

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 5, May 2019

Effectiveness of Domestic Wastewater Treatment by Using Water Hyacinth and Porous Concrete in Constructed Wetland System

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ABSTRACT- Overall 97% of water is available on earth. Out of which 2% is in polar regions, 95% is in oceans and only 1-2% is fresh water. Therefore it is more important to conduct effective management of water resources. Natural wetlands like swamps, marshes, fens are beneficial for food and habitat of wildlife, flood protection, shoreline erosion control etc. From past few decades it is observed that wetlands are used for waste-water treatment also. Therefore “artificial” or “engineered” wetlands have been constructed for specialized treatment functions. As we know, there are 4 components of constructed wetland; wetland vegetation, supporting media, water column and living organism. For wetland vegetation various types of aquatic plants can be used like cattails, reeds, bulrushes, water hyacinth, duck weeds etc because they are responsible for removal of nutrients such as heavy metals, phosphorous, nitrate, suspended solids etc. The media which supports wetland vegetation is coarse and fine gravel. The bottom layer of wetland normally of coarse gravel and upper is of fine gravel in size range of 12-15mm. Void spaces in media serve as flow channels of waste-water. The despite of all these information, the main aim of this research is to find out the different supporting media which will increase the overall efficiency of domestic waste-water system. Therefore after the detailed study it was decided to use of porous concrete as a supporting media and water hyacinth as a aquatic plant and treat building waste-water. For this work small pilot constructed wetland system is designed. After experimentation and analysis it was observed that various waste-water parameters such as (BOD, COD, TDS, TSS) etc are decreasing and water quality will be increasing. Based on results it is concluded that removal efficiency of waste-water system is increased and meet regulatory discharge limits. Therefore pilot study can be recommended for large scale also. This study mainly helps in rural areas where waste-water treatment is necessary.

KEYWORDS: Domestic Wastewater, Water Hyacinth, Porous Concrete, Constructed Wetland System, engineered wetlands

I. INTRODUCTION

1.1 General

During most of this century the trend has been for more mechanized wastewater treatment systems with almost every aspect of the various processes under the direct control of the operator. In the last twenty years. However, approaches that do not involve the same "concrete and steel" mentality have drawn more attention. Shortly after the enactment of

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the Clean Water Act (PL92-500) of 1972, alternate methods of wastewater treatment once again became recognized as valid means of achieving the required level of effluent quality. Initially, attention was centered on existing natural systems such as wetlands and coastal marshes, but more recently, constructed systems using aquatic plants have been investigated. In the early days of sanitary engineering, natural treatment was the only method known. Initially, treatments was not even an objective, nor were the processes understood. Wastewater were simply disposed off in the nearest river, lake, or swamp if one was available.

1.2 Natural systems for wastewater treatment

Conventionally, wastewater treatment is accomplished by physical, chemical and biological processes. Typically, these processes are supported by natural components such as microbial organisms, but in a complex array of energy-intensive mechanical equipment. Conventional treatment systems, therefore contribute to i) depletion of nonrenewable fossil fuel sources, and ii) environmental degradation that occur due to extraction of nonrenewable resources, and also due to the by-products/final products of these technologies, such as biosolids and sludge. Therefore, attempts at developing a cost-effective treatment approach always revolved around using only the natural components devoid of any mechanical requirements that use up energy. Using plants to purify wastewater has always fascinated researchers and holds intuitive appeal to the general public as well. Consequently, many natural systems that use the ability of plant species in up taking or degrading the pollutants were developed.

The natural treatment systems are available under three major categories:

- (i) Aquatic or pond/ lagoon systems;
- (ii) Terrestrial or land application systems;
- (iii) Wetland systems.

The aquatic natural treatment systems involve impounding wastewater in ponds or lagoons for sufficient period so that pollutants and pathogens in wastewater are removed through natural biological degradation processes. Floating plant species such as algae, duckweed and water hyacinth may also be present in these systems to support the biological processes. Oxidation ponds, facultative lagoons and waste stabilization ponds are some of the examples for aquatic treatment systems.

