

# TREATMENT OF GREY WATER USING CONSTRUCTED WETLANDS

S. Sinthana Gorky

Department of Civil Engineering, V R S College of Engineering & Technology, Tamilnadu  
sinthanaswaminathan@gmail.com

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**ABSTRACT:** Grey water is water from bathroom sinks, showers, tubs and washing machines. Grey water contains some amount of dirt, food, grease, hair and certain household cleaning substances. While grey water may look “dirty”, it is safe and even beneficial source of irrigation water in yard. If the grey water is released into rivers, lakes or estuaries, the nutrients in it become pollutants. Besides the benefits of saving water, reuse of grey water helps in reducing the pollution in local water bodies. Constructed wetland treatment system has proved to be an effective method of recycling the grey water.

In this study, the effectiveness of the wetland plant *Colocasia esculenta* in the treatment of grey water by vertical subsurface flow constructed wetland system is studied. A laboratory scale vertical flow reed bed of size 0.4 x 0.3 x 0.2m was constructed. Seven numbers of *Colocasia esculenta* species was grown. The system was fed at the flow rate of 3.0 litres / day. The raw Grey water and treated Grey water were collected periodically and tested for quality. It is seen that reed bed unit is reducing the concentrations of TSS, TDS, BOD, COD by 66%, 89%, 85%, 82% respectively on an average.

**Keywords:** Constructed wetland, grey water, vertical flow reed bed, *Colocasia esculenta*

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## I. INTRODUCTION

### GENERAL

A grey water biofiltration system is a constructed wetland that removes a significant amount of pollutants from grey water before it flows into the water bodies. Certain amount of pathogens, bacteria, and non-biodegradable toxins entering to the surface water can be avoided with this type of treatment, to promote a better ecosystem and more sterile conditions. This treatment can be used for residential areas at low cost.

Grey water is the wastewater produced from sinks, baths, or clothes-washing; it does not include toilet water, which contains bacteria and pathogens. Grey water may also contain some traces of toxic chemicals, soaps, salt, microorganisms, bleach, froth, and foodstuff. Additions of grey water to surface water bodies can cause imbalance in pH levels, increase in oxygen demand and increase in turbidity.

### DEFINITION

#### GREYWATER

Grey water is defined as the wastewater generated from the kitchen, washbasins and baths, it can be recycled for uses such as toilet flushing, land irrigation and engineered wetlands. Greywater also includes wastewater from clothes washing machines and sometime include discharge from dish washers and kitchen sinks.

It differs from the discharge of toilets, which is nominated as sewage or black water to indicate it contains night soil.

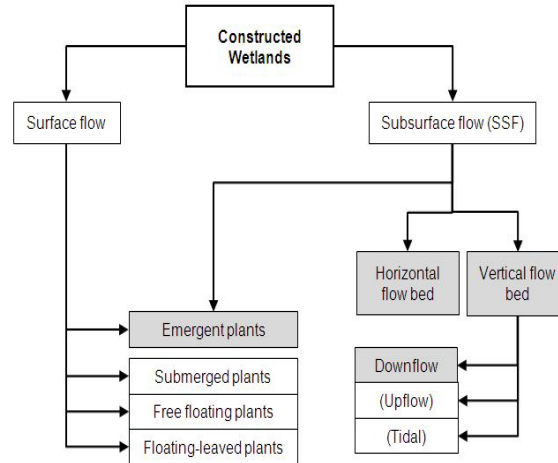
### CONSTRUCTED WETLANDS

Constructed wetlands are the management systems, designed and constructed to exploit the natural functions of wetland vegetation. Microbes in soil treat contaminants in surface water, ground water or waste streams.

### TYPES OF CONSTRUCTED WETLANDS

Constructed wetlands are classified according to the water flow regime into either free water surface flow or subsurface flow and according to the type of macrophyte plant as well as flow direction.

Subsurface flow CWs are designed to keep the water level totally below the surface of the filter bed. They can even be walked on. This avoids the mosquito problem of FWS. The coarse sand used in subsurface flow CWs contribute to the treatment process by providing a surface for microbial growth and by supporting adsorption and filtration processes. This results in lower area demand and higher treatment performance per area for subsurface flow CWs, compared to free water surface flow CWs.



