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Upshots of Bioswales in Stormwater Management: A Pilot-scale Study

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ABSTRACT: Low Impact Development (LID) is a different approach that retains and infiltrates rainfall on-site. The LID approach emphasizes site design and planning techniques that mimic the natural infiltration-based, groundwaterdriven hydrology of our historic landscape. Bioswales are one component of LID. Bioswales are shallow ditches filled with vegetation that collect and purify surface water. Bioswale can help reduce heat stress in a locality. The vegetation and water together improve the air quality in an area. This method of purification can be very beneficial to urban areas, as bioswales combat flooding. Overall, bioswales are excellent tools to remove water pollutants in urban areas. Bioswales are very sustainable implementations, as they are cost effective, environmentally friendly, and easy to construct. Our paper will discuss the pilot study on experimental investigation of Bioswales and analyze the process of water purification through a bioswale by testing Soil, Plant and Water.

KEYWORDS: Bioswales, trapezoidal channel, Stormwater Runoff, Low Impact Development, Vegetation.

I. INTRODUCTION

Water is vital to the economic and social development of any country. Water scarcity and groundwater pollution are issues being faced by every city in India. Ironically, according to global standards, India receives abundant rainfall. The problem lies in rainwater getting polluted and hence, causing groundwater pollution. Urbanization has led to the creation of impermeable surfaces like building rooftops, pavements and roads. Such surfaces do not allow rainwater to percolate into the ground. During rainfall, water flows from the rooftops of buildings and paved areas, washing away dirt, dust and pollutants, thus getting contaminated. This runoff enters stormwater drains. These storm-water drains often lack maintenance and get choked during the monsoons because of accumulation of garbage. Rainwater that could have gone through these drains accumulates on roads, causing water-logging. The runoff pollutes natural bodies too, as seen in the river like Vaigai. The pollutants also enter the ground, thereby contaminating our groundwater

[1]. Bioswales (how it works)

Biofiltration Swales are one of several Best Management Practices for treatment of stormwater runoff from project areas that are anticipated to produce pollutants of concern (e.g., roadways, parking lots, maintenance facilities, etc.). Bioswales are vegetated, typically trapezoidal channels, which receive and convey storm water flows while meeting water quality criteria and other flow criteria. Pollutants are removed by filtration through the vegetation, uptake by plant biomass, sedimentation, adsorption to soil particles, and infiltration through the soil. Pollutant removal capability is related to channeldimensions, longitudinal slope, and type of vegetation. Bioswales are effective at trapping litter, Total Suspended Solids (soil particles), and particulate metals.

[2]. Design of Bioswales

Bioswale systems are generally preferred for areas with permeable grounds and relatively low groundwater levels. The only construction activity it requires is the digging of a linear depression with slanted walls (Parabolic or trapezoidal shapes are recommended with side slopes no steeper than 3:1). A simple bioswale is divided into 4 different layersThe top layer of a bioswale is all about the closely-packed vegetation that provides a high amount of surface area for contact with stormwater. The thicker and heavier the grasses, the better the swale can filter out the pollutants. Specially chosen plants (native plants preferably) are planted that have high nutrient uptake ability.A layer of sand is laid beneath the vegetation that serves as an absorbent. It causes colloids in murky water to gather into larger masses and ease removal from the water. These materials have large empty voids, allowing the rainwater to drain off. The layer is packed in geotextile to prevent the layer from becoming clogged by sludge or roots. An infiltration pipe/drain tube is situated below the second layer. In order to prevent a bioswale from overflowing its banks during heavy rainfall, overflows are added that are connected directly to the drain tube. Once prepared, bioswales require very little maintenance as they need less water and no fertilizer.

[3]. Geometric Design Principles

The basic components of bioswale design include: longitudinal slope, cross section (shape), length, and roughness. Roughness is a function of the 3 vegetation coverage and type.

Longitudinal Slope: The longitudinal slope of a bioswale is a critical design element that affects the design of the bioswale and its performance. Appropriate slopes typically range from one percent to six percent. The optimal longitudinal slope of a bioswale is between one and two percent. Low slopes limit erosion by reducing water velocities and increase pollutant removal by increasing residence (contact) time of water in the swale. As longitudinal slope and velocity increase, erosion may increase and pollutant removal rates typically decrease. On slopes less than or equal to one percent, drainage is marginal, and standing water may be present if the underlain soil type does not allow much infiltration or the water table remains high.