1.2. Objectives of study

1. To decide the type of waste water to be filtered.
2. To study the various parameters of domestic wastewater.
3. To determine the artificial filter material and aquatic plant which is suitable in constructed wetland systems for wastewater treatment.
4. To evaluate the performance of water hyacinth as a aquatic plant.
5. To carry out the study and evaluate the performance of porous concrete as a filter material.
6. To develop an small scale experimental setup/model for treatment process.
7. To find out the final results obtained by that experimental model.
8. To determine the overall treatment efficiency of constructed wetland when porous concrete and water hyacinth is used.
9. To decide whether that porous concrete which is used as a filter material is useful or not for constructed wetland system.

1.3 Scope of study

1. This project focuses only on treating domestic wastewater with subsurface vertical flow with water hyacinth as a aquatic plant and porous concrete as a filtering material.
2. This project provides an overview and basic idea about how efficiently domestic wastewater can be treated by using water hyacinth plant and porous concrete.
3. This study/treatment process only used for constructed wetlands and when ample of land is available.

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II. LITERATURE SURVEY

2.1 General

This chapter deals with the detail literature survey of various national and international research papers related with study about wastewater treatment, types of wetlands and its design etc. Efforts towards controlling water pollution focused mainly on expensive centralized collection and treatment systems for municipal wastewater. Conventionally, wastewater treatment is accomplished by physical, chemical and biological processes that are capital and energy-intensive. There is a critical global need for cost-effective, long-term wastewater treatment technologies and approaches to deliver public health and environmental protection [1].

The aim of this research paper lays stress on using water hyacinth as a aquatic plant and porous concrete as a filter material how effeciently domestic wastewater is treated. For this treatment process one small scale experimental model was constructed. The methodology adopted will help in the identification of pollutants in domestic wastewater which will undergo the process of phytoremediation. For this purpose wastewater sampling of domestic water will be collected depending upon the availability. The comparative analysis will be performed. Constructed wetlands can mitigate ecological risks to aquatic receiving systems by decreasing concentrations and toxicity of contaminants [2].

In this paper, one small scale experimental model was constructed to treat a domestic wastewater. building wastewater, was collected as a domestic wastewater for treatment. The role of plants in the treatment of effluents by constructed wetland (CW) systems is under debate.

With the rapid increase in population as well as all round development in India during the recent years, there has been a competing demand of water for irrigation, domestic use and power generation which are exerting enormous pressure on the country's existing water resources ,as the water reserves are also depleting at a fast pace. The precarious balance between growing demands and supplies has brought forward the importance of recycling and reuse of water and thereby reducing the fresh water demand supply. The paper highlights the wastewater treatment in the country in the recent years for the urban and rural areas. The present focus of the paper is the latest trend for wastewater treatment which has been recently proven as an efficient technology is the adoption of artificial wetlands or constructed wetlands (Shutes, 2001) in developing countries. An attempt has been made to provide an overview on the comparative analysis of various treatment technologies. In comparison to the conventional treatment systems, the constructed wetlands involve low cost, and can be operated and maintained easily. In terms of initial cost, operational cost and maintenance cost the constructed wetlands having the least expenditure amongst the other conventional processes can prove to be the most suitable option for wastewater treatment for developing countries where cost is the most critical parameter[6]. Natural wetlands (e.g. swamps, bogs, marshes, fens, sloughs. etc) are being considered beneficial for food and habitat for wildlife, water quality improvement, flood protection and shoreline erosion control. However during past few decades it has been observed that the planned use of wetlands for meeting wastewater treatment and water quality objectives has been seriously studied and implemented in a controlled manner. Constructed wetland systems (CWS) for wastewater treatment have been proven to be effective, low cost and sustainable alternative for conventional wastewater treatment technologies. The removal of pollutants in these systems relies on a combination of physical, chemical and biological processes that naturally occur in wetlands and are associated with vegetation sediment and their microbial communities. Numerous studies on the performances of the wetlands treating wastewater carried out during the last few decades have provided quantitative information which has been used to improve the treatment efficiency through design and operation measures. The CWS generally falls under two categories: Subsurface Flow System and Free Water Systems. Subsurface flow system are designed to create subsurface flow through a permeable medium, keeping the water being treated below the surface, such system have also been referred as "root zone system", "rock reed filters", and "vegetated submerged bed system". Free water surface systems on the other hand are designed to simulate natural wetlands, with the water flowing over the soil surface at the shallow depth[7].

