Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 06, June - 2024

Treatment of Domestic Waste Water Using Natural Material in Multi Soil Layering System

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***Abstract* - Since ancient times, wastewater has been treated using soil. The main issue our nation is facing presently is the treatment and disposal of domestic wastewater. It progressively contaminates the waterways if left untreated. A decentralized treatment unit must be erected in villages or rural regions where dispersed housing makes centralized wastewater treatment impractical. One such decentralized method for treating home wastewater is the multi-soil layering system. The primary goal of the study is to check the Multi Soil Layering System experimental setup for treating household wastewater. For the experimental investigation, a prefabricated iron steel material model with dimensions of 25 cm (L), 25 cm (W), and 90 cm (H) was utilized. The potential of the system is checked by changing the hydraulic loading rate (HLR) 0.1 m^3 /m^2 /hour,0.25 m^3 /m^2 /hour,0.5 m^3 /m^2 /hour, and 1 m3 /m2 /hour. It was found that that no clogging effect due to high HLR. The pH of the studied HLR is nearly neutral. BOD_5 removal efficiency is very high 86.13% at a flow rate of 0.5 m^3/m^2/hr. COD removal efficiency is nearly equal to 82.18% and 82.36% respectively flow rate 0.25 m^3/m^2/hr and 0.5 m^3/m^2/hr.TSS removal efficiency is 82.17% and 84.23% respectively flow rates of 0.1 m^3/m^2/hr and 0.25 m^3/m^2/hr. After the overall study, 0.5 m^3/m^2/hr is the effective flow rate for the MSL study by observing a 1-month study.**

***KeyWords*: Multi Soil Layering (MSL), Soil Mixture Tray(SMT), Reduced Level(R.L.), Total Suspended Solids(TSS), Permeable Layer(P.L.), Chemical Oxygen Demand(COD), Biochemical Oxygen Demand in 5 days at 20^{0}C(BOD_5), Hydraulic Loading Rate (HLR), Hydraulic Retention Time(HRT), Hour(hr)**

1. INTRODUCTION

Nowadays, centralized wastewater is not feasible everywhere. Some residential communities and rural regions do not treat wastewater and discharge it into lower-lying regions. The effluent contained biological pollutants, which contaminated the water body and soil. The installation, operation, and maintenance of a wastewater treatment facility in a small area is costly. People utilize low-cost treatments for small entities like natural wetlands, constructed wetlands, and soil filtration systems. The multi-soil layering system is an adaptation of the soil filtration system that prevents clogging because of greater HLR.

The main components of the MSL system soil mixture layer in fibre bag and permeable layer. The soil mixture layer includes soil, powdered activated carbon, iron scrap, and organic matter (sawdust, rice straw, kenaf, and corncob). Permeable layers include expanded clay aggregate, zeolite, oyster shell, and Granular activated carbon. The Soil Mixture Layer was made by combining sandy clay, powdered activated carbon, rice straws, and iron scraps in a dry-weight ratio of 75%, 10%, 5%, and 10%, respectively [2]. The PL consists of gravel, pumice, or zeolite aggregates with a diameter of 3-5 mm. Pollutant removal from wastewater by MSL is a complex process that includes chemical, physical, and biological processes. MSL systems are a promising and cost-effective treatment technology for sustainable water management. However additional study is needed to understand their effectiveness [10].

MSL system arranged soil mixture block and permeable layer in an alternating pattern. The cost of construction and installation is very less due use of locally available materials. Sludge is decomposed into the system which is beneficial to the economy [1].

2. STUDY AREA AND EXPERIMENTAL MODEL:

Madilge Budruk is a village in Bhudargad Taluka in Kolhapur District, Maharashtra, India. It belongs to the Pune Division. It is 45 km south of the district headquarters in Kolhapur. Madilge Budruk is situated near Ajara Taluka to the south, Radhanagari Taluka to the north, Kagal Taluka to the north, and Gadhinglaj Taluka to the east. It is located between 16^0 36'30" N and 16^0 37'30" N latitudes, 74° 15' 30" E and 74° 16 30" E. The village has a total population of 6,200. According to the local survey, the water supply per capita is 55 LPCD (Liters per capita per day). The total water supply per day is 341000 Liters. Each day, around 238700 Liters of sewage is generated.

The model was set up at a study location to pass 25 liters of wastewater through an equal intake distribution each day. An adjustable valve with a 2 cm diameter was used to control the flow of entering wastewater, ensuring even distribution throughout the model. The treated MSL water was released from the system through a 3 cm outflow attached to the valve. Throughout the experiment, pH, BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), and TSS (Total Suspended Solids) parameters were analyzed on a daily and weekly basis for approximately a month.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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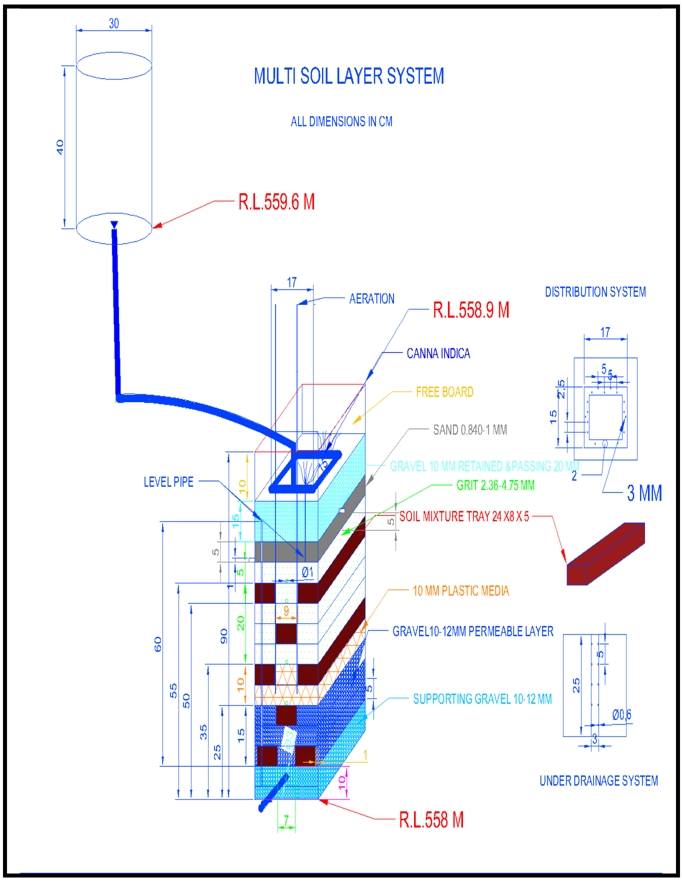