Swale Cross Section (Shape): There are four basic cross sections for bioswales: rectangular, triangular, trapezoidal, and parabolic. Trapezoidal cross sections are the most common shape for bioswales because they are easy to construct, offer good hydraulic performance, facilitate maintenance, and are aesthetically pleasing. Triangular cross sections can also be appropriate if the side slopes are very gentle (approximately 10:1 or shallower). Rectangular cross sections are generally not used for grassy swales because they are difficult to construct and maintain, difficult to establish with vegetation in the sides, and because the vertical side slopes can present a safety hazard. In general, shallow side slopes are more desirable, although they increase the amount of area required for the bioswale. A 3:1 slope (horizontal: vertical) is considered the steepest to limit erosion and/or slippage of the slopes. A 5:1 slope is considered the steepest slope that allows regular mowing.

Bottom Width: A wide, flat swale bottom maximizes the available treatment area and pollutant removal while also providing ease of maintenance. In order to be able to mow the vegetation in a bioswale, the bottom should be at least two feet wide. The maximum free width of the bioswale bottom should be less than eight feet wide to avoid rilling and gullying and ensure sheet flow. Depth The bioswale should be at least six inches deeper than the maximum design flow depth. This additional depth is known as "freeboard," and provides a safety factor to prevent the bioswale from overflowing onto adjacent areas if the channel becomes obstructed or if runoff volumes exceed the design size.

Length: The time it takes water to flow from its inlet into the bioswale to the bioswale's outlet is the “residence time” or retention. Residence time for bioswales should be at least five minutes. In general, the greater the residence time, the greater a bioswale's ability to remove pollutants from runoff.

Channel Depth: The swale should be designed such that the water quality volume flows at a depth approximately equal to the grass height. For most applications this will be four inches. The overall depth should permit conveyance of the 10- year runoff event while providing a minimum of six inches of freeboard. Additionally, channel depth should be such that the check dam height does not exceed one half of the total channel depth.

Water Velocity: The speed at which water flows in the bioswale is its velocity. Velocity is calculated for two storm sizes: water quality design storm and the peak 5 flow design storm. Velocity should be less than or equal to one-and-a-half feet per second for the water quality design storm, and below five feet per second or the erosive velocity of the channel for the peak flow design storm. This is generally three to six feet per second depending on vegetation type and the use or erosion control fabric or other stabilization method. Erosion may be a problem if average discharge velocities frequently exceed three feet per second. Where velocities make erosion a concern, erosion control fabrics or geotextiles may be used to achieve added erosion resistance while still allowing the growth of a dense stand of vegetation.

[4]. Vegetation

Swale vegetation must meet certain criteria for the vegetation planted along a swale to maintain channel stability and improve the bioswale's ability to filter pollutants from stormwater. The vegetation must:Provide a dense cover and a root or rhizome structure that holds the soil in place in order to resist erosion;During water quality level flows (event design), it must stand upright in order to provide maximum residence time and pollutant removal; Tolerate a

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bioswale's soil conditions (pH, compaction, composition); andTolerate periodic flooding and drought. It must not be dormant during the period of the year that the pollutants are to be treated. In some cases, the bioswale vegetation must also meet aesthetic and functional criteria by selecting the appropriate plant for the use, water cycle, aesthetic goals, and local government codes. Many municipalities require setbacks from intersections; require low height vegetation for visibility at intersections, along parking lots, streets, and pedestrian walkways, or for police surveillance. Bioswales and their plant materials can present unique and different visual characteristics from conventional drainage or landscape design. Turf grass lawns, woody perennials, drought-tolerant, riparian or exotic plants, and cobbles can all be used, depending on the desired aesthetic effect.

[5]. Bioswale Plants

Bioswale beds need to be planted with specialization local plants/reeds/grasses, etc., which help in filtering and treating pollutants before the water enters the sub-soil or is conveyed away. Such plants help cut down costs of localized rainwater harvesting/water treatment and also contribute to reduction of heat island effect and air pollution.Planting more specifically suited vegetation in bioswales can allow bioswales to play a greater part in enhancing the town or city’s biodiversity and affords them a more diverse and pleasing appearance. The process of the working of such plants is illustrated in Fig 1. and Table 1 represtents image and name of bioswale plants.