Increasing urbanization, industrialization and over population are the factors mainly responsible for adding hazardous components in water, which mainly constitutes heavy metals and chemicals etc. Water bodies are the main targets for

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disposing the pollutants directly or indirectly. This is a review paper illustrating the role of plants to assist the treatment of industrial and residential wastewater. The prevailing purification technologies used to remove the contaminants are too costly and sometimes non-ecofriendly also. Therefore, the research is oriented towards low cost and ecofriendly technology for waste water purification, which will be beneficial for community. The paper discusses the potential of different process and utilization of terrestrial and aquatic plants in purifying water and wastewater from different sources [8].

Pervious concrete is a new concrete with high porosity which usually used for flat work applications in order to allow water to pass through it, and by that it reduces the volume of direct water runoff from a site and increases the quality of storm water and water pollution. Due to the high flow rate of water through Pervious concrete pavement, rainfall can be captured and percolate into the ground, recharging groundwater, supporting sustainable construction, reducing storm-water runoff, and providing a solution for construction that is sensitive to environmental concerns. In urban areas especially where the land is very expensive, Pervious concrete pavement and its sub-base may provide a good amount of water storage capacity which eliminates the need for precipitation runoff containment strategies. This study examines the advantages of using such material to maximize storm-water, minimize flooding and improve water filtration in Jordan by replacing a selected parking lot area in the University of Jordan campus with Pervious concrete. The findings of this research support that using Pervious surfaces in storm-water management is a sustainable and yet environment friendly way of water- storming [9].

III. PROBLEM STATEMENT AND METHODOLOGY OF WORK

3.1 Problem statement of work

- a) Constructed wetlands have been used as a convenient wastewater discharge.
- b) For constructed wetlands different types of supporting media or substrate were used and from that we got different treatment efficiencies.
- c) But the main aim of this research is to find out the different supporting media and aquatic plant which will increase overall efficiency of wastewater system. So after the detail study, it is decided that
 1. Top layer is planted with water hyacinth plant and
 2. The wetland is constructed with porous concrete rather than use of sand, gravel etc.

3.2 Methodology of work

This chapter deals with the detailed methodology of the project, which includes various steps. Following flow chart shows the detail methodology for project work.

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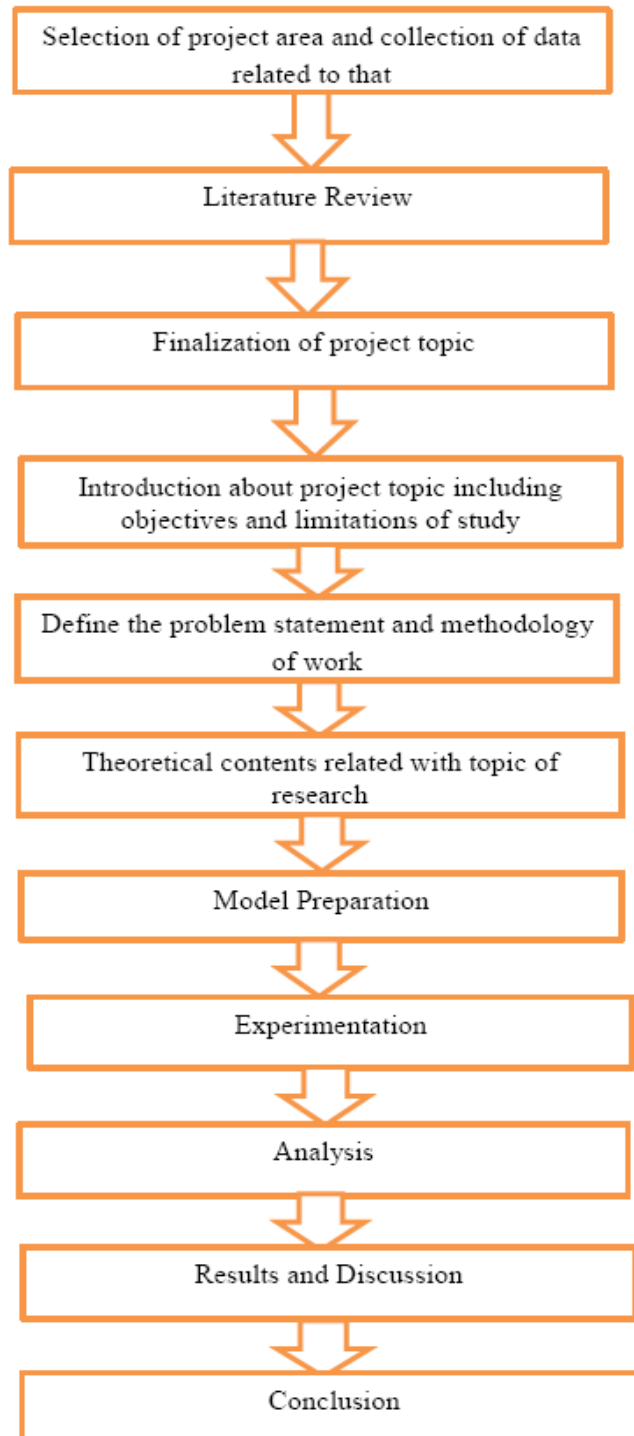


