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Research Article

PERFORMANCE EVALUATION AND ECONOMICS OF GREY WATER TREATMENT PLANT FOR USE IN RURAL AREAS

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ABSTRACT

The grey water treatment plant is designed and developed by Department of Irrigation and Drainage, DBSKKV, Dapoli. It is a combination of natural and locally available material in which physical operations such as inflow, filtration and collection could be performed. The most effective combination of media found after experimentation were 45 cm sand, 45 cm grit, 30 cm brick pieces, 30 cm charcoal and 30 cm gravel, respectively. The hydraulic retention time (HRT) of designed filter was found 24.00 hours at hydraulic loading rate of (HLR) of 3.77 m/day. The filter cross sectional area will increases with the required capacity. The grey water treatment plant was found effective for reduction of turbidity from 80 NTU before filtrationupto 30NTU after filtration. It also reduced effectively the colour and odour of the treated water up to acceptable standards. The BOD, COD, oil and grease, RSC and SAR which are considered to be major parameters influencing water quality were reduced by 82.70, 86.10, 78.78, 69.23, and 21.33 percent respectively. Similarly Sodium, Magnesium, Nitrogen, Potassium, bicarbonate, calcium, TDS, EC and pH were also reduced by 31.42, 33.33, 5.55, 48.76, 44.62, 20.00, 31.19, 26.19 and 0.6 percent respectively. All the chemical parameters of the filtered water were found in permissible range according to irrigation water quality standards. The cost of the construction of the treatment plant is Rs. 31958 per square meter. The filtration capacity per square meter filtration plant is 3770 liter per day. Considering cost of 1 m^3 water was Rs. 10, shows the payback period of one square meter grey water treatment plantis 3.0 years. The low construction cost, use of locally available material, less maintains cost and long life increases the importance of the system under scarcity driven situation in rural as well as urban areas.

INTRODUCTION

The pressure on freshwater resources is growing around the world and as new sources of supply become increasingly scarce, expensive, or politically controversial. The efforts to identify new ways of meeting water needs, reduce water demand by increasing the efficiency of water use and to expand the usefulness of alternative sources of water previously considered unusable (Raschid *et al*., 2008). Among these potential source of supply are greywater reuse, desalination and rainwater harvesting are getting focus now days. Among theses the grey water is readily available water which can be possibly used after treatment for urinal and toilet flushing, irrigation of lawns (college campuses, athletic fields, cemeteries, parks and golf courses, domestic gardens), washing of vehicles and windows, fire protection, boiler feed water, concrete production, develop and preserve wetlands, infiltrate into the ground (for recharge of aquifers), agriculture and viticulture reuse.

In many places throughout India, rural as well as urban communities live without access to household water connection. In these communities, women and children often have to walk long distances or wait in line in order to access water which then needs to be carried home.

Economic status, geographical location, population size, public health considerations, religious practices and social acceptability also affect the grey water availability and use. Many developed countries have gone ahead to encourage greywater re-use by formulating appropriate legislative

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framework. Grey water reuse is illegal in some Middle Eastern countries. Australia, Korea and Cyprus have incentive programs for greywater re-use. Australia has developed guidelines for greywater reuse, and reuse is encouraged through a program that offers $500 rebates for the installation of a greywater system. In Tokyo, Japan, not only are there incentives for installing greywater systems, but they are mandatory for buildings with an area of over 30,000 square meters, or with a potential to reuse 100 cubic meters per day (CSBE 2003). Several municipalities around the world have passed regulations to promote greywater reuse in multistory buildings. This high level of water stress has driven many low and middle income earners to take the initiative of unconventional (untreated) greywater re-use. However, the level of hygiene in the way the greywater is reused may pose some health risks to the users (Yeole, 2012). On-site greywater reuse within the urban and rural sectors may have a significant role in reducing the overall water consumption, leading towards more sustainable urban water utilization, and easing water stress in several areas of the world (Amerasinghe, 2013).