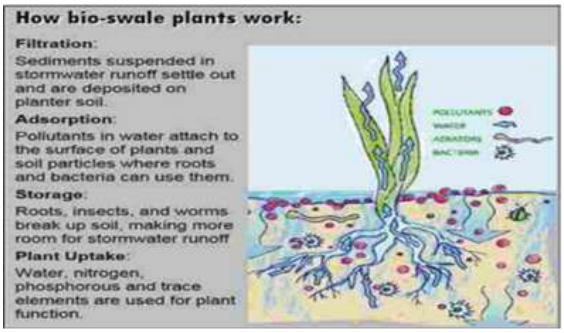

Fig 1. Working of Bioswale Plant

Table 1. Bioswale plants (Names)

	**Yellow Canna**
	**Red Canna**
	**Pampas Grass**
	**CyperusSpp**

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	**Spider Lily**

[6]. Maintenance

Although through proper vegetation selection a bioswale may be relatively low maintenance, some bioswales may require regular plant maintenance for aesthetic reasons. This maintenance includes regular mowing, irrigation, and pruning. Mowing or cutting back the vegetation also reduces evapotranspiration and reduces the amount of pollutant uptake until the vegetation reestablishes full growth. Vegetation in the bioswale should be trimmed every year or two to prevent woody species from taking over. Clippings from plants should be disposed of properly as they may have absorbed hazardous toxins. Removal of vegetation clippings following this practice removes pollutants that have been absorbed by the vegetation. Fertilizers and herbicides are a source of organic compounds which are some of the pollutants that are removed by the vegetation in a bioswale and their use for maintenance of the bioswale should be avoided as much as possible. Regrading may be necessary to reshape the bioswale cross-section as sediments collect and form pools. Inspections and repair to bioswales should be scheduled far enough in advance of the first seasonal rains to allow for any repairs that may be necessary, and during and after each major storm. Trash and debris left to accumulate in either the storm drainage system leading to the bioswale or in the bioswale can restrict the flow of water causing localized flooding and possible erosion, create sediment buildup, and create aesthetic problems that create poor public perception of the site.

II. METHODOLOGY

The methodology adopted for the experimental investigation of pilot scale bioswale is shown in Fig 2.

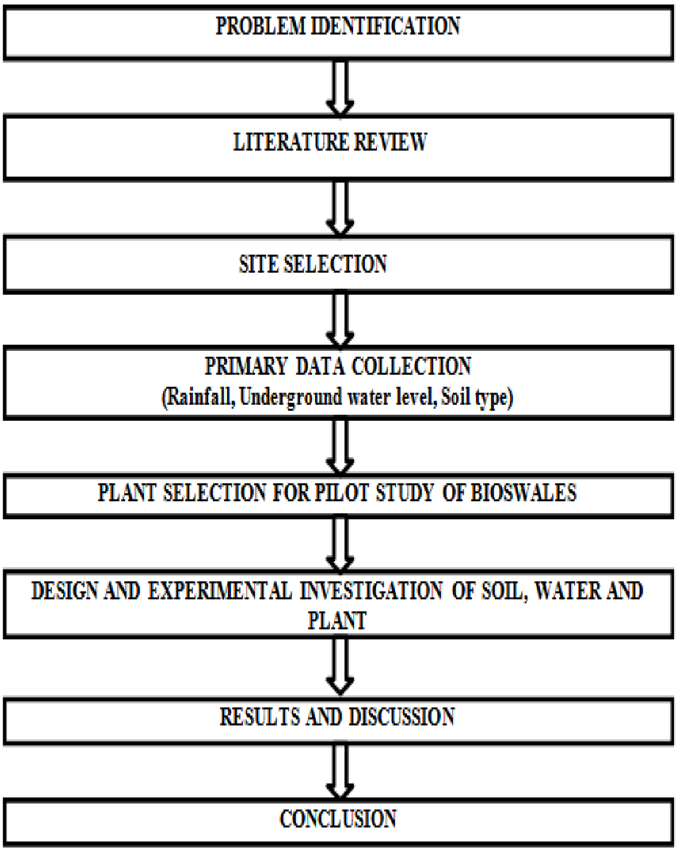

Fig 2. Methodology Flow Chart

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2.1 SITE SELECTION

Madurai, formerly (until 1949) Madura, city, south-central Tamil Nadu state, southern India. It is located on the Vaigai River, about 30 miles (48 km) southeast of Dindigul. Madurai is the third most populous, and probably the oldest, city in the state. Madurai is located at 9.93°N 78.12°E. Mariamman Teppakulam is a beautiful square tank spread over a huge area of almost 16 acres, located about 4 Kms East of Meenakshi Temple in Madurai City. This is the location where the king Thirumalai Naicker excavated the soil to fabricate the bricks required for constructing his palace, Thirumalai Nayakkar Mahal. The pit that was thus formed is seen as tank now. It is approximately 305 m long and 290 m wide, nearly equal area to that of Meenakshi Amman Temple. Fig 3. shows the site selected for study.