Fig 01 Methodology of Work

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IV. Conceptual Background

4.1 Use of Water Hyacinth as an aquatic plant

Vegetation is considered as a dominant feature of constructed wetlands, and acts as an important biotic factor in the treatment process [9]. Among the free-floating species, the water hyacinth (*Eichhorniacrassipes*) appears to be a promising candidate for pollutant removal owing to its rapid growth rate and extensive root system. *Eichhorniacrassipes* known as water hyacinth is a free-floating aquatic macrophyte that rapidly grow to high depth (over 60kg/m²) in an open pond, irrigations and other water bodies cause the clogging of water bodies and triggers unfavorable environment effect, human health and affects the economic development as well [11,12]. Despite, *Eichhorniacrassipes* shoot covers the surface of water bodies prevent the entry of sunlight impacts the algae growth and also aquatic organisms and this disturbs the balance of ecosystem. The common *Eichhorniacrassipes* species has long pendant roots, rhizomes, stolon and it can grow in the range of 40 cm to 100 cm height. It has the ability to float due to the stem and leaf contain air-filled tissue that provides substantial buoyancy and also able to grow in drastic condition such as moist sediments for several months. Water hyacinth (*Eichhorniacrassipes*) having fast growth rate characteristics in the polluted areas which has been used for many research activities. Anatomical parts of water hyacinth contains some chemical constituents which are capable to remove several impurities. The concentration of contaminants has been reduced by water hyacinth. Different physio-chemical parameters like TSS, TDS, COD, BOD in municipal wastewater can be minimized. Water hyacinth is having a high nutrient removal ability. The plant has a unique ability to treat wastewater by absorbing nutrients and other substance from water and hence pollution levels are toned down. The roots of water hyacinth participate actively in treatment of wastewater. Uptake of contaminants in the plant occur primarily through the root system. The root system consisting of principal mechanisms which inhibit the toxicity of the contaminants.

4.2 Materials

Pervious concrete, mainly consists of the usual Portland cement, water and coarse aggregates (either single-sized coarse or grading between 19 and 9.5 mm). It also contains a paste to fill the voids. These ingredients give concrete a porosity of 15 to 35%. Typical Pervious concrete mix designs used in the United States consists of cement, single-sized coarse aggregate, and a water to cement ratio ranging from 0.27 to 0.43

4.3 Applications

1. High flow rate through Pervious concrete include drainage media for hydraulic structures, parking lots, tennis courts, and greenhouses.
2. It has high porosity it is thermally insulating (for example, in walls of buildings)
3. It has good acoustical properties for sound barrier walls.

4.4 Environmental Benefits

1. Pervious concrete pavement provide a useful storm-water management tool since it collects oil, anti-freeze, and other automobile fluids that can be washed into streams, lakes, and oceans when it rains.
2. Pervious concrete collects what is known as the “first flush” of rainfall and “treat” the pollution prior to release.
3. It helps earning a credit point in the U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED).
4. It also helps in lowering heat island effects in urban areas due to two main points; the amount of absorbed heat from solar radiation is smaller than usual pavements, and the relatively open pore structure of Pervious concrete stores less heat.

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4.5 Procedure of various tests parameters

◇ pH meter

1. Select the water samples
2. Switch on the pH meter.
3. pH meter will show the pH reading of the selected water samples.
4. Note down the readings.