Fig.1: AutoCAD Drawing of Model

Fig.2: Model Setup

3. MATERIAL AND METHODOLOGY:

The lab scale model is made of steel 18-gauge material with dimensions of 25 (L) x 25 (B) x 90 (H) cm sheets with a 1% bottom slope. So, the model is 0.25 cm bigger on one side. A total of six backwashing ports are provided, four in the front of the model and two on the side. The diameter of the port is 1 cm. Two level tubes are used: one for the MSL system, which includes the soil mixture tray, and another to monitor the level of water over the MSL. The overall volume of the system is 56.25 Liters. The system consists of mainly two parts Soil Mixture Tray (SMT) and Permeable Layer(PL).

3.1 Soil Mixture Tray (SMT):

Soil ,powdered activated carbon, sawdust, and iron scrap are all included in the soil mixture tray. Materials are sourced locally. The soil employed in this study is made up of 50% Red soil and 50% Laterite soil.

Some Properties of materials used in this study:

i. Soil:

Soil is a complex combination of organic components, minerals, gases, liquids, and organisms that support life. Soil is used to manage microbial activity throughout the wastewater treatment process. The research used equal amounts of laterite and red soil. The soil combination tray was prepared with soil that had been passed through a 4.75 mm sieve. The soil utilized in this study is red soil taken from Madilage bk and laterite soil collected from laterite stone transportation waste.

ii. Powdered Activated Carbon:

Activated carbon, also known as activated charcoal, is commonly used to filter pollutants from wastewater, among other purposes. It is treated (activated) to create small, low-volume pores that greatly expand the surface area available for adsorption or chemical reactions, resulting in a microscopic "sponge" structure. Adsorption, not to be confused with absorption, is the process by which atoms or molecules stick to a surface. Coconut shell-activated carbon in powder form, smaller than 75 microns in size, was the material used in our investigation.

iii. Sawdust:

Sawdust is organic matter. Organic matter provides a carbon source for microorganisms. The sawdust passing through an 840-micron sieve and retaining on a 75-micron sieve was used in the experimental setup.

iv. Iron scrap:

Adding iron scraps into the SMTs facilitates phosphorus adsorption considerably.

3.2 Soil Mixture Tray Details (SMT):

Dimension of SMT	: 24 cm x 8 cm x 5 cm
Volume of SMT	: 960 cm^3
Number of SMT	: 8 No.
Density of material	: 0.7513 gm/cm^3
Size of tray hole	: 3 mm
Size of sieve	: 1 mm

Table -1: Soil Mixture Tray Details.

Material	**Percentage (%)**	**Volume per SMT cm^3**	**Weight per SMT (gm)**	**Total Weight (gm)**	**Density (gm/cm^3)**
Soil	(60+10)	672	637.297	5098.376	0.9483586
Activated Charcoal	20	192	36.399	291.192	0.1895781
Sawdust	10	96	43.3112	346.4896	0.4511583
Iron Scrap	10	96	4.31	34.48	0.0448958
Total	**(100+10)**	**1056**	**721.3172**	**5770.538**	

International Journal of Engineering Research & Technology (IJERT)
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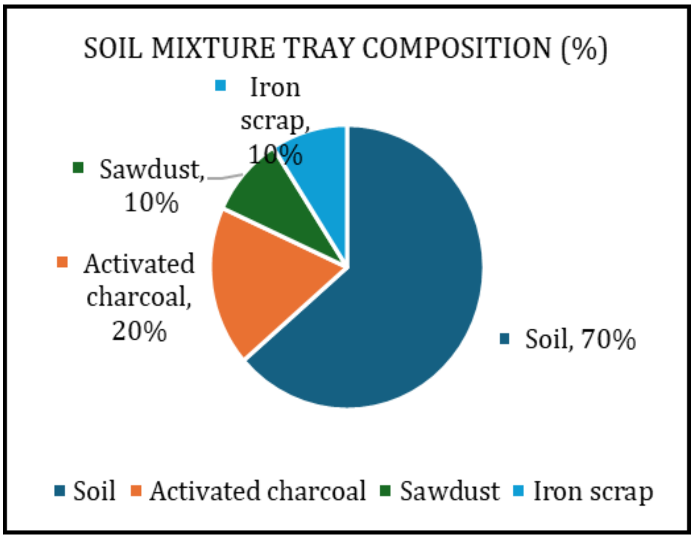
For the experimental setup choose soil (60+10) %, activated carbon 20%, iron scrap 10%, and sawdust 10%. Soil is chosen 10% extra because the soil mixture checks to pass through water it it observed that 5 cm height soil settles nearly 4 mm.

So, overall, 8% is a reduction in height.

For calculating extra soil = 4 mm + $(\frac{4}{100}x8)$ + $((\frac{4}{100}x8))\frac{8}{100}$ +....

= 4.45 mm≅ 5 mm

So, the requirement of extra soil is 5 mm hence it is 10%.