Fig 3. Site Selected for Study

2.2 Primary Data Collection

In order to detect the efficiency of the Bioswales, Pilot study is made and various data like Rainfall pattern, Underground water level, Soil type are collected**.**

i. Rainfall Pattern: Rainwater is relatively free from impurities except those picked up by rain from the atmosphere, but the quality of rainwater may deteriorate during harvesting, storage and household useThe average annual rainfall and the 5 years rainfall collected from Indian Meteorological Department, Chennai is as shown in Fig 4.

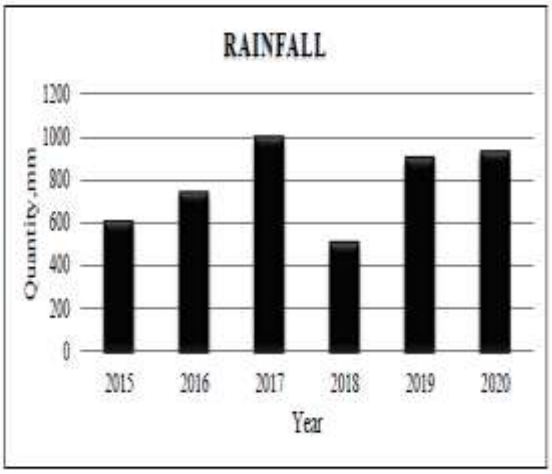

Fig 4. Rainfall data

ii. Groundwater Level: The Ground Water levels from the 31 number of observation wells of TWAD have been analyzed for Post-Monsoon and Pre-Monsoon. 5 years average Ground water level in m below Ground Level for pre- and post-monsoon is given in Table 2.

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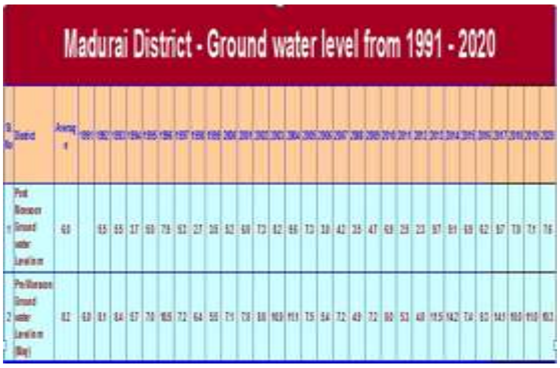
Table 2: Groundwater Level



Madurai District - Ground water level from 1991 - 2020

S. No	District	Average	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Post Monsoon Ground water Level in m	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	Pre Monsoon Ground water Level in m (bgl)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

iii. Site Soil: The soil available at the location is Black Cotton Soil. Black cotton soil is heavy clay soil, varying from clay to loam; it is generally light to dark grey in colour. The soil consists of less than 30 percent clay, wedge-shaped pedestrians, and cracks that regularly open and close.

2.3 Design of Bioswale Structure

Bioswale has been designed by using SP-119 2018. The Cross Sectional View of Bioswale is shown in Fig 5.
Length of the Road = 1033 ft
Width of the Road = 28.5ft
Side Width = 3.9 ft
Bottom width of the swale = 2.5 ft
Side Slope = 4:1
Length of the Swale = 12 ft
Depth of the Swale = 4.5 ft
Area of the swale = 135 ft^2
Perimeter = 49 ft
Hydraulic Radius = 2.76
Manning's Coefficient, n = 0.05
Discharge = 3947ft^3/sec
Velocity of flow = 29.23 ft^2/sec
HRT = 6 mins

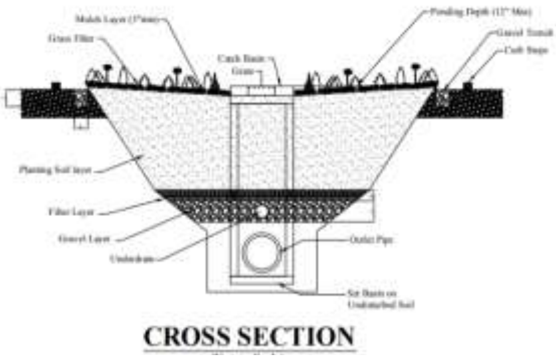


Fig 5. Cross section of Bioswale

2.4 Plants Selected for Pilot Study

Plants chosen for the purification of stormwater are Periwinkle, Cape jasmine, and Yellow Elder and are shown Fig 6.

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Fig 6. Images of Periwinkle, Cape jasmine, and Yellow Elder

The Fig 7. shows the reactor setup used for the pilot scale study.