**Fig.1 Classification of Constructed Wetlands.**

## SELECTION OF PLANTS

There are a few plants that are most frequently used for greywater biofiltration wetlands, many of which can be found in natural wetlands. Wetland plants found close to the constructed wetland area are the most beneficial because they are already accustomed to the local climate. If these plants cannot be found locally, any wetland plants that grow well can be used.

- Cattails (*Typha* spp.) are hardy, easy to propagate, and capable of producing a large annual biomass. Typically they remove large amounts of nitrate and phosphate.
- Bulrushes (*Schoenoplectus* spp., *Scirpus* spp.) grow in clumps and grow well in water 5cm to 3 m deep. This aggressive plant achieves a high pollutant removal.
- Reed Grasses (*Phragmites australis*) are tall plants with deep roots, enabling more oxygen to reach the root zone than the above two plants.
- Reed Plants (*colocasia esculenta*) has hole from the leaves throughout the stem to the root zone. It supplies oxygen to the root zone from atmosphere. Hence, the root zone is sufficient to growth the aerobic bacteria.

## II. METHODOLOGY

### DESIGN OF VERTICAL SUBSURFACE CONSTRUCTED WETLAND SYSTEM

The vertical subsurface root zone system for treating grey water is designed such that the flow rate determined at first and then the hydraulic loading rate as well as organic loading rate are calculated and checked with the standards from Central Pollution Control Board.

### ORGANIC LOADING RATE ACCORDING TO CPCB.

For dimensioning RZTS for domestic waste water the following inflow characteristics have to be considered:

- BOD, settled, 27°C, 3days, in grams/day
- Quantity of wastewater, in litres /day

The BOD criteria (organic loading) ranges for dimensioning are:

- For horizontal flow 10 – 30g/BOD/m<sup>2</sup>/day
- For vertical flow 20 – 40g/BOD/m<sup>2</sup>/day

For industrial effluents specific recommendations according to type of industry are required. Future revisions of these guidelines will incorporate such recommendations.

Parts near the lateral sides and the infiltration and drainage areas may not be included in the surface calculations.

**HYDRAULIC LOADING RATE ACCORDING TO CPCB.**

The hydraulic load criteria range for dimensioning are:

- For horizontal flow 40 – 100 L/m<sup>2</sup>/day
- For vertical flow 50 – 130 L/m<sup>2</sup>/day

If the percolation is tested for the determination of the percolation cross section and the bed geometry in the case of vertical RZTS, a  $k_f$  - value reduced by a power of 10 should be applied. Hydraulic verification is indispensable.

**FLOW RATE ACCORDING TO CPCB.**

Hydraulic calculation are carried out according to the law of DARCY:

$$Q = k_f i A$$

$$q \text{ [m}^3\text{/s]} = \text{Flow (discharge per unit time)}$$

$$k_f \text{ [m/s]} = \text{permeability}$$

$$I \text{ [m/m]} = \text{Hydraulic gradient}$$

$$F \text{ [m}^2\text{]} = \text{Total cross section area of soil mass,}$$

Perpendicular to the direction of flow.

The effective hydraulic load is highly dependent upon the characteristics of the bed media as well as the characteristics of the effluent. Therefore, these figures should be treated as indicative only.

**DETERMINATION OF PERMEABILITY.**

The total depth of the bottle (H) and diameter (D) are measured and then the bottle is filled with coarse aggregate. A known quantity of water is taken and poured into the bottle and the time taken for the water to penetrate and flow out of the bottle is noted. Similarly for the fine aggregate this experiment is done and the time is noted. Then by using the formula given below the permeability of coarse and fine aggregate is determined.

$$K = \frac{\frac{D}{2} \ln(h_1/h_2)}{2(t_2/t_1)}$$

Where, D = Diameter of the bottle

$h_1$  = Initial height of the water

$h_2$  = Final height of the water

$t_1, t_2$  are the initial and final time taken by the water to travel from  $h_1$  to  $h_2$ .