◇ Biochemical Oxygen Demand :-

1. Collect the field sample.
2. Fill a field sample in BOD bottle with sample water without making air bubbles.
3. Add 2ml of manganese sulfate to the BOD bottle carefully by inserting the pipette just below the surface of water. So that you can avoid the formation of air bubbles.
4. Add 2 mL of alkali-iodide-azide reagent in the same manner.
5. Close the bottle and mix the sample by inverting many times. A brownish cloud will appear in the solution as an indicator of the presence of Oxygen.
6. Allow the brown precipitate to settle out to the bottom.
7. Add 2ml of Conc.H₂SO₄ carefully without forming air bubbles.
8. Close the bottle and mix the solution well to dissolve the precipitate.

◇ Chemical Oxygen Demand

1. Collect the field sample.
2. Pour 10ml of water sample in three 100 ml conical flask labelled as Test1, Test2, and Test3.
3. Simultaneously the distilled water need to take in three 100ml conical flask labelled as Blank1, Blank2 and Blank3.
4. Add 5ml of potassium dichromate solution in each of the six conical flasks
5. Keep the flask in water bath at 100°C (boiling temperature) for 1 hour
6. Allow the samples to cool for 10 minutes
7. Add 5ml of potassium iodide in each flask
8. Add 10ml of sulphuric acid in each flask.
9. Titrate the contents of each flask with 0.1N Sodium thiosulphate until the blue colour disappear completely.
10. Total Soilds

❖ Total soilds (TS)

i) Weigh and clean empty crucible(A) = (W1)gm

ii) Take a measured volume of the waste water sample in (A), say 25ml if the sample appears strong, 50ml if it appears moderately strong and 100ml if it appears weak and evaporate to dryness in a hot air oven at 103-105 degree.

iii) Cool the crucible to room temperature and weigh(W2)gm.

$$TS \text{ (mg/lit)} = \frac{(W2-W1)gm * 1000(ml/lit) * 1000(mg/gm)}{\text{Volume of sample taken (ml)}}$$

❖ Total dissolved soilds (TDS)

i) Weigh and clean empty crucible (B) = W3gm

ii) Take a known volume sample, filter it through Whatman filter paper no.40 and collect the filtrate in (B) as above.

iii) Evaporate the filtrate in (B) to dryness in a hot air oven at 103 degree celcius. Cool the crucible to room temperature and weigh = W4gm.

$$TDS \text{ (mg/lit)} = \frac{(W4-W3)gm * 1000(ml/lit) * 1000(mg/gm)}{\text{Original volume of sample taken (ml)}}$$

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V. PREPARATION OF SMALL SCALE MODEL

5.1 Materials used for preparation of small scale model

3 different types of plastic boxes with capacity 11lit, 9lit and 6lit.

1. Plastic tap
2. Plastic pipe
3. Square size porous concrete
4. Water hycinth plant
5. Wastewater of our building
6. White cement

5.2 Setup details

Steps of setup preparation and its details are as follows

1. 3 plastic containers with different sizes as per capacity were brought from shop and arrange in vertical order and one plastic tap is fixed to first box and one small pipe is attached to first and second container, due to that wastewater from 1st container is transferred to 2nd container through pipe and tap.
2. Collection of wastewater from building.
3. Collection of water hycinth plant and allowed it to grow for 4 weeks in tub of freshwater because the color of roots was black initially which turned into grey after growing and then it will be placed in collected wastewater to purify the water.
4. Fixed the porous concrete in the bottom of second container due to that wastewater is freely passed and treated wastewater is collected in last container.
5. We have to take intial readings of wastewater after collection and final readings with the interval of 3days,6days and 9days of wastewater after passing through water hycinth and porous concrete. And then compare the both readings and find the overall efficiency of wastewater system.



Fig no 5.1 Different sizes plastic containers



Fig no 5.2 Porous concrete layer



Fig no 5.3 Water hycinth plant



Fig no 5.4 water hycinth plant after growing

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Fig no 5.4 Preparation of initial setup



Fig no 5.5 Porous concrete fixed in bottom of container



Fig no 5.6 Porous concrete (bottom view)



