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Management of Greywater in Rural Areas of Punjab (India) by Use of Constructed Wetland

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Abstract— *In order to save the useful water getting waste out, a present study is carried out to treat the greywater coming from the domestic houses & surrounding areas. It was carried out in two selected rural areas located in a radius of about 20 kilometres of Kapurthala District. Greywater was allowed to pass over to low cost treatment technology i.e. Constructed Wetlands. With the available parametric information, design parameters and results of applied technology i.e. Horizontal flow Constructed Wetlands are discussed further in this study.*

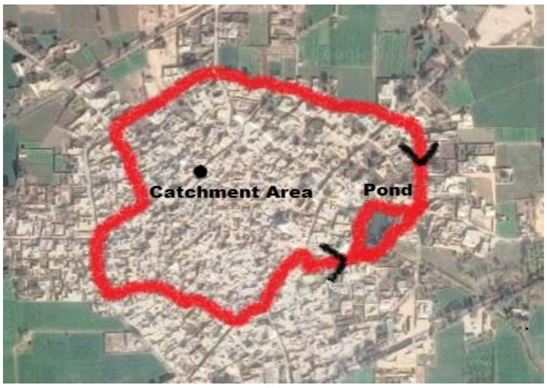
Keywords— *Low cost wastewater treatment, constructed wetlands, greywater.*

I. INTRODUCTION

In Wetlands, the important point is in the removal of Odour in accordance to the wetlands construction for different agricultural wastewater treatment technologies, particularly in the areas which are heavenly populated in the reduction of malodours (Harrington et al 2005). The acceptance of wetland results in wider & vast application in wetland treatment technology, particularly for rural farming communities & municipal systems. Also a wide range of heterotrophic bacteria is found in facultative pond. Some of the aerobic heterotrophic bacteria are Pseudomonas, Archromobacter, Beggiato, Alcaligenes, and Bacillusas that remove Biological Oxygen Demand in this pond (Pearson et al. 1998). This different range of heterotrophic bacteria oxidizes organic compounds (electron donor) and reduce O2 (electron acceptor) supplied by pond algae. CO2, NH4+, PO42ñ) are aerobic heterotrophic reaction products also for algae production & growth these products are used. The objective of this study was to separate out to treat the grey water coming from the domestic houses & surrounding areas and make use of low cost natural treatment technique namely constructed wetlands to treat the wastewater at the source itself. The importance of the work also lies in the fact that domestic wastewater from the major source of water entering the pond contains Blackwater and greywater. Different treatment required for both these type of wastewater to treat as well as utilize the pond water in a beneficial way. Therefore, this study which has been proposed for rural areas pond and its wastewater collection system to become a stepping stone for the integrated water resources management in rural areas by planning effective treatment, management and utilization of the pond water.

A. *Description of the Rural Areas*

Two different villages were identified and selected in the radius of around twenty kilometres in Doaba region of Punjab namely Samrai and Pippa Rangi. The existing condition of the village pond and its surroundings were examined. Pippa Rangi (Phagwara) is a small sized catchment village located on the outskirts of an urban centre and having multiple storm water outlets. Pond of the village is located in its centre and the condition of the pond as observed is not healthy and hygienic. Samrai (Phagwara) is a large village having at least four identified outlets. The information on the village catchments was obtained through the survey maps provided by the Department of Water Supply and Sanitation, Government of Punjab and physical survey visits. The location of the study areas and the area of catchments areas are shown in figure 1 (a) & (b) respectively.



(a)

(b)

Fig. 1. Maps view of (a) Samrai (b) Pippa Rangi

B. *Methodology Adopted*

Greywater coming from bathroom showers, kitchen, wash basins is treated in constructed wetland type namely in horizontal flow constructed wetland (sub-surface). The greywater passes over a wetland bed and is pumped in intervals to the papyrus reed bed. In HFSS wetlands, there is a better removal efficiency of pathogens (up to a factor of 100) and organic matter (almost 90%) and can be achieved. Comparing constructed wetlands to different technical systems (e.g. RBC) is more economical & relatively easy to maintain also. They are applicable and suitable for treatment of grey water coming out from different sources from house. Disinfection of the treated grey water can also be suitable when reuse is to be considered.

Subsurface Horizontal Flow Systems– Subsurface Flow is a vegetated bed system which consists of gravel or rock media and emergent vegetation. Water level is raised by filling the wetland with crushed/gravel rocks materials up to 6-10cm which results in no wastewater exposure to the surface. Subsurface horizontal flow systems need to be covered with waterproofed, either through reinforced concrete of polyethylene or through compacted clay. Dirt water flows through the pond; sewage/waste effluent fills the space between the gravel and circulates horizontally, naturally, each time when the water comes into the system.

The Horizontal flow type of wetland is selected over Free Water Surface wetland due to different reasons and advantages, if the surface of water is maintained below the surface media than there is less risk of insect/mosquitoes, odours or exposure. Also the media provides treatment for larger surface area available for Free Water Surface types of wetland so the treatment responses might be quicker for the Horizontal flow type, which therefore can be smaller in area than a Free Water Surface system designed for the same wastewater conditions. The position of subsurface of the water and the accumulated plant debris on the surface of the Surface Flow bed offer larger thermal protection in cold climates than the Free Water Surface flow of wetland.

Horizontal flow type design criteria

The exact arrangement and design of a pond will to a large extent be site specific. Few aspects are to be generally considered to achieve a positive performance in the pond.

- Depth of gravel: 0.41m – 0.86m
- 4.1mm-8.1mm, clean and screened as main media and 40-80 mm at entrance and exit for 1m-2m length for large systems to avoid short-circuiting over time.
- Piping: 100-220+ mm PVC
- Inlet & Outlet pipe of Constructed Wetland- (38-81) mm
- Filter media diameter at both the in-outlet of the Constructed Wetland over 1.1m - 2.1m length

Design Process in Horizontal Flow Constructed Wetland

Wastewater characteristic parameters include Biochemical Oxygen Demand, TSS, Nitrogen & Ammonia compounds and pathogenic organisms.

1. Hydraulic loading rate

$$HLR = \frac{100Q}{As}$$

Where Q = average flow rate (m3/day), *As* = area of treatment of the wetland (m2), HLR = hydraulic loading rate (cm/day).

2. Retention time- The retention time is volume/flow, and the flow is the mean of the outflow and inflow; therefore

$$\theta = \frac{\varepsilon AD}{0.5(Q_i + Q_e)}$$

Where ε is the bed medium porosity (0.4 for pea gravel), A = Area of Constructed Wetland (m2), D = Depth of Constructed Wetland (m), Qe = outflow (m3/d) & Qi = inflow (m3/d).

The outflow here is inflow less loss due to evapotranspiration, where e is the net evapotranspiration (i.e. evapotranspiration - rainfall) (mm/d).

Qe= Qi-0.001eA

Thus:

$$\theta = \frac{2\varepsilon AD}{2Q_i - 0.001eA}$$

3. Area of wetland

$$A = \frac{Q_i(\ln Li - \ln Le)}{kA}$$

For Sub Surface Horizontal Flow Constructed Wetland the design value of *kA* is 0.06 m/d, here Li and Le is Inflow and outflow BOD, respectively (mg/l) and Qi is the inflow wastewater flow rate (m3/d).

4. Total suspended solids removal

Se = Si (0.1058 + 0.0011HLR)

Where HLR = hydraulic loading rate (cm/day), Si = influent pollutant concentration (mg/l), Se = outlet pollutant concentration (mg/l).

5. Ammonia removal

Ce = Ci e^ *k*Nθ

Where *k*N = rate constant of first order for ammonia removal at t°C (m/d), *C*e is the effluent mean ammonia concentrations (mg N/l) and *C*i is influent mean concentration of ammonia (mg N/l), θ = retention time

For Sub Surface Horizontal Flow Constructed Wetland the variation of *k*N with mean of winter and summer temperature is taken.

kN (T)= 0.126 (1.008)^ T-20

6. Total phosphorus removal

Pe = Pi .*e*^ (-Kp/HLR)

Where Pi = concentration of influent phosphorus (mg /l), Pe = concentration of outlet phosphorus (mg/l), Kp = first order phosphorous reaction rate, HLR = hydraulic loading rate (cm/day)

II. RESULTS AND DISCUSSION

A. *Wastewater Parameter Analysed*

TABLE I. Surveyed data of village Pippa Rangi.

Catchment area of village pond	40107.28m2
Total population of village	858
Cattle population in village	124
No. of houses	175
Area of village pond	815.0146m2
Volume of village pond	1975m3
No of households with toilet user	143
No of households without toilet	32

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The number of users required in village Pippa Rangi to use EcoSan Latrine is 4 per person from a house

TABLE II. Surveyed data of village Samrai.

Catchment area of village pond	114765.5m2
Total population of village	2335
Cattle population in village	164
No. of houses	450
Area of village pond	3324.5084 m2
Volume of village pond	8059.4 m3
No of households with toilet user	405
No of households without toilet	45

The number of users required in village Samrai to use EcoSan Latrine is 5 per person from a house

B. *Results and Design Parameters used for the Constructed Wetlands Design*

TABLE III. Constant design parameters.

Average Winter Temperature (Degree Celsius)	21
Average Summer Temperature (Degree Celsius)	31
Mean Temperature (Degree Celsius)	26
Net Evapotranspiration (mm/d)	12
Depth of Constructed Wetland (m)	0.7
ε for pea gravel	0.4
First order phosphorous reaction rate, Kp (cm/day)	2.73

TABLE IV. Constructed wetlands design parameters for village Pippa Rangi.

Average flow rate (m3/day)	90.948
Mean BOD (mg/l)	261.66
Hydraulic loading Rate (cm/day)	4.32809
Area of Wetland (m2)	2101.34
Retention Time (days)	7.51055
First-order rate constant for ammonia removal at winter temp (m/d)	0.12701
Ammonia Concentration (mg/l)	51.05
Ammonia Removal For Winter (mg N/l)	19.6645
First-order rate constant for ammonia removal at Summer temp (m/d)	0.13754
Ammonia Removal For Summer (mg N/l)	18.1687
Total Suspended Solids influent (mg/l)	482.16
TSS Removal (mg /l)	53.308
Total Phosphorus Influent (mg /l)	39.4
Total Phosphorus Removal (mg /l)	22.7732

TABLE V. Constructed wetlands design parameters for village Samrai.

Average flow rate (m3/day)	206
Mean BOD (mg/l)	276.66
Hydraulic loading Rate (cm/day)	4.32808
Area of Wetland (m2)	4775.55
Retention Time (days)	7.51056
First-order rate constant for ammonia removal at winter temp (m/d)	0.12701
Ammonia Concentration (mg/l)	38.9
Ammonia Removal For Winter (mg N/l)	14.98
First-order rate constant for ammonia removal at Summer temp (m/d)	0.13754
Ammonia Removal For Summer (mg N/l)	13.8445
Total Suspended Solids influent (mg/l)	273.3
TSS Removal (mg /l)	30.2163
Total Phosphorus Influent (mg /l)	23.92
Total Phosphorus Removal (mg /l)	13.8258

III. CONCLUSIONS

After examining the existing condition of village pond and surroundings of different villages namely Doaba region of Punjab, BOD values were noted higher in wastewater samples of village Samrai & Pippa Rangi due to variation in organic load and presence of large number of cattle in these villages. For Ammonia concentration removal mean of summer and winter temperature is taken which shows the removal content is more in summer season than in winter, which shows ammonia concentration depends upon temperature, weather surroundings around the village. Total phosphorus was also high in village Pippa Rangi which cause algal blooms and more plant growth as observed in the village ponds. Microorganisms were found to be present in large numbers which make water unfit for any beneficial use even for cattle use. Analysis of pond water showed the high values of Total Suspended Solids values in wastewater, which are important to remove if the wastewater entering the pond is to be used for some useful purpose i.e. irrigation. At low construction and Maintance costs the subsurface flow constructed wetland concept can give better results for reduction of Total Suspended Solids and Biochemical Oxygen Demand. This type of wetland is suitable to installations recommended for small to medium size and where land area is available at reasonable price.

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