Pie chart 1: Soil Mixture Tray

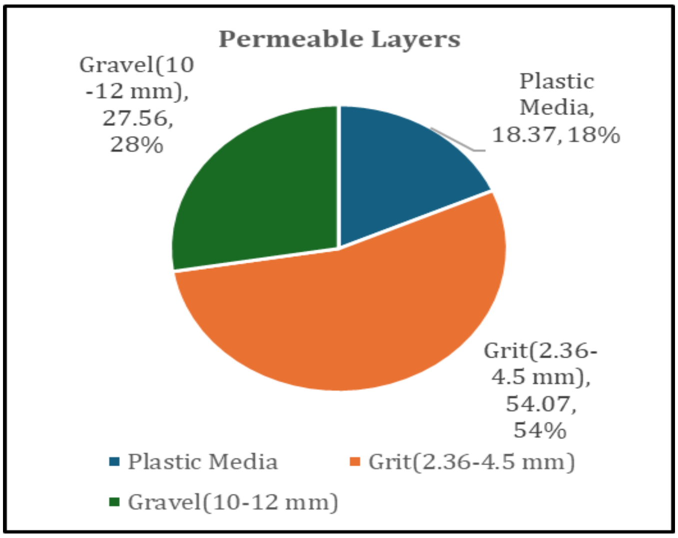
3.2Permeable Layers:

This consists of the material that will act as a permeable medium for wastewater to pass through. The substance should be utilized based on local availability. It should consist of gravel (10-12 mm), grit (2.36-4.5 mm), and a plastic ball (10 mm). This is used as a less costly substance for the permeable layer than other substances like zeolite, activated carbon, and charcoal, which are replaced with natural and synthetic components respectively.

In addition, for synthetic materials, compare Moving Bed Biofilm Reactor Media and Trickling Filter Bio balls, although their much higher costs than currently used materials. Furthermore, their permeability is very high. So, the material used for Permeable layers consists of three parts: grit (25 cm), plastic medium (10 cm), and gravel (15 cm). Which contain highly natural materials.

Table -2: Permeable Layer Details.

Permeable Layer	Volume(cm^3)	weight (gm)	Percentage %
Plastic Media	4330.00	721.66	18.37
Grit (2.36-4.5 mm)	12745.00	18301.82	54.07
Gravel (10-12 mm)	6495.00	12431.43	27.56
Total	**23570.00**	**31454.91**	100.00



Pie chart 2: Permeable Layers

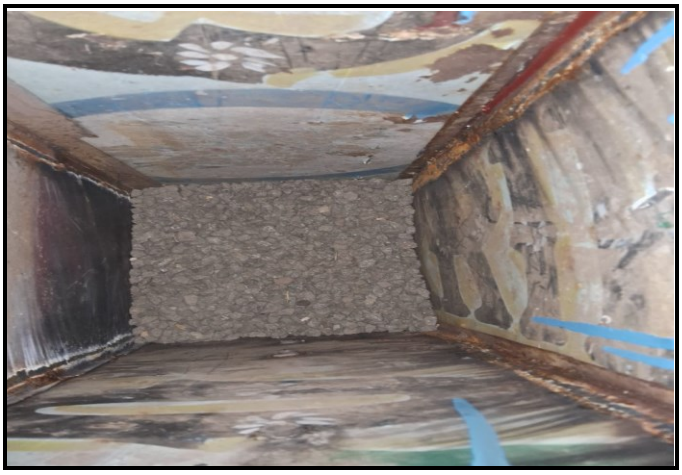


Fig.3: Permeable Layer During Preparation

3.3Supporting Gravel:

For supporting the system 10-12 mm gravel with a 10cm thick layer is provided. It is an extra layer provided to the system at the bottom of 10-12 mm gravel to get maximum efficiency.

3.4 Canna Indica:

In our investigation, two Canna Indica plants were used. They grow in 10-20 mm gravel. Below that, river sand ranging from 0.840 mm to 1mm is utilized. River sand aims to hold suspended particles with greater particle sizes. Canna Indica enhances dissolved oxygen levels and treats suspended solids by absorbing nutrients through the root zone. They prevent bacterial growth, odor, and eutrophication.

3.5 Electric Components:

In this system, two electric components are used: the aerator and the recirculation pump. The aerator provides air to enter the second permeable layer from the bottom, distributing air to bacteria. The recirculation pump mixes and stirs the sewage continuously in the storage tank.

The aerator air supply rate was about 3 Litre /minute and the Recirculation pump flow was 1000 Litre/hour.

International Journal of Engineering Research & Technology (IJERT)
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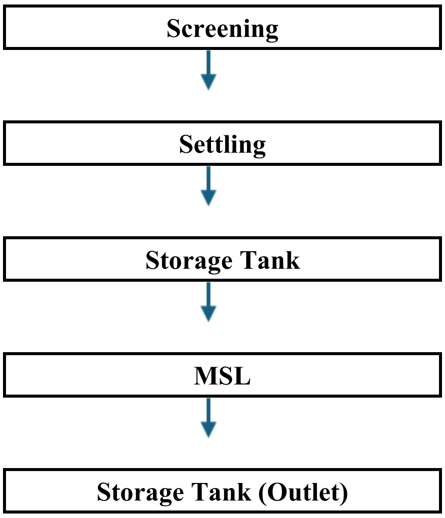
Fig.4: Recirculation Pump and Aerator

3.6 Process:



Initially, 25 liters of wastewater samples were collected from the study area site gutter. Manual screening is carried out to remove big plastics and floating debris.

The water is then settled for 30 minutes to settle out the primary sludge before being transferred to the storage tank. Storage tank with a recirculation pump. A recirculation pump is added to ensure continual mixing of effluent. A recirculation pump is essential because it prevents effluent from settling again. For MSL operation, the Hydraulic Loading Rate (HLR) varies from 0.1,0.25,0.5 and $1 m^3/m^2/hr$.

Hydraulic Loading Rate(HRT) also vary with HLR.

Table -3: HRT.