Fig no 5.7 Preparation of final setup

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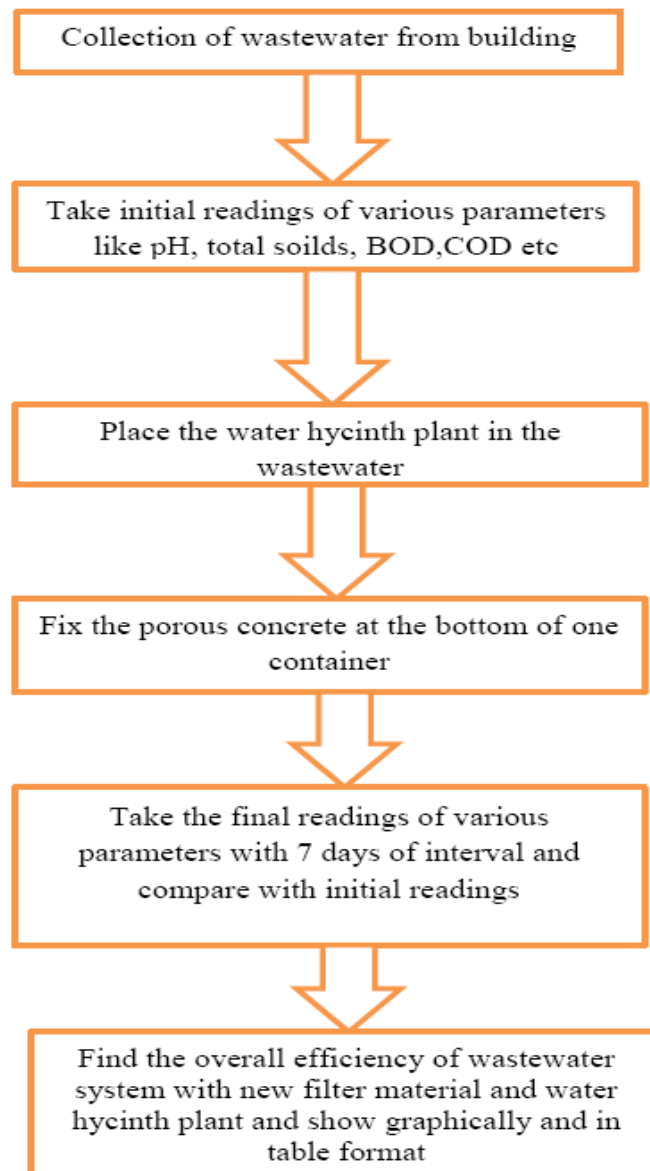
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5.3 Process of experimentation

In this chapter, the detailed experimentation process is discussed below with the help of flow diagram



VI. RESULTS AND DISCUSSION

6.1 Test Performance

For this project, wastewater (sample) were collected from a outlet of building for analyzing various parameters like pH, TS, BOD, COD etc. and find out the results.

I Part - In the 1st part we have to calculate initial readings of various parameters of building wastewater which are given below.

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Reading	pH	TS (mg/lit)	TDS (mg/lit)	TSS (mg/lit)	BOD (mg/lit)	COD (mg/lit)
Initial Reading	7.61	790.12	665.23	190.00	80.12	152.31

Table no 6.1 Initial Readings of various parameters

II Part - In the 2nd part we have to calculate final readings of various parameters of wastewater with the interval of 3days,6days and 9 days of building wastewater which can be naturally purified with the help of water hycinth plant and then passed through porous concrete which is used as a filter material with the interval of 3days,6days and 9 days and determine the overall efficiency of treatment process.

Day	pH	TS (mg/lit)	% Reduction	TDS (mg/lit)	% Reduction	TSS (mg/lit)	% Reduction	BOD (mg/lit)	% Reduction	COD (mg/lit)	% Reduction
3 rd	7.72	594.21	24.79	454.43	31.68	111.98	41.06	52.77	34.13	119.40	21.60
6 th	8.32	311.61	60.56	229.83	65.45	80.45	57.65	43.12	46.18	60.61	60.21
9 th	8.56	215.58	72.71	208.36	68.67	60.13	68.35	33.72	57.91	49.43	67.54

Table no 6.2 Final Readings of various parameters after passing through water hycinth with the interval of 3,6 and 9 days

III Part - In the 3rd part we have to calculate final readings of various parameters of wastewater after passing through porous concrete which can be used as a filter material.

