International Journal of ChemTech Research
CODEN(USA): IJCRGG ISSN : 0974-4290
Vol.3, No.4, pp 1808-1815, Oct-Dec 2011

Performance of grey water treatment plant by economical way for Indian rural development

Saroj B. Parjane[1]*, Mukund G. Sane[2]

[1]Sir Visvesvaraya Institute of Technology (Affiliated to the University of Pune), Chincholi, Tal: Sinnar, Dist.: Nashik, India – 422 101.

[2]Ex. Scientist, National Chemical Laboratory, Pune, India.

***Corres.author: sarojparjane@gmail.com**
Ph. No.: +91 2551 271 278; Fax: +91 2551 271 277.

Abstract: India is facing a water crisis and by 2025 it is estimated that India's population will be suffering from severe water scarcity. Conventional groundwater and surface water sources are becoming increasingly vulnerable to anthropogenic, industrial and natural pollution. The best alternative and cost effective process in rural areas is the reuse of grey water. In this report present the finest design of laboratory scale grey water treatment plant, which is a combination of natural and physical operations such as primary settling with cascaded water flow, aeration, agitation and filtration, hence called as hybrid treatment process. This grey water reuse system is developed for the small college campus in rural areas. The economical performance of the plant were investigated for treatment of bathrooms, basins and laundries grey water and recycled in residential hostel at college campus in rural Maharashtra. The water reuse or recycling systems collected, treated and reused bathroom water for flushing of toilets, floor washing, cloth washing, gardening and irrigation. The cost benefit analysis of the system on the large scale was also done and found the more effective process in the rural region.
Keywords: Grey water, reuse of water, rural area, water pollution.

1. Introduction

Water is becoming a rare resource in the world. In India alone the International Water Management Institute (IWMI) predicts that by 2025, one person in three will live in conditions of absolute water scarcity (IWMI, 2003). It is therefore essential to reduce surface and ground water use in all sectors of consumption, to substitute fresh water with alternative water resources and to optimize water use efficiency through reuse options. These alternative resources include rainwater and grey water [1].

With increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. Alternative sources of water can potentially save significant amounts of precise fresh water. One alternative source of water is grey water. Scientists around the globe are working on new way of conserving water. It is an opportune time, to refocus on one of the technique to recycle water—through the reuse of grey water by economical way. Grey water is non-industrial waste water generated from domestic processes such as washing dishes, laundry and bathing. Grey water is distinct from black water in the amount and composition of its chemical and biological contaminates (from feces or toxic chemicals). Dish, shower, sink, and laundry water comprise 50-80% of residential waste water [2-4].

Due to rapid industrialization and development, there is an increased opportunity for grey water reuse in developing countries such as India. Although India occupies only 3.29 million km^2 geographical area, which forms 2.4% of the world's land area, it supports over 15% of world's population. The population of India as of March 31, 2011 was 1,210,193,422 persons (Census, 2011). India also has a livestock population of 500 million, which is about 20% of world's total livestock. However total annual utilizable water resources of the country are 1086 km^3 which is only 4% of world's water resources [5]. Total annual utilizable resources of surface water and ground water are 690 km^3 and 396 km^3 respectively [6]. Consequent to rapid growth in population and increasing water demand, stress on water resources in India is increasing and per capita water availability is reducing day by day. In India per capita surface water availability in the years 1991 and 2001 were 2300 m^3 (6.3 m^3/day) and 1980 m^3 (5.7 m^3/day) respectively and these are projected to reduce to 1401 and 1191 m^3 by the years 2025 and 2050 respectively [5]. Total water requirement of the country in 2050 is estimated to be 1450 km^3 which is higher than the current availability of 1086 km^3. Various options including rainwater harvesting and wastewater reuse will have to be considered to meet the anticipated deficit [7]