Permeability for coarse aggregate is determined by

$$K_{\text{coarse}} = [ (0.10/2) \ln (0.20/0.01) ] / [2(35-0)]$$

$$= 2.14 \times 10^{-3} \text{ m/s}$$

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Permeability for fine aggregate is determined by

$$K_{\text{fine}} = [ (0.10/2) \ln (0.20/0.01) ] / [2(360-0)]$$

$$= 2.08 \times 10^{-4} \text{ m/s}$$

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Let  $k_{\text{vertical}}$  be the average permeability of the soil deposit parallel to the bedding plane. The total discharge through the soil deposit is equal to the sum of the discharge through the individual layers.

$$q = q_1 + q_2 + \dots + q_n$$

$$q = k_{\text{vertical}} i H$$

$$= k_1 i H_1 + k_2 i H_2 + \dots + k_n i H_n$$

$$K_{\text{vertical}} = [H / (H_1/K_1 + H_2/K_2 + H_3/K_3)]$$

$$K_{\text{vertical}} = 4.011 \times 10^{-4} \text{ m/s}$$

**DETERMINATION OF FLOW RATE:**

By using Darcy formula,

$$\begin{aligned}
 q &= k_{\text{vertical}} i A \\
 &= k \times (h/l) \times A \\
 &= 4.011 \times 10^{-4} \times (0.0035/0.4) \times (0.3 \times 0.15) \\
 &= 1.579 \times 10^{-7} \text{ m}^3/\text{s} \\
 &= 13.645 \text{ litre/day} \\
 q &= 13.645 \text{ litre/day}
 \end{aligned}$$

**DETERMINATION OF HYDRAULIC LOADING RATE:**

Hydraulic loading refers to the daily quantity of wastewater applied to each unit surface area of the treatment basin.

$$\begin{aligned}
 \text{HLR} &= (\text{Flow} / \text{surface area}) \\
 &= 13.645 / 0.4 \times 0.3 \\
 &= 113.70 \text{ l} / \text{m}^2 / \text{day} \\
 \text{HLR} &= 113.70 \text{ l} / \text{m}^2 / \text{day} \\
 50 \text{ l} / \text{m}^2 / \text{day} &< 113.70 \text{ l} / \text{m}^2 / \text{day} < 130 \text{ l} / \text{m}^2 / \text{day}
 \end{aligned}$$

The hydraulic loading rate obtained is within the limit stated by CPCB

**DETERMINATION OF ORGANIC LOADING RATE.**

Organic loading means the total quantity of organic matter (in terms of BOD and COD) that is applied per day over the unit surface area or per unit volume of the treatment basin or tank. Normally, it is designated in the unit of kg BOD or COD per m<sup>2</sup> surface area or kg BOD or COD per m<sup>3</sup> volume of the tank.

$$\begin{aligned}
 \text{OLR} &= [\text{BOD} \times \text{flow} / \text{surface area}] \\
 &= [250 \times 10^{-3} \times 13.645 / (0.4 \times 0.3)] \\
 &= 28.427 \text{ g} / \text{BOD} / \text{m}^2 / \text{day} \\
 \text{OLR} &= 28.427 \text{ g} / \text{BOD} / \text{m}^2 / \text{day} \\
 20 \text{ g} / \text{BOD} / \text{m}^2 / \text{day} &< 28.427 \text{ g} / \text{BOD} / \text{m}^2 / \text{day} < 40 \text{ g} / \text{BOD} / \text{m}^2 / \text{day}
 \end{aligned}$$

The organic loading rate obtained is within the limit stated by CPCB.

**CONSTRUCTION AND WORKING OF REED BED**

The unit was constructed by placing separate layers of bricks (bricks or brick bats) stone chips, sand, stone dust, after arranging the layers the plants were planted in the unit. It is filled as follows:

- The first layer of 0.05m considered of coarse aggregate gravel(Fig.3.2)
- The second layer of 0.07m consisted of fine aggregate, sand 0.3 – 1mm size
- The third layer of 0.03m considered of coarse aggregate gravel
- 0.05m freeboard

Further the growth of plants was monitored. Then the sewage water was let into the root zone system and the samples were collected. The *colocasia esculenta* is planted and thus the root zone system by vertical subsurface flow is constructed.



**Fig.2 Reed Plants in Tank**

**GREY WATER FLOW**

The grey water is collected and is made to pass through the filter. It filters through the graded stone layer and enters the prepared bed where the treatment takes place. After passing through the bed the treated sewage is allowed to filter through the down end filter. It rises up to the initial level maintained. It is collected in a tank and discarded to the farmlands. The particles present above the stone layers are scrapped and disposed.