Fig 7. Bioswale setup

III. EXPERIMENTATION AND RESULTS

3.1 Experimental Investigation of Soil

Testing of Soil Properties:

Soil present at the location is tested for various experiments like Sieve Analysis, Specific Gravity, Liquid limit and Plastic Limit. Testing enables a successful and effective stormwater management design that incorporates a suitable infiltration rate for design calculations. Soil Testing also helps investigate the subsurface conditions below existing surfaces/pavement, and identifies existing soil horizons (layers), as well as any limiting features, historic conditions, etc. Table 2 represents the Properties of Site soil.

Table 2: Properties of Site Soil

Properties	**Values**
Grain Size Distribution	
Coarse	9.6 %
Medium	64.9 %
Fine	15.2 %
Specific Gravity	2.65
Atterberg Limits	
Liquid Limit	56.12 %
Plastic Limit	36.26 %

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i. Sieve Analysis: Sieve Analysis is conducted to observe the grain size distribution of the soil. The grain size distribution curve (GSD curve) is plotted and the effective size of soil, Uniformity co-efficient (C_u) and Co-efficient of Curvature (C_c) are found.the particle size distribution curve between the particle diameter in mm and % finer. Table 3 and Fig 8. represents the Test results of Sieve analysis and Test result graph and Fig 9. shows the set of I.S Sieves used for sieve Analysis.

Table 3: Test results of Sieve analysis

S. No	I.S Sieve (mm)	Wt. Retained (g)	Cum. Wt. Retained (g)	Cum. % Retained	% Finer
1	4.75	74	74	7.4	92.6
2	2.36	96	170	17.0	83
3	1.18	240	410	41.0	59
4	1	180	590	59.0	41
5	600µ	229	819	81.9	18.1
6	300µ	449	863	86.3	13.7
7	150µ	108	971	97.1	2.9
8	Pan	29	1000	100.0	0

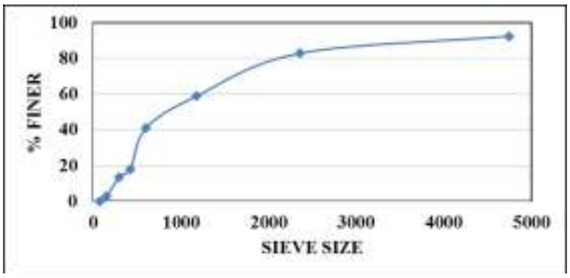

Fig 8. Test result graph (sieve analysis)

Fig 9. Sieve analysis

ii. Specific Gravity: Specific gravity is defined as the ratio of the unit weight of soil solids to that of water. By conducting the Pycnometer test, the specific gravity of the soil is determined. From the test results, Soil Specific Gravity of Soil (G) = 2.56. Table 4 represents the Test results of Specific gravity and Fig 10. Shows the Pycnometer used for test.

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Table 4: Test results of Specific gravity

S.No	Particulars	Weight (g)
1	Weight of pycnometer (W_1)	647
2	Weight of pycnometer + Soil (W_2)	1866
3	Weight of Pycnometer + Soil + Water (W_3)	2169
4	Weight of Pycnometer + Water (W_4)	1427

Fig 10. Pycnometer

iii. Atterberg Limits: The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit. The objective of finding Atterberg Limits is to determine the shrinkage and settlement characteristics of soil.

Liquid Limit: The liquid limit (LL) is conceptually defined as the water content at which the behavior of a clayey soil changes from plastic to liquid. However, the transition from plastic to liquid behavior is gradual over a range of water contents, and the shear strength of the soil is not actually zero at the liquid limit. The observation for the untreated soil is noted and a graph is plotted between the water content and the number of blows. The moisture content corresponding to 25 blows gives the liquid limit of soil. Table 5 and Fig 11. shows the Test Results of Liquid Limit and Result Graph and Fig 12. shows the Liquid Limit Apparatus.

Table 5: Test Results of Liquid Limit

S.No	Quantity of Water added (ml)	% of Moisture Content (%)	No. of Blows(n)
1	52	46	50
2	64	52	37
3	68	60	25

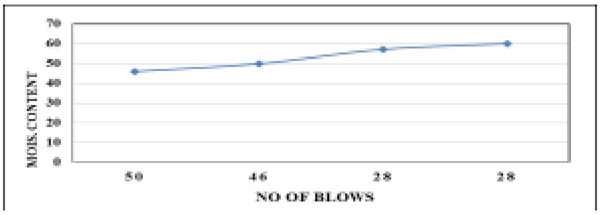

Fig 11. Liquid Limit Test Result Graph

Fig 12. Liquid Limit Apparatus

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Plastic Limit: The plastic limit (PL) is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. If the soil is at moisture content where its behavior is plastic, this thread will retain its shape down to a very narrow diameter. The sample can then be remolded and the test repeated as the moisture content falls due to evaporation, the thread will begin to break apart at larger diameters. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 2 mm. Fig 13. shows the plastic limit test. The results are tabulated in Table 6.