Day	pH	TS (mg/lit)	% Reduction	TDS (mg/lit)	% Reduction	TSS (mg/lit)	% Reduction	BOD (mg/lit)	% Reduction	COD (mg/lit)	% Reduction
3 rd	7.89	160.21	79.72	80.12	87.95	66.18	65.16	50.81	36.58	97.42	36.03
6 th	8.38	90.11	88.59	68.24	89.74	53.18	72.01	39.65	50.51	50.23	67.02
9 th	8.70	52.73	93.32	60.16	90.95	42.31	77.73	30.48	60.95	33.86	77.76

Table no 6.3 Final Readings of various parameters after passing through porous concrete with the interval of 3,6,9 days

6.2 Calculation of % Reduction

Sample calculation of TS =

$$\% \text{ reduction} = 100 - (1^{\text{st}} \text{ reading of TS}) / (\text{Initial reading of TS}) * 100$$

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6.3 Graphical Representation of various parameters

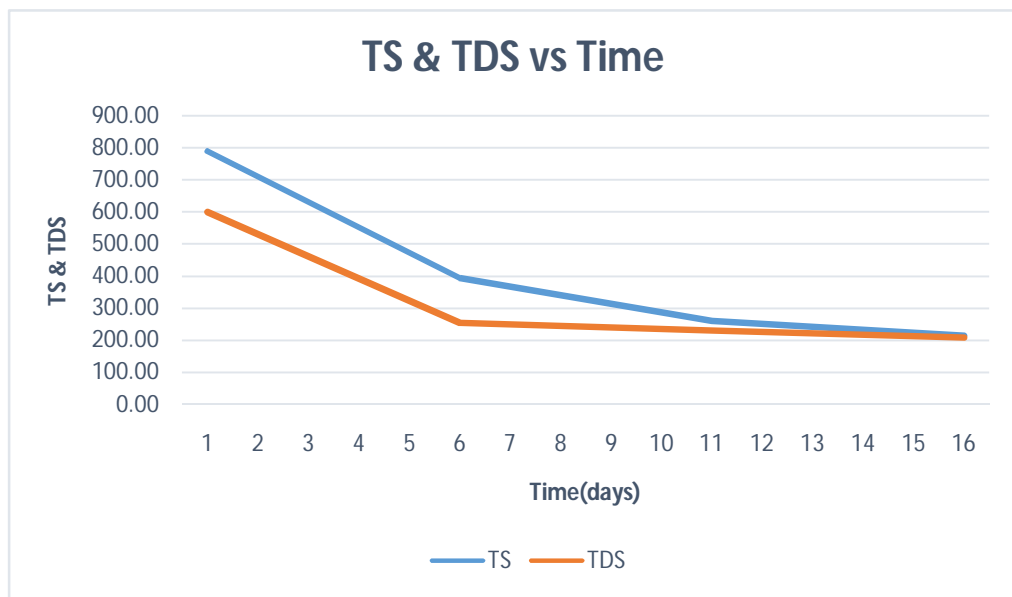


Fig no 6.3 Variation of TDS and TS in batch for treated wastewater with an interval of 3,6,9 days