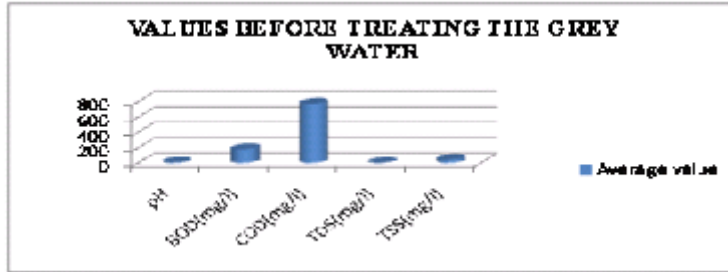
**III. RESULTS AND DISCUSSION**

**CONCENTRATION OF VARIOUS PARAMETERS BEFORE TREATMENT**

The Grey water is collected and before letting to the vertical subsurface constructed wetland the various parameters are tested. The values so obtained are tabulated in Table 1.

PARAMETERS	SAMPLES			AVERAGE VALUE
	1	2	3	
pH	7.2	8	7.3	7.5
BOD (mg/l)	120	187	250	186
COD (mg/l)	769	780	783	777
TDS (mg/l)	2	4	2.5	2.8
TSS (mg/l)	40	56	44	47

**Table 1 Concentration of Various Parameters Collected ( Before Treatment)**



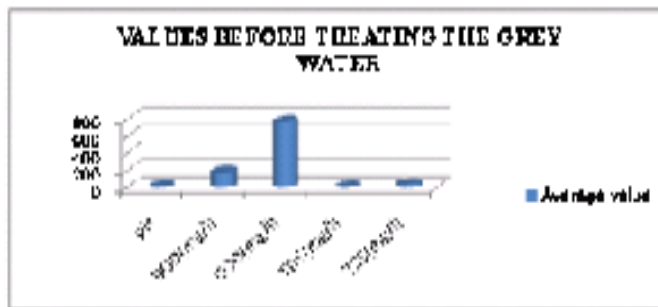
**Fig.3 Graph Showing Values Before Treating the Grey Water**

**CONCENTRATION OF VARIOUS PARAMETERS AFTER TREATMENT**

The treated water obtained from the vertical subsurface flow constructed wetland were collected and then various parameters are tested. The values so obtained are tabulated in Table 2.

PARAMETERS	SAMPLES			AVERAGE VALUE
	1	2	3	
pH	7	6.9	7	7
BOD (mg/l)	30	28	27	28
COD (mg/l)	138	140	149	142
TDS (mg/l)	1	0	0	0.3
TSS (mg/l)	18	13.8	15	16

**Table 2 Concentration of Various Parameters Collected (After Treatment)**



**Fig.4 Graph Showing Values After Treating the Grey Water**

## DISCUSSION

The results show the concentration of five parameters for grey water treatment by vertical subsurface flow root zone. It is clear that there is a remarkable reduction in pH, BOD, COD by reed bed treatment and the treated water has become fit enough to be let out directly into a receiving water body as the concentrations are below allowable limits. Thus the root zone treatment can be used independently or as an addition to conventional treatment so as to make the final output fit enough for discharge into a natural water body. During the starting stage the CW system shows quite low efficiency in BOD and COD due to minimum growth of the plant. In the later stage the root zone bed showed greater efficiency. Further efficiency can be improved by using aerators to increase the oxygen supply or else hybrid root zone system i.e combination of horizontal and vertical root zone system can be used for zero discharge efficiency.

## IV. SUMMARY AND CONCLUSION

The grey water was analyzed to determine its characteristics. The constructed wetland method (root zone) was employed on a lab scale to treat the grey water. Based on the experimental results, the following conclusions are made.

1. This study demonstrated that the designed sub-surface vertical flow constructed wetland system could be used for treatment of the grey water. A constructed wetland system can be an effective treatment facility for grey water.
2. Regarding the performance achieved, the sub-surface vertical flow constructed wetland was able to reduce further the level of the main physicochemical pollution parameters. The plants do play an important role in the treatment.
3. The treatment level was affected by not only by the change of seasons, but also by the variations in influent quality and quantity.
4. The overall experimental results demonstrated the feasibility of applying sub-surface vertical flow constructed wetland unit to treat grey water. Thus the root zone treatment can be utilized independently or as an addition to conventional treatment for complete treatment of grey water.

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