Table 6: Test results of Plastic Limit

S.No	Particulars	Wt. (g)
1	Weight of Can (W1)	18
2	Weight of wet soil with can (W2)	42
3	Weight of Dried soil with can (W3)	39
4	Weight of water (W3-W2)	3
5	Weight of dry soil (W2-W1)	24

Fig 13. Plastic limit Test

3.2 Experimental Investigation of Water

In order to check the water quality, various tests like pH, Turbidity, Conductivity, Hardness and ChemicalOxygen Demand are conducted. Each test has been conducted for 5 days for each sample.

i. pH: pH is a measure of the hydrogen ion concentration in water. Acidic waters tend to be corrosive to plumbing and faucets, particularly if the pH is below 6. Waters with a pH above 8.5 may tend to have a bitter taste. Fig 14. Shows pH meter and Samples.

Fig 14. pH meter and Samples

ii.Turbidity: Turbidity is a measure of light transmission and indicates the presence of suspended material such as clay, silt, finely divided organic material, plankton and other inorganic material. If turbidity is high, be aware of possible bacterial contamination. Normally the ground water is clear in nature and it will satisfy the code's need. The ground water may get contaminated by intrusion of domestic or industrial wastewater causing turbidity of the sample. Turbidity in excess of 5 NTU is usually objectionable for aesthetic reasons. Fig 15. shows the Turbidity meter used for study.

Fig 15. Turbidity meter

iii. Conductivity: Conductivity is the capacity of water to carry an electrical current and varies both with number and types of ions the solution contains, which in turn is related to the concentration of ionized substances in the water. Most dissolved inorganic substances in water are in the ionized form and hence contribute to conductance. Rinse the electrode thoroughly blots and dry. Immerse the electrode in 0.01 N KCL solutions and the conductivity should be 1413 micro mhos at 25°C Temperature. Fig 16. shows the Conductivity meter used for study.

Fig 16. Conductivity meter

iv. Hardness : Originally hardness of water is a measure of soap consuming capacity to produce foam or lather. Also produce scale in hot water pipes, heaters, boilers and other units, precipitated chiefly by Calcium and Magnesium ions commonly present in water. Hardness of water varies from place to place. Surface waters are softening than the ground water, due to the dissolved salts of Carbonates, Bicarbonates, Chlorides, Sulphate, Nitrates of Calcium and Magnesium. Temporaryhardness is mainly due to Carbonate and Bicarbonate of Calcium and Magnesium**.** Fig 17. shows the test conducted to determine Hardness.

Fig 17. Hardness Test

v. Chemical Oxygen Demand: The chemical oxygen demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g., lakes and rivers), making COD a useful measure of water quality. It is expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution. COD is the measurement of the amount of oxygen in water consumed for chemical oxidation of pollutants**.** Fig 18. shows the COD Apparatus and sample preparation.

Fig 17. COD Apparatus and sample preparation

The Table 7 represents the Water Quality Test results on 5th, 10th, 15th, 20th, and 25th day respectively as follows:

Table 7: Water Quality Test results on 5th, 10th, 15th, 20th, and 25th day

Day		pH	Turbidity (NTU)	Conductivity (mS/cm)	Hardness (mg/L)	COD (mg/L)
5th Day	**Sample 1 Control**	8.21	9	8.7	154	169
	Sample 2 Periwinkle	8.04	5	6.3	128	133
	Sample 3 Cape Jasmine	7.6	2	4.2	112	114
	Sample 4 Yellow Elder	7.4	1	2.1	87	88
10th Day		**pH**	**Turbidity (NTU)**	**Conductivity (mS/cm)**	**Hardness (mg/L)**	**COD (mg/L)**
	Sample 1 Control	8.54	13	9	176	167
	Sample 2 Periwinkle	7.98	8	7.8	152	148
	Sample 3 Cape Jasmine	7.66	4	5.2	128	122
	Sample 4 Yellow Elder	7.2	2	3.1	108	97
15th Day		**pH**	**Turbidity (NTU)**	**Conductivity (mS/cm)**	**Hardness (mg/L)**	**COD (mg/L)**
	Sample 1 Control	8.01	23	10.6	168	184