Flow($m^3/m^2/hr.$)	**HRT (hr.)**
0.1	5.6
0.25	2.24
0.5	1.12
1	0.56

MSL treats wastewater biologically through the attach growth mechanism. The permeable layer facilitates the aerobic attachment of the growing process to SMT-treated wastewater. Activated carbon in SMT enhances adsorption. Sawdust supplies carbon to microorganisms. Iron scrap eliminates phosphorus effectively. Through an aerator, air is supplied to the bacteria. It maintains the bacteria for wastewater treatment. After the final effluent is collected the sample is tested in the laboratory analysis of pH, BOD_5, COD, and TSS.

4. RESULTS AND DISCUSSION:

4.1) Soil Testing and SMT:

In this study soil used red soil and laterite soil. Their property check in the laboratory is the following:

a) Grain Size analysis: Grain size analysis is done for particles with different size diameters in soil.

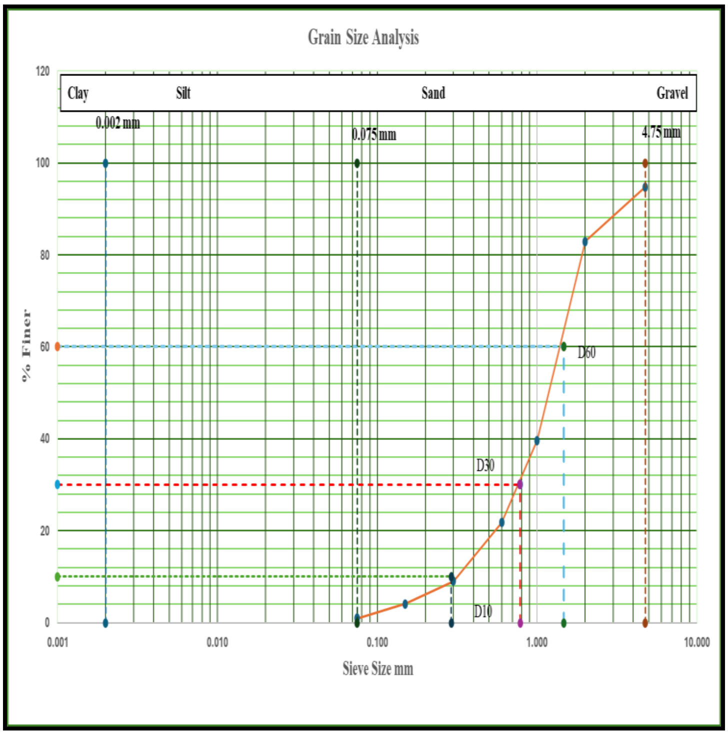


Chart 1: Grain Size Analysis

4.2) Properties of Material:

Table-4: Properties of Material

Property	**Value**
Specific Gravity	2.61
Moisture Content	13%
Void Ratio	0.36
Porosity	0.27
Permeability of soil	18.33×10^{-3} cm/second
Permeability of SMT	8.75x10-3 cm/second
Permeability of Gravel (2.36-4.75 mm)	0.043 cm/sec
Permeability of Gravel (10-12 mm)	0.19 cm/sec
Permeability of Plastic media	0.071 cm/sec

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International Journal of Engineering Research & Technology (IJERT)
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4.3) Initial weekly Domestic wastewater analysis of the study area:

Table-5 Initial Weekly analysis of domestic wastewater of study area

Days	pH	BOD_5(mg/L)	COD (mg/L)	TSS (mg/L)
Day1	7.56	165.00	400.00	240.00
Day2	8.05	160.00	380.00	235.00
Day3	7.95	195.00	460.00	216.00
Day4	7.40	155.00	360.00	192.00
Day5	6.80	190.00	368.00	209.00
Day6	7.35	210.00	468.00	257.00
Day7	7.80	170.00	360.00	219.00
Average	**7.56**	**177.86**	**399.43**	**224.00**

4.4 pH Analysis:
i) pH analysis of 0.1 $m^3/m^2/hr$ HLR:

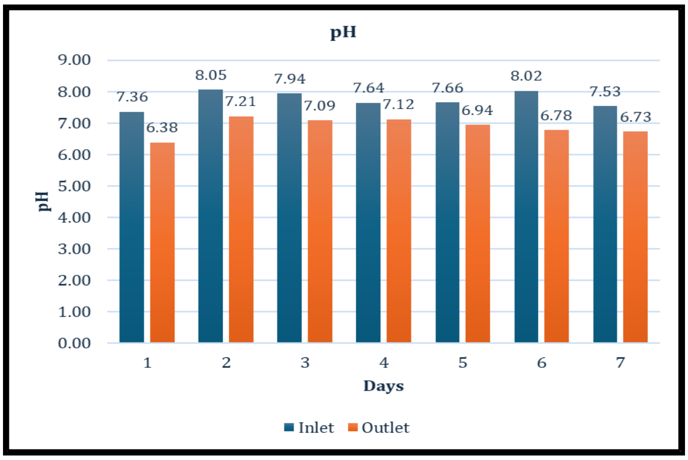

Chart-2: Inlet and outlet pH analysis of 0.1 $m^3/m^2/hr$.
The average inlet and outlet values for pH 7.62 and 6.82

ii) pH analysis of 0.25 $m^3/m^2/hr$ HLR:

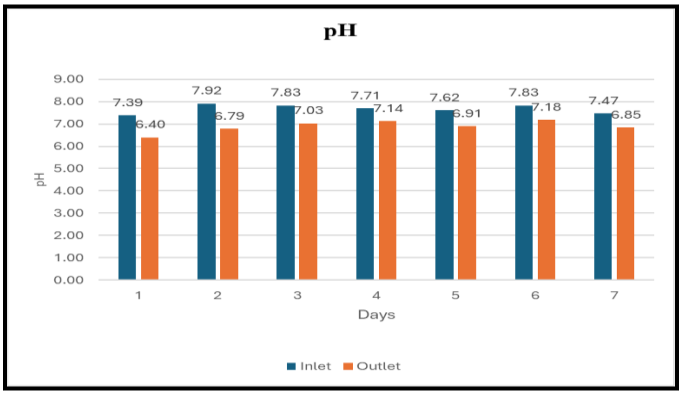

Chart-3: Inlet and outlet pH analysis of 0.25 $m^3/m^2/hr$.
The average inlet and outlet values for pH 7.74 and 6.89

iii) pH analysis of 0.5 $m^3/m^2/hr$ HLR:

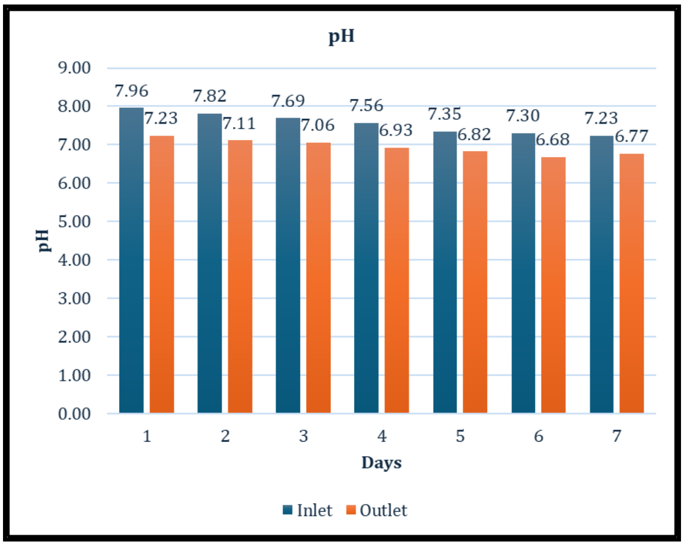

Chart-4: Inlet and outlet pH analysis of 0.5 $m^3/m^2/hr$.
The average inlet and outlet values for pH 7.56 and 6.94

iv) pH analysis of 1 $m^3/m^2/hr$ HLR:

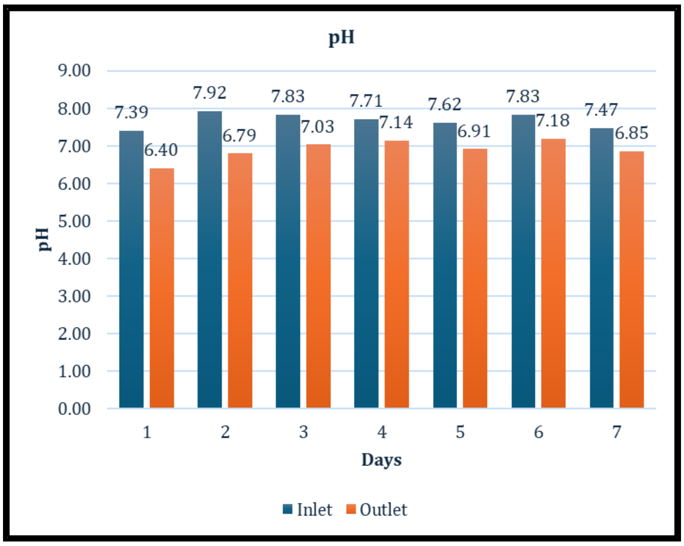

Chart-5: Inlet and outlet pH analysis of 0.5 $m^3/m^2/hr$.
The average inlet and outlet values for pH 7.68 and 6.90

4.5 BOD_5 analysis:
i) BOD_5 analysis of 0.1 $m^3/m^2/hr$ HLR:

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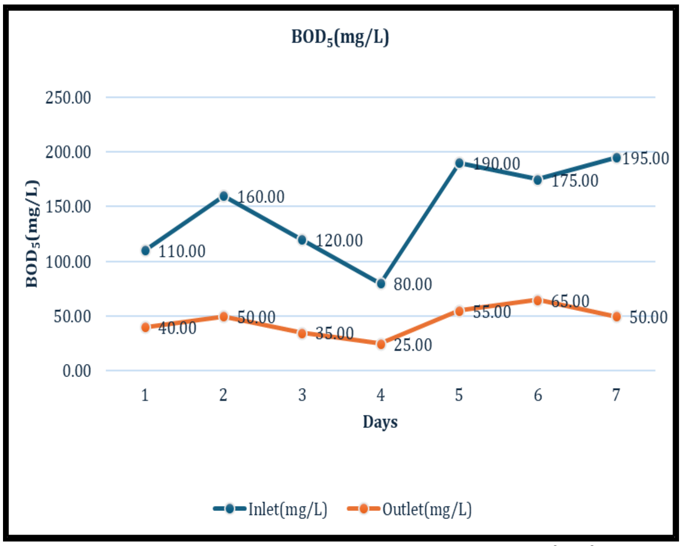

Chart-6: Inlet, Outlet BOD_5 of Flow rate-0.1 $m^3/m^2/hr$

The average inlet and outlet values of BOD_5 are 147.14 mg/L and 45.71 mg/L during a flow rate of 0.1 $m^3/m^2/hr$.
The percentage of removal observed was 68.93%

ii) BOD_5 analysis of 0.25 $m^3/m^2/hr$ HLR:

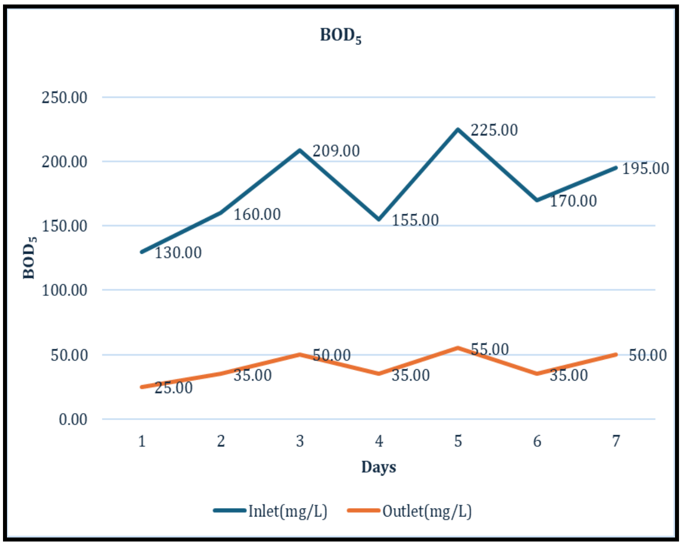

Chart-7: Inlet, Outlet BOD_5 of Flow rate-0.25 $m^3/m^2/hr$

The average inlet and outlet values of BOD_5 are 177.71 mg/L and 40.71 mg/L during a flow rate of 0.25 $m^3/m^2/hr$.
The percentage of removal observed was 77.39%

iii) BOD_5 analysis of 0.5 $m^3/m^2/hr$ HLR:

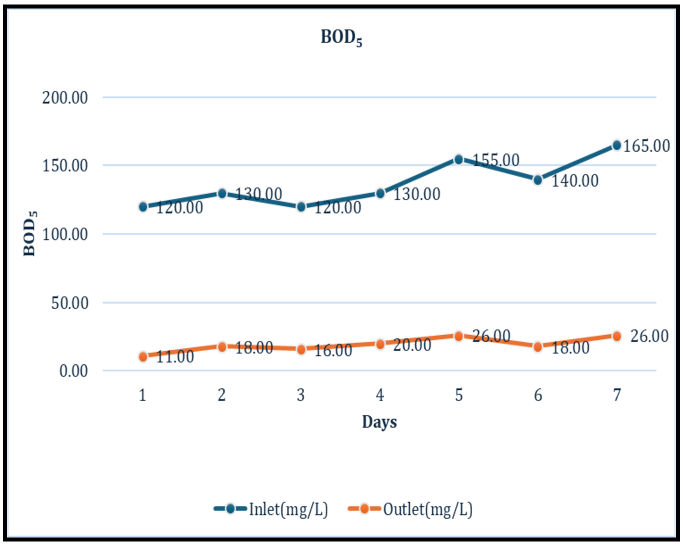

Chart-8: Inlet, Outlet BOD_5 of Flow rate-0.5 $m^3/m^2/hr$

The average inlet and outlet values of BOD_5 are 137.14 mg/L and 19.29 mg/L during a flow rate of 0.5 $m^3/m^2/hr$.
The percentage of removal observed was 86.13%

iv) BOD_5 analysis of 1 $m^3/m^2/hr$ HLR:

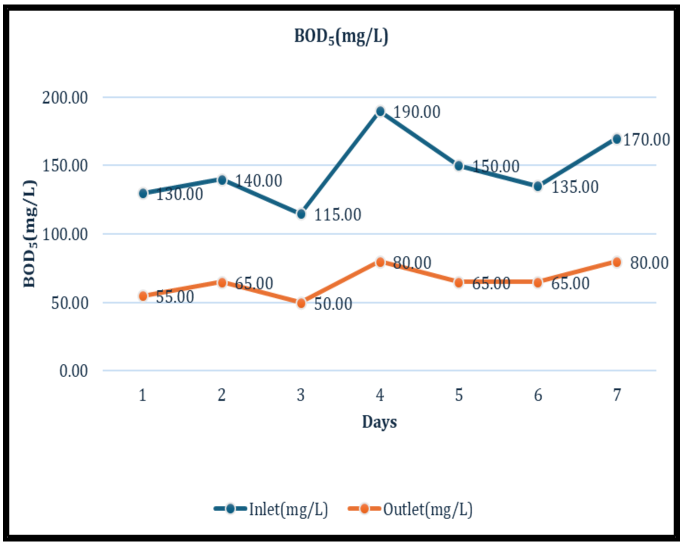

Chart-8: Inlet, Outlet BOD_5 of Flow rate-1$m^3/m^2/hr$

The average inlet and outlet values of BOD_5 are 148.16 mg/L and 65.71 mg/L during a flow rate of 1 $m^3/m^2/hr$.

The percentage of removal observed was 55.31%

4.6 COD analysis:
i) COD analysis of 0.1 $m^3/m^2/hr$ HLR:

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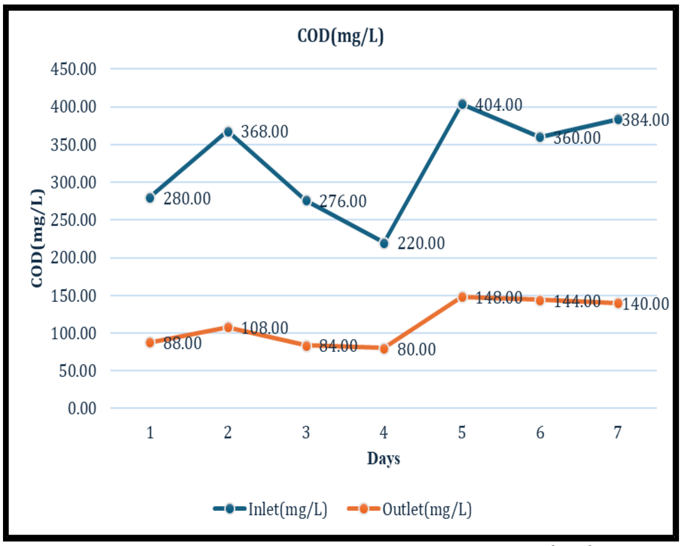

Chart-9: Inlet, Outlet COD of Flow rate-0.1m^3/m^2/hr

The average inlet and outlet values COD are 327.43 mg/L and 113.14 mg/L during a flow rate of 0.1 m^3/m^2/hr.
The percentage of removal observed was 65.45%

ii) COD analysis of 0.25 m^3/m^2/hr HLR:

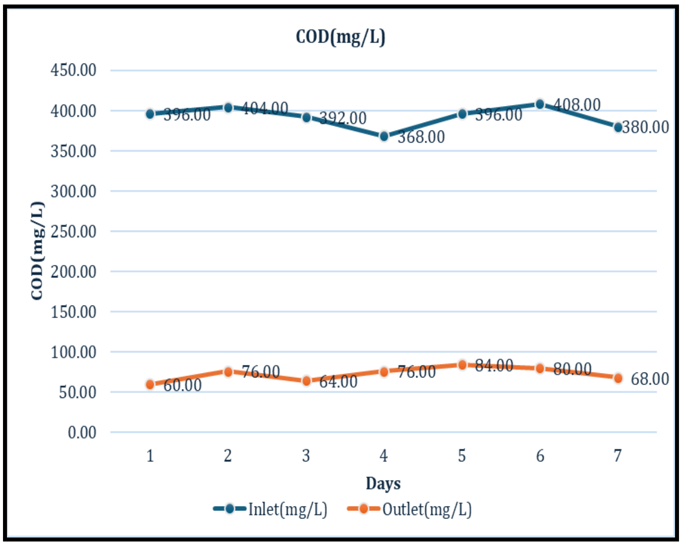

Chart-10: Inlet, Outlet COD of Flow rate-0.25m^3/m^2/hr

The average inlet and outlet values COD are 398 mg/L and 70.91 mg/L during a flow rate of 0.25 m^{3S}/m^2/hr.
The percentage of removal observed was 82.18 %

iii) COD analysis of 0.5 m^3/m^2/hr HLR:

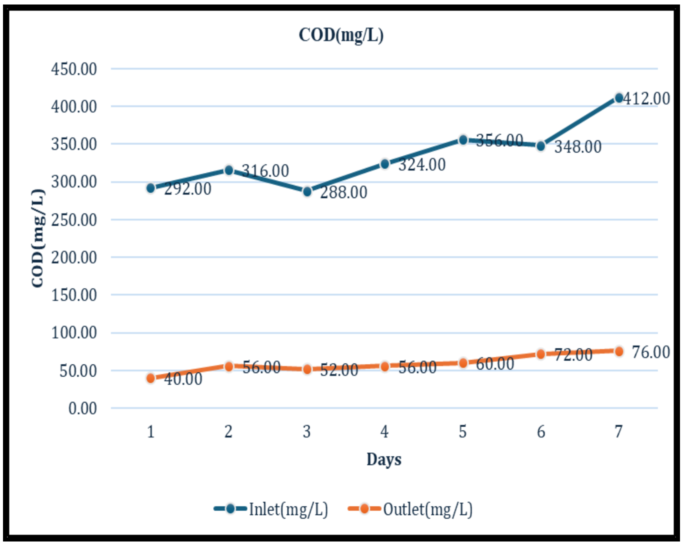

Chart-11: Inlet, Outlet COD of Flow rate-0.5m^3/m^2/hr

The average inlet and outlet values COD are 333.71 mg/L and 58.66 mg/L during a flow rate of 0.5 m^3/m^2/hr.
The percentage of removal observed was 82.36%

iv) COD analysis of 1 m^3/m^2/hr HLR:

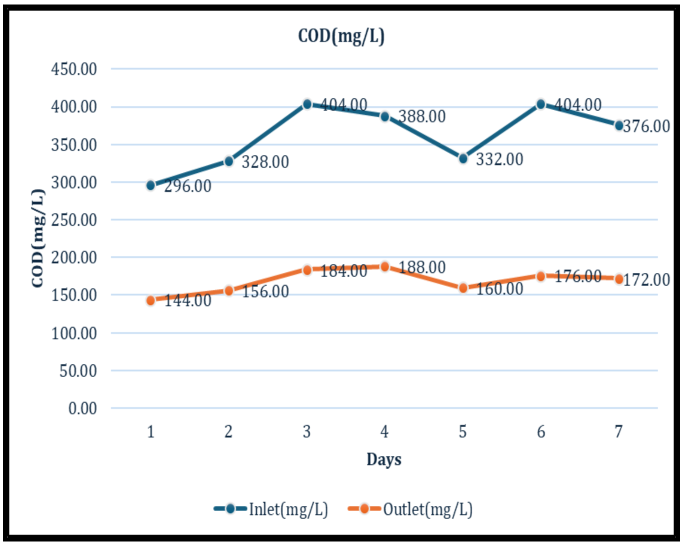

Chart-12: Inlet, Outlet COD of Flow rate-1 m^3/m^2/hr

The average inlet and outlet values COD are 361.14 mg/L and 168.57 mg/L during a flow rate of 1 m^3/m^2/hr.
The percentage of removal observed was 53.32%

4.7 TSS analysis:
i) TSS analysis of 0.1 m^3/m^2/hr HLR :

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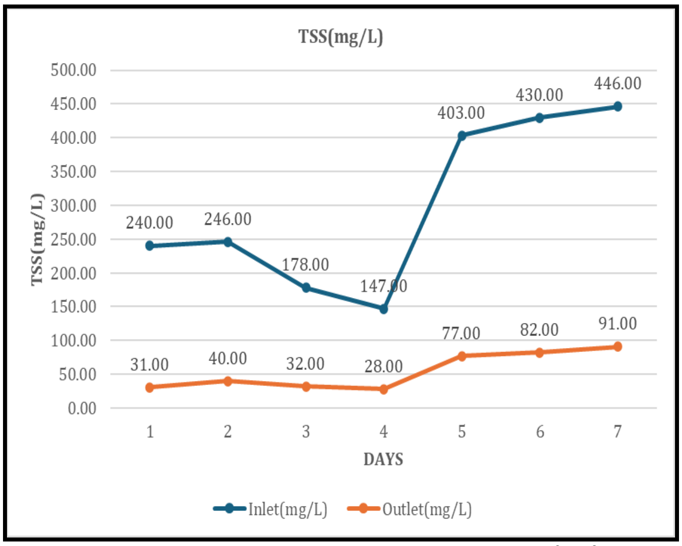

Chart-13: Inlet, Outlet TSS of Flow rate-0.1 $m^3/m^2/hr$

The average inlet and outlet values are 298.57 mg/L and 54.43 mg/L during a flow rate of 0.1 $m^3/m^2/hr$.
The percentage of removal observed was 82.17% for TSS

ii) TSS analysis of 0.25 $m^3/m^2/hr$ HLR:

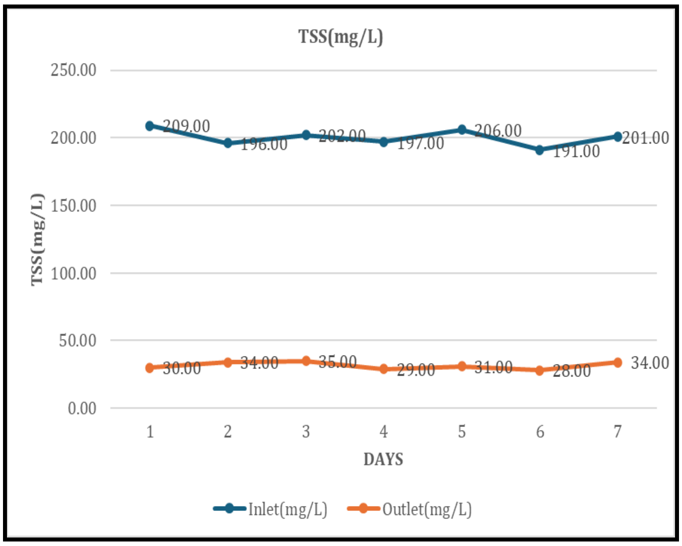

Chart-14: Inlet, Outlet TSS of Flow rate-0.25 $m^3/m^2/hr$

The average inlet and outlet values are 200.29 mg/L and 31.57 mg/L during a flow rate of 0.25 $m^3/m^2/hr$.
The percentage of removal observed was 84.23% for TSS

iii) TSS analysis of 0.5 $m^3/m^2/hr$ HLR :

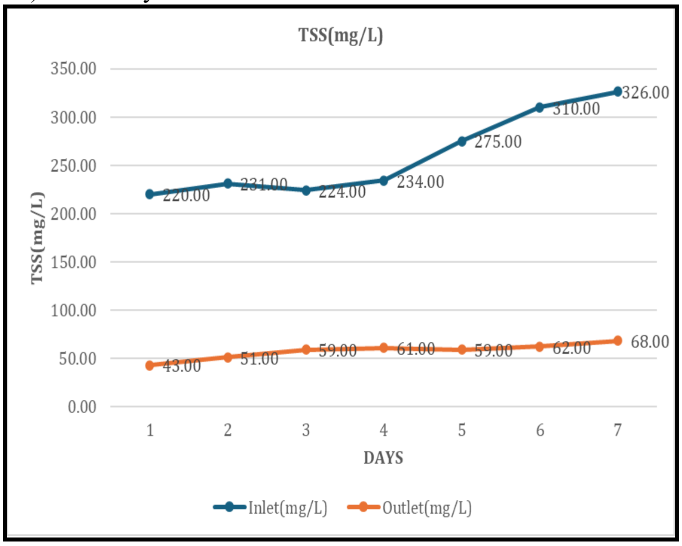

Chart-15: Inlet, Outlet TSS of Flow rate-0.5 $m^3/m^2/hr$

The average inlet and outlet values are 260 mg/L and 57.57 mg/L during a flow rate of 0.5 $m^3/m^2/hr$.
The percentage of removal observed was 77.67% for TSS

iv) TSS analysis of 1 $m^3/m^2/hr$ HLR:

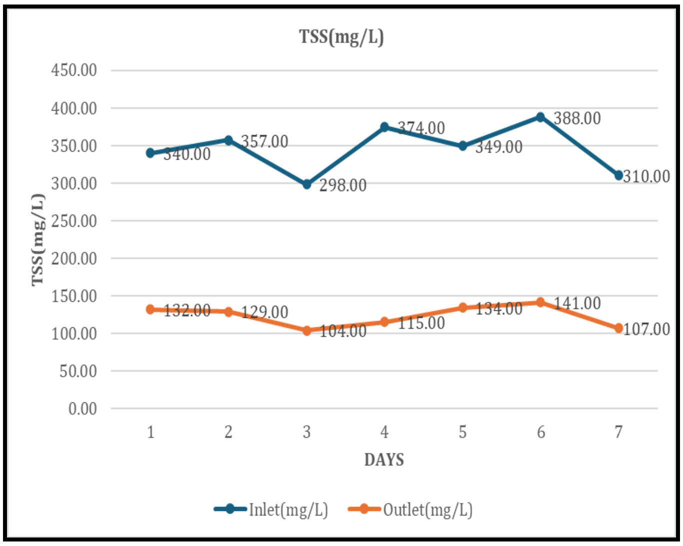

Chart-16: Inlet, Outlet TSS of Flow rate-1 $m^3/m^2/hr$

The average inlet and outlet values are 345.14 mg/L and 123.14 mg/L during a flow rate of 1 $m^3/m^2/hr$.
The percentage of removal observed was 64.31% for TSS

5. CONCLUSIONS

In the present study, it is observed that no clogging effect is due to high HLR. The pH of the studied HLR is nearly neutral. BOD_5 removal efficiency is very high 86.13% at a flow rate of 0.5 m^3/m^2/hr. COD removal efficiency is nearly equal to 82.18% and 82.36% respectively flow rate 0.25 m^3/m^2/hr and 0.5 m^3/m^2/hr.TSS removal efficiency is 82.17% and 84.23% respectively flow rates of 0.1 m^3/m^2/hr and 0.25 m^3/m^2/hr. After the overall study, 0.5 m^3/m^2/hr is the effective flow rate for the MSL study by observing a 1- a month study.

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