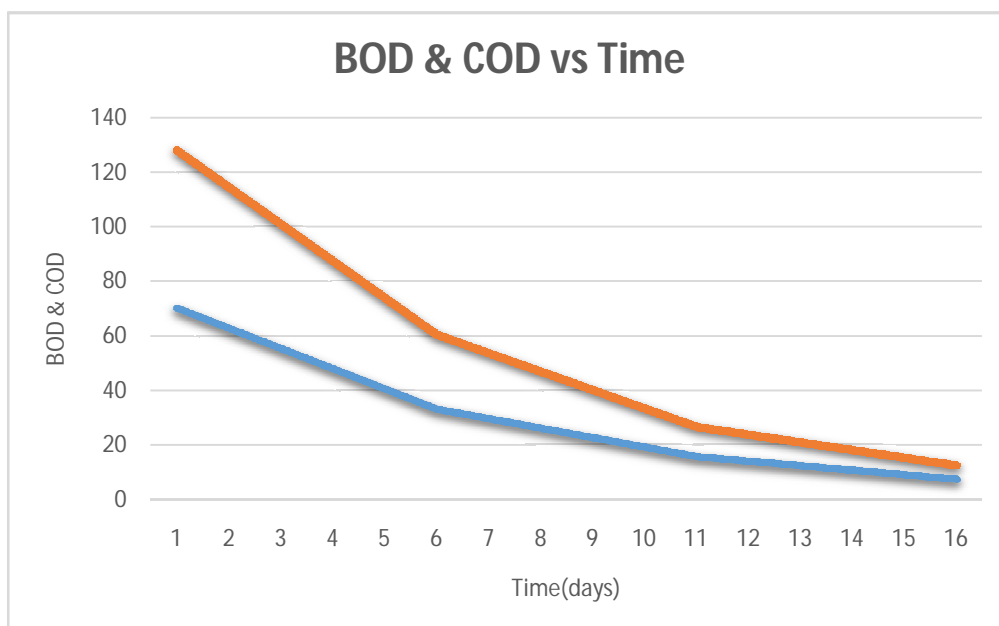


Fig no 6.4 Variation of BOD and COD in batch for treated wastewater with an interval of 3,6,9 days

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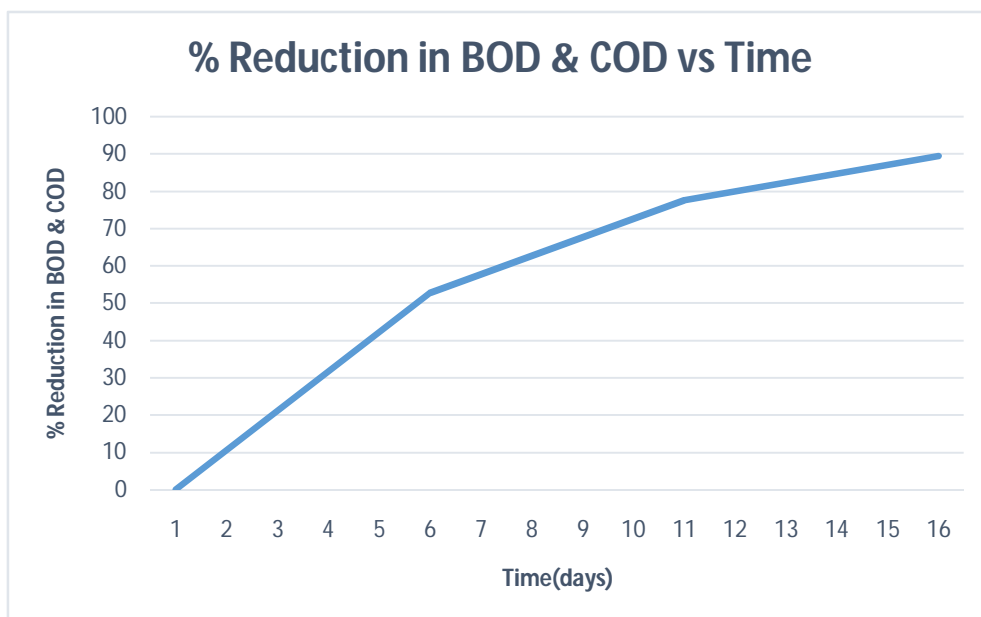


Fig no 6.5 Variation of % BOD and % COD removed in batch for treated wastewater with an interval of 3,6,9 days

VII. CONCLUSION

From this project work we can come to the following conclusions. It is observed that water hyacinth plant is very effective aquatic plant for the purification of wastewater because it has ability to absorb nutrients from wastewater and reduce the pollutants from waste and also reduce the amount of TS, TSS, TDS, BOD, COD etc. and also reduce harm to ecosystem. In this project, mainly we use porous concrete as a filter media which is different and artificial material than soil, gravel, sand etc. Then also it acts as an effective filter media because it allows the wastewater to flow through it freely and collects various pollutants, therefore the overall efficiency of wastewater system is also increased and water is also clean and treated than previous untreated water. The initial results of various parameters of wastewater are higher than permissible values but after use of water hyacinth plant and again passing through porous concrete, the final results of wastewater system are reduced and it can be freely disposed off to the river or pond. And the above table of final results shows that overall efficiency of wastewater treatment also increased which is in the range of 60%-90%. Many researches have been done and in literature survey, we come to know that porous concrete is used for various purposes like for construction of road pavement, parking blocks, storm water management etc, but for wastewater system also it acts as an effective filter material. Therefore it is concluded that use of water hyacinth plant and porous concrete as a filter material is highly effective methodology for wastewater systems.

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