The treatment technologies to be used now days for greywater include membrane filters to remove contaminants, bacteria, and viruses along with aerobic biological treatment (Karlsson, 2012). Biological greywater treatment also includes membrane bioreactors (MBR) (Bower and Scholzed, 1999). Physical and chemical greywater treatment systems (Nwajuaka, 2015) primarily utilize disinfection and filtration to remove contaminants while biological treatment uses aeration and membrane bioreactors. Ultra violet disinfection has been included as a final safety measure before the use in toilet flushing. Though there are treatment technologies available for the greywater reuse, these technologies are at present expensive and are not well known among the members of the communities. Hence, the objectives of this research work are performance evaluation and to work out the economics of use of domestic scale grey water treatment plant for rural region.

MATERIALS AND METHODS

The experimental set up of grey water treatment plant was designed for 24 lit/day capacity. The sources of the grey water was water collected from bathrooms, basins and laundries in Jayaprabha Girls hostel, DBSKKV., Dapoli. The flow rate of feed raw water was controlled by the manual control valve. The schematic diagram of the designed grey water treatment plant is shown in fig. 1(Morel and Diener 2006). Vertical slow flow media filter model was constructed using two PVC pipe candles of external diameter 90 mm diameter of height 200 cm. Both ends of candles were closed with 90 mm diameter end cap. The inflow of raw grey water was controlled by the manual control valve of size 16 mm diameter. Supply, interconnecting and delivery line used for model were of 16 mm diameter flexible pipe. The air vent of 16 mm diameter and drain valve of 16 mm diameter were installed at the top and bottom cap of each candles respectively. The head difference between outlet of storage tank and inlet of waste water treatment plant was adjusted at 1.5 m. The screen filter of capacity of 7 m^3 hr^{-1} was installed after second candle. The untreated grey water was stored in 100 litre capacity storage tank. The easily available and natural materials were used as filter beds The media size and depth were decided by experimentation were Sand (0.42 mm), Grit (6-8mm), Brick pieces (25-30 mm) and Charcoal (12-16 mm), Gravel (15-25 mm), (Zaidun,2011) having layer thickness of 45 cm, 45 cm , 30 cm, 30 cm and 30 cm respectively. The samples of the filtered water were analyzed by standard methods.

Table 1 Specification of the Designed Grey Water Treatment Plant

Sr. No.	Design Parameter	Specifications
1.	Discharge (Q)	24 lit/day
2.	Flow velocity (v)	3.8 m/day
3.	Surface area of filter bed (A)	6.35×10^{-3} m^2
4.	Hydraulic Loading Rate (HLR)	3.77 m/day
5.	Volume of filter unit (v)	0.011m^3
6.	Hydraulic Retention Time (HRT)	16.00 hrs
7.	Average interstitial velocity (V_a)	9.7m/day
8.	Equivalent vertical hydraulic conductivity (K_z)	8.18 m/day
9.	Types of flow through filtration multilayer media on the basis of Reynolds number (N_R)	Laminar flow
10.	Frictional head loss through media, (h_L)	1×10^{-3}m

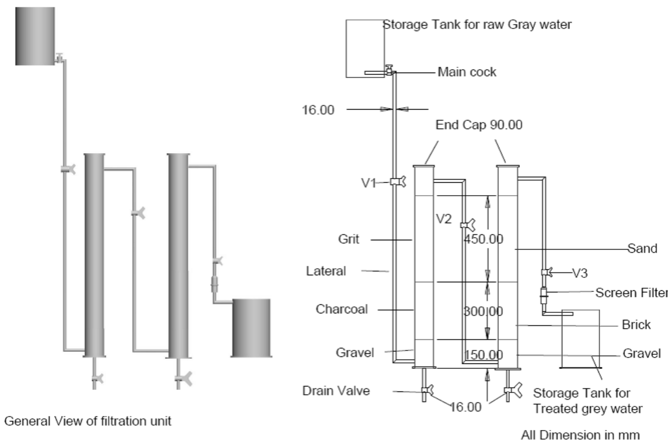

Fig 1 Components of Designed Filtration Unit

RESULTS AND DISCUSSION

The physical parameters viz. color, odor, turbidity were found within permissible limit of irrigation water quality. The samples were analyzed for chemical parameters such as pH, Electric conductivity (EC), Total dissolved solids (TDS), Calcium (Ca), Carbonate, Bicarbonate, Potassium (K), Nitrogen (N), Magnesium (Mg), Sodium (Na), Sodium adsorption ratio (SAR), Residual sodium carbonate (RSC),Oils and Grease (Saponification value), Chemical oxygen demand (COD), Biological oxygen demand (BOD) and compared with standard irrigation water quality. The percent reduction in the physical and chemical parameters of treated water over untreated water gives the insight into performance of designed filter.

Table 2 Percent reduction of different chemical parameters

Sr. No.	Properties	Untreated	Treated	Percent reduction
1.	pH	7.32	7.27	0.6
2.	Electrical conductivity (EC), ds/m	2.1	1.5	26.19
3.	Total Dissolve Solids, mg/lit	134	92.2	31.19
4.	Calcium, me/l	1	0.8	20
5.	Carbonate, me/l	Nil		-
6.	Bicarbonate, me/lit	2.9	1.6	44.82
7.	Potassium, me/l	8.1	4.15	48.76
8.	Nitrogen, mg/l	5.04	4.76	5.55
9.	Magnesium, me/l	0.6	0.4	33.33
10.	Sodium, me/lit	1.05	0.72	31.42

11.	Sodium Adsorption Ratio, me/l	1.17	0.92	21.33
12.	Residual Sodium Carbonate, me/lit	1.3	0.4	69.23
13.	Oil and grease	13.2	2.8	78.78
14.	Chemical Oxygen Demand (COD), mg/lit	376	56	85.10
15.	Biological Oxygen Demand (BOD), mg/lit	185	32	82.70

Cost Economics and Benefit Cost Ratio

The cost effective grey water treatment plant is very essential in the rural region. The capital cost, energy cost, operating and maintains cost are important while deciding economy of the plant. The cost of grey water filter having cross sectional area 1 m^2 were presented here for study. The cost-benefit analysis considers the capital cost, maintains and operating cost of the grey water reuse system against the saving in particularly potable water used for toilet flushing, garden watering, car and floor washing, fire control, cooling system, boilers etc is shown in the table 3.

Table 3 Cost of grey water filter having cross sectional area 1 m^2

Sr. No.	Particulars	Rate, Rs/-	Amount, Rs/-
1.	Cost of construction of cement concrete tank having inside dimensions 1 m (W) x 1 m (L) x 2 m (H) including brick, sand , cement and construction cost	14,000/- per m^3	28,000/-
2.	Sand- size 0.42 mm, density 0.86 g/cc, volume 0.45 m^3	2135/- per m^3	960.75
3.	Grit- size 6 to 8 mm, density 0.95 g/cc, volume 0.45 m^3	1601/- per m^3	720.45
4.	Gravel- size 15 to 25 mm, density 1.12 g/cc, volume 0.30 m^3	1601/- per m^3	480.30
5.	Brick pieces- size 25 to 30 mm, density 0.54 g/cc, volume 0.30 m^3 , weight 16.2 kg	10/- per kg	162/-
6.	Charcol- size 12 to 16 mm, density 0.25 g/cc, volume 0.30 m^3, weight 7.5 kg	15/- per kg	112.50
	TOTAL		30,436/-
7.	Labour cost @5 percent of the Project Cost		1521.80
8.	Cost grey water treatment plant per square meter cross sectional area having depth 2 m		31,957.80 Say 31,958/-

(Todd,1980 and Allision,1953)

The erection cost of grey water filter having cross sectional area 1 m^2wasgiven in the Table 3.The total cost of one square meterfilter including cost of construction, media cost and labour charges were Rs. 31,958.00.The cost benefit analysis of Jayprabhagirlshostel shows payback period of 3.0 years in Table 4

Table 4 Cost Benefit Analysis of the grey water system of 3770 LPD capacity

S.N.	Parameter	Quantity
1.	Capital cost (Rs) (Fixed cost)	31958.00
2.	Operational and maintenance cost @ 20 percent of the capital cost (Rs/year) (labor, consumables, replacements etc)	6392.00
3.	**Total**	38350.00
5	Annual amount of grey water filtration	1376 m^3
6	Annual cost of water saving (@ Rs 10 per Cumec)	Rs 13760
7	Payback period of the system	2.78 say 3.0 years

CONCLUSION

The designed grey water filter of cross sectional area 1 m^2 has capacity to filter 3770 lit. grey water per day. Annually it will filter 1376 m^3 grey water. The cost of the filtered water at the rate of Rs.10 per m^3 is Rs 13760. The payback period of the designed filter is 3 years. It could be used efficiently in the rural water scarce areas for reuse of the grey water.

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