	Sample 2 Periwinkle	7.88	18	8.3	143	167
	Sample 3 Cape Jasmine	7.32	11	7	121	132
	Sample 4 Yellow Elder	7.21	5	4.2	98	100
20thDay		**pH**	**Turbidity (NTU)**	**Conductivity (mS/cm)**	**Hardness (mg/L)**	**COD (mg/L)**
	Sample 1 Control	8.43	9	8.8	131	176
	Sample 2 Periwinkle	8.1	8	8.1	127	159
	Sample 3 Cape Jasmine	7.89	6	7.3	113	123
	Sample 4 Yellow Elder	7.64	5	5.1	88	87
25thDay		**pH**	**Turbidity (NTU)**	**Conductivity (mS/cm)**	**Hardness (mg/L)**	**COD (mg/L)**
	Sample 1 Control	8.21	9	4.2	163	187
	Sample 2 Periwinkle	8.02	8	3.8	145	156
	Sample 3 Cape Jasmine	7.34	6	3.5	123	124
	Sample 4 Yellow Elder	7.19	2	3.1	97	98

The following Fig 18-22 shows the test result graphs on Water quality tests like pH, Turbidity, Conductivity, Hardness and COD respectively for different reactor setup on 5th, 10th, 15th, 20th and 25th day.

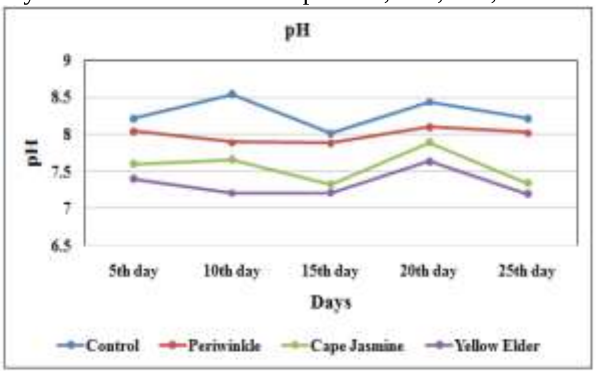

Fig 18. Test result graph for pH

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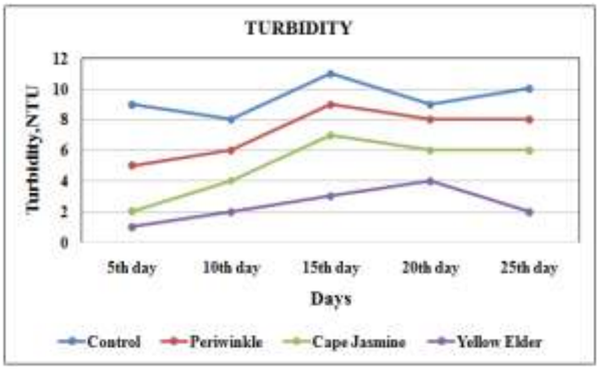

