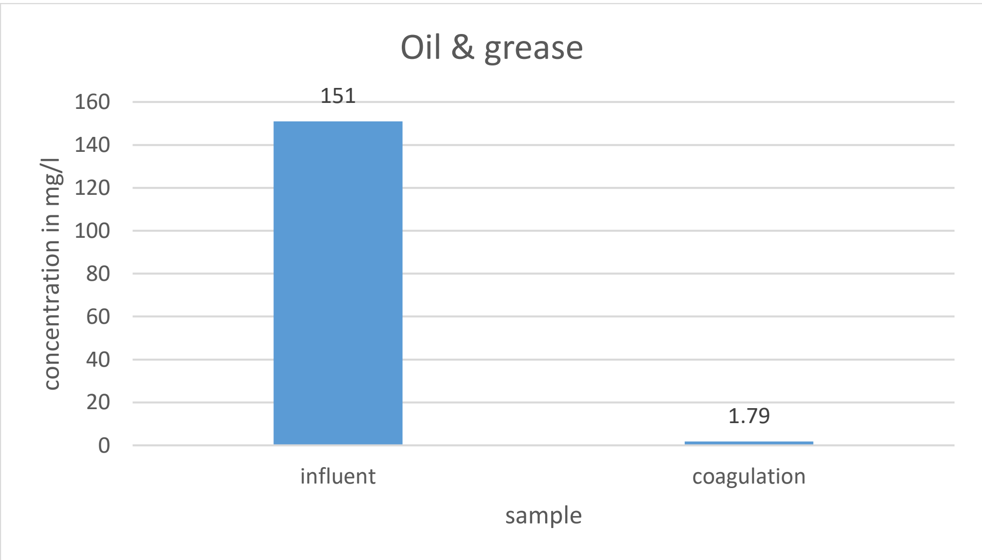


Fig 4.14 variation in oil and grease

4.3.7 pH

pH of the initial sample was 7.68, but when alum was added as coagulant to treat the grey water, its pH got reduced to 3.48. That means the water turned to acidic water.

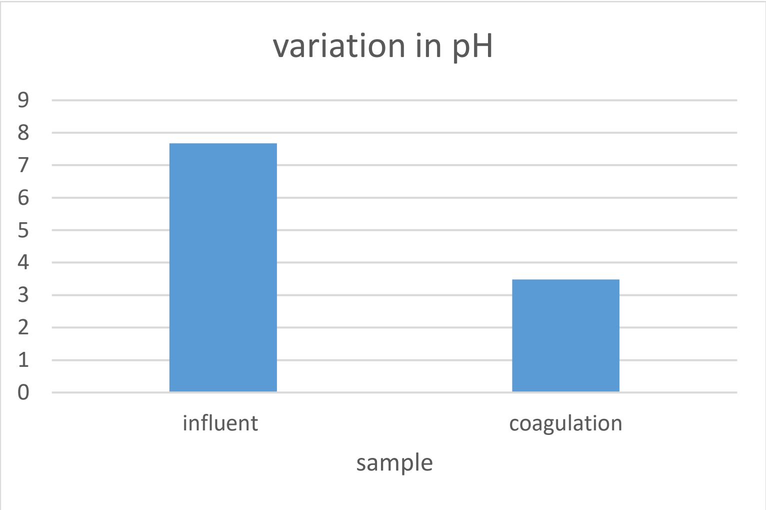
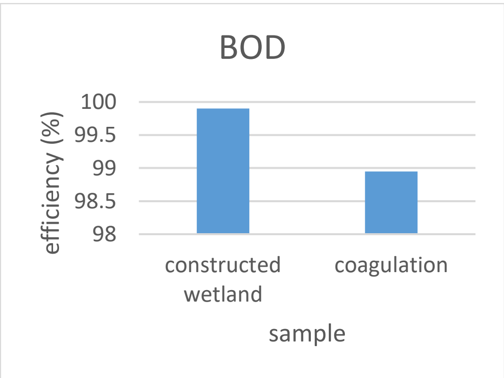


Fig 4.15 variation in pH

4.3.8 Nutrient Removal

The phosphorous content the influent was 2.6 mg/l. and after the treatment the phosphorous content was so low that it was not able to determine chemically that means it was below detection level. Also nitrogen content was not removed in coagulation method.

4.4 EFFICIENCY GRAPHS



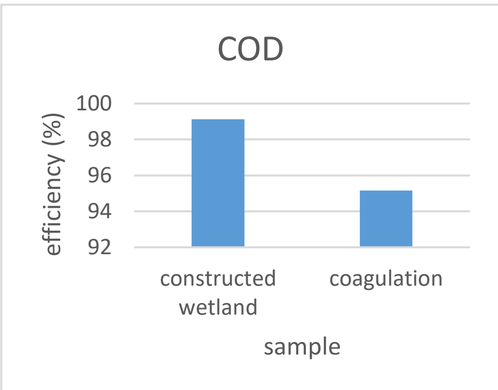


Fig 4.16 BOD efficiency variation

Fig 4.17 COD efficiency variation

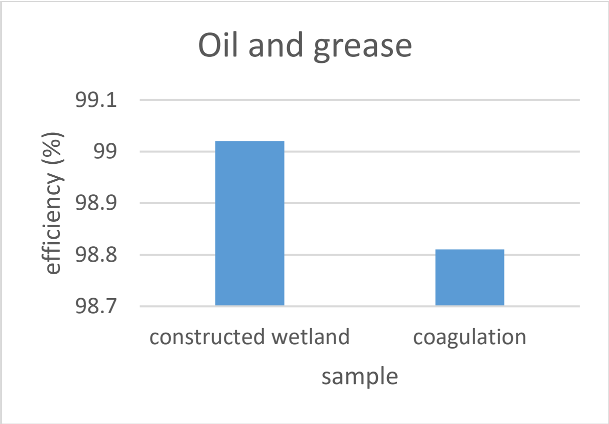


Fig 4.18 scum removal efficiency

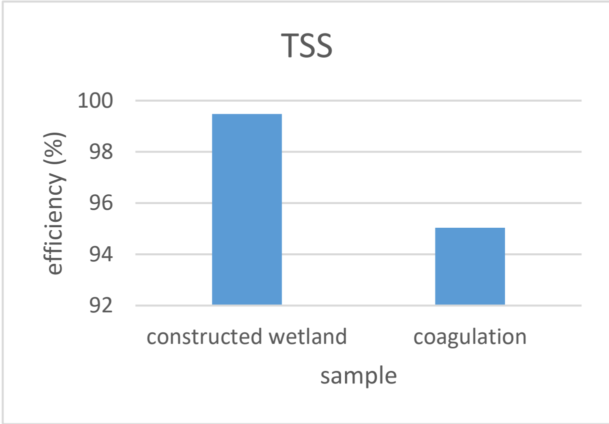


fig 4.19 TSS removal efficiency

CHAPTER 5

SUMMARY AND CONCLUSION

Considerable amount of wastewater are being generated by the population growth and industrialization. Numerous methods are present through which the wastewater can be treated and reused for purposes like irrigation. If the waste water is discharged back to environment without treating, it can cause harm to the environment. So to protect our environment treatment of wastewater is essential. Various studies have shown that constructed wetland and coagulation method is an effective treatment systems. This project aims a comparative study between the two methods.

This research includes 2 water treatment systems- coagulation method and constructed wetland method. In the constructed wetland method, the grey water is treated with canna plant. The treated water is found to be of good quality. The advantage of this method is that crystal clear water around neutral pH is obtained by this method.

BOD is a measure of degree of contamination of water. Hence BOD test indicate the oxygen utilized by bacteria during the removal of organic matter from water. BOD_5 indicates the 5-day biochemical oxygen demand. The BOD of the influent was analysed as 1280 mg/l. So the removal efficiency of BOD in constructed wetland method is 99.99 % and that of coagulation method is 98.95 %. There is much less variation between the two methods.

COD estimates the oxygen equivalent of organic matter of a sample that is susceptible to oxidation by a strong chemical oxidant. The COD of the influent is 1738 mg/l. thus the removal efficiency was found to be 99.12 % for constructed wetland method and 95.16 % for coagulation method.

Water quality can be varied with variation in hydraulic retention time. Water quality increases with increase in HRT, but longer HRT can cause stagnation of water. Also, shorter period will not remove the pollutants completely. So appropriate HRT is required. Here in this study an HRT of 5 days was maintained.

Nutrients like nitrogen and phosphorous are essential and important nutrients required in irrigation water. But in excess can cause algal blooms, eutrophication etc. Light grey water mainly consists of phosphorous and nitrogen. The emergent macrophytes in constructed wetland removes phosphorous and nitrogen. But in constructed wetland only phosphorous is removed, Nitrogen is not removed.

One of the most important physical characteristics is total solid content. In the influent the TSS was very high, but in the treated waters, TSS was reduced to 99.48 and 95.04 % for constructed wetland and coagulation method respectively.

pH is the negative logarithm of hydrogen ion concentration. The influent pH initially was around 7.68 and it was reduced to 7.58 in the constructed wetland. But still it is around the neutral value. With the use of seashell at the outlet section, the pH of the water was neutralised in the constructed wetland. But in the coagulation method the pH was drastically reduced to 3.48. Here alum is used as the coagulant. So when lime is added along with alum, the pH variation will not be drastic. That was the main drawback of the coagulation method.

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