The grey water effluent from a household or group of households is made up of contribution from various appliances, such as kitchen sink wash basin, bath, shower, washing machine etc. elimination of toilet waste from the residential waste water stream by using non water carriage toilet will reduce the mass of organic matters; pathogenic organisms; nitrogen and phosphorus in the remaining waste water we have proposed the onside waste water differentiable treatment system based on the concept of a differentiable management and treatment of household waste water effluents. Reduced volume black water higher load and lower load grey water are new concept that are intended to introduced in this model. Grey water has promising potential as a resource that can be used to supplement or replace potable water for the purpose of landscape irrigation. However, limiting state regulations and health concerns associated with its use preclude grey water from being used as efficiently as possible**.** [2,3,5,6,8,9]

Throughout the world, supply of water to the rural population has been a challenging risk. In India, the 'water shortage' is one of the major issues coming from the rural area. Due to this, the government of Andhra Pradesh has designed and constructed a number of slow sand filtration for rural water supply schemes in the state [10]. Our designed grey water treatment process is like a low technology systems, also called extensive or natural systems, are based on the imitation or adaptation of processes that occur naturally in soils and water bodies. The various conventional intensive technologies are in competition with natural systems to treat the grey water of medium and small size communities. In big cities, the sophisticated technologies are used by authorities and plants operated by highly skilled personnel to abide by discharge regulations and prevent the failure that could damage the environment. Large town can afford high treatment expenses, which is not the case for rural communities [11-13]. This study will focus on grey water treatment and its use as an alternative water resource in rural areas by an economical way.

2. Experimental Materials and Methods

Laboratory scale grey water treatment plant was designed for 180 lit/hr capacity restricted four stages such as primary settling with cascade flow of water has 20 liters capacity, aeration has 15 liters tank capacity, agitation has also 15 liters and filtration unit of 20 liters. The sources of the grey water was collected from bathrooms, basins and laundries in residential rural area in a tank and sent to the primary settling unit by the 0.5 HP pump. The flow rate of feed raw water was controlled by the manual control valve. The laboratory scaled designed grey water treatment plant is explained in fig. 1 contained the operation of primary settling tank with cascade flow of water, aeration, the agitation and last major operation of plant is a filtration. The gravitational force was used for the flow of water from primary settling tank with 04 steps of cascade system to the aeration, agitation and filtration unit to the storage tank. The 0.18 m diameter agitator and 0.125 HP motor was used in the agitation operation. The easily available and natural materials were used as filter beds in the filtration unit such as fine particles (equal size) sand bed, course size bricks bed, charcoal bed, wooden saw dust bed and bed of coconut shell covers. The bed height of each material was determined and finalized by the experimentation. The samples were collected from raw water and from each stage for the analysis. These samples were analyzed by standard method for water and waste water analysis [10] at environmental laboratory. The parameters such as pH, total dissolved solids (TDS), total suspended solids (TSS), chemical oxygen demand (COD), total hardness and oil and grease contained in grey water were determined for each samples. Additionally, parameters like ammonia nitrogen (NH_4-N), fluorine (F), Chlorine (Cl), nitrites (NO_2), nitrates (NO_3), phosphates (PO_4), sulphates (SO_4), sodium (Na), potassium (K), magnesium (Mg) and calcium (Ca) were determined of raw and treated water sample for the performance study of the plant.

From the previous study [14], the depth of each bed were selected as 0.15 m, 0.1 m, 0.2 m, 0.15 m and

0.2 m for sand, bricks, charcoal, saw dust and coconut shell covers respectively set from bottom to top in the filtration unit based on the pH level effect. The total filter media depth in the filtration tank is shown in fig. 2. The maximum pH effect found by the coconut shell covers bed was kept at top in the filtration unit.

3. Results

3.1. Performance of the laboratory scale system for grey water treatment

The grey water was collected from the bathrooms, basins of the residential area of college hostel located at Sinnar rural area in Nashik city, India. Total 08 samples of grey water were taken at first day of morning and evening of every week and the performances of system were investigated for these 08 samples of grey water at steady state conditions and the average value data are summarized in **Table 1.** The average organic load in grey water found 327 mg COD/lit. The solids in grey water were found to have about 76% dissolved and 24% suspended particles. From Table 1, all the parameters found in grey water were reduced and found the better performance of the natural system. The average 83 % of organic load was removed and the 46 % anions and 49 % cations were found to be adsorbed by the natural adsorbents used in filtration