Fig 19. Test result graph for Turbidity

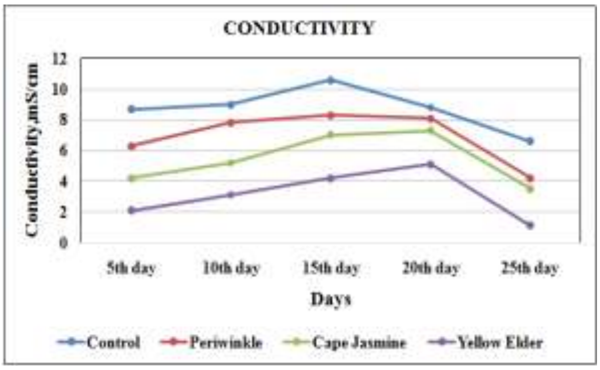

Fig 20. Test result graph for Conductivity

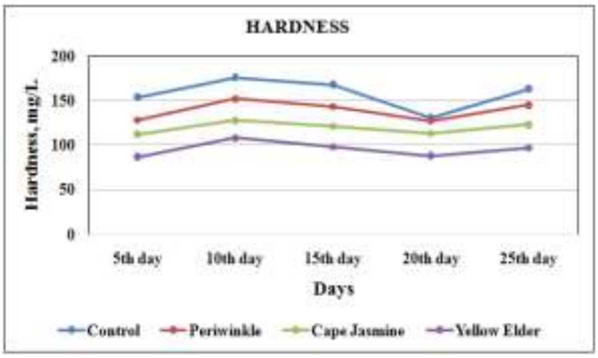

Fig 21. Test result graph for Hardness

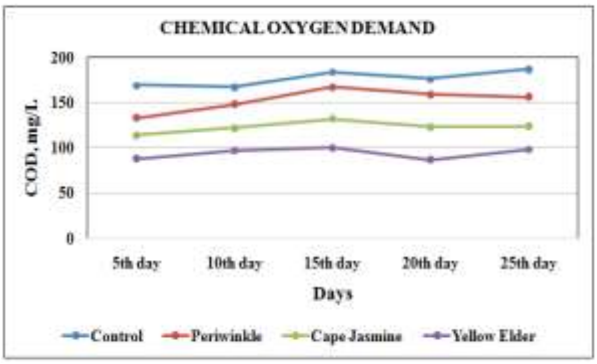

Fig 22. Test result graph for COD

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3.3 Experimental Investigation of Plants

Characteristics of Plants: For this Pilot study, Plants are chosen which satisfies the Bioswale criteria. Plants like Periwinkle, Cape Jasmine and Yellow Elder are chosen**.**

i. **Periwinkle:** Catharanthus roseus (Periwinkle) is chosen. It is a species of Catharanthus genus and Apocynaceae family. The periwinkle is a perennial herb with flowers that can bloom throughout the year. Its other popular names are Vinca rosea Ammocallis rosea, and Lochnera rosea. It is also widely cultivated and is naturalized in subtropical and tropical areas of the world**.**

ii. Cape Jasmine: Gardenia jasminoides, commonly called common gardenia or Cape jasmine, is an evergreen flowering plant of the coffee family Rubiaceae. Gardenias are evergreens with lustrous, dark green foliage. The leaves range from 2 to 4 inches long and serve as a lush background to the large, white flowers the plant produces in spring and summer. Gardenia's highly fragrant, waxy blooms may be up to 4 inches in diameter**.**

iii. Yellow Elder: Yellow elder (Tecoma stans) is a flowering perennial shrub of the trumpet vine family. Common names include Yellow Trumpetbush, Yellow Bells, Yellow Elder, Ginger-Thomas, and Esperanza. The plant is cultivated as an ornamental and blooms throughout the year. It has characteristic sharply-toothed, lance-shaped green leaves and large bright yellow trumpet-shaped flowers. It is drought-tolerant and grows well in warm climates.

Overall Infiltration rate of the selected plants

The time taken (min) by the Plant to uptake water is calculated and its filtration rate has been computed using Staff Gauge. Table 8 represents Infiltration Rate of different reactor setup and Fig 23. shows the Test result graph of Infiltration Rate.

Table 8: Infiltration Rate

	Sample 1 (Control)	Sample 2 (Periwinkle)	Sample 3 (Cape Jasmine)	Sample 4 (Yellow Elder)
5th Day	760	490	420	610
10th Day	630	520	480	520
15th Day	810	620	590	480
20th Day	780	530	570	620
25th Day	790	640	560	630

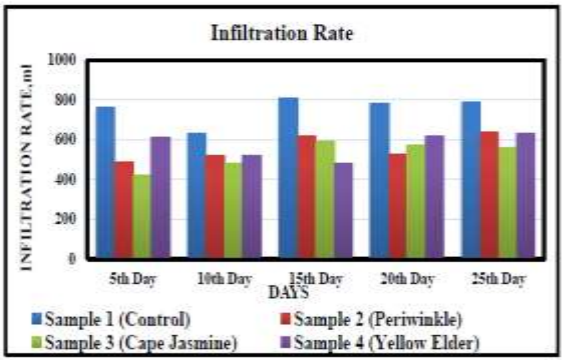

Fig 23. Overall Infiltration Rate

IV. CONCLUSION

Overall, Bioswale has proven that they are capable of removing pollutants through the layers and they recharge the underground water table.Testing of Materials like Soil, Water and Plant are done as per the objectives and investigations are accomplished for pilot study.The pilot study gave as the better results and among them Yellow Elder plant neutralizes the Stormwater, reduces hardness and removes organic and inorganic compounds.

Bioswales can also be designed to be aesthetically pleasing and attract animals and create habitats. Bioswales can also be beneficial for groundwater recharge.Bioswales can be implemented in areas that require stormwater management to regulate the runoff velocity and decontaminate the runoff.

Aesthetic maintenance is required to remove weeds that affect the performance of the other plants and the bioswale itself, clean and remove trash, and maintaining the looks of the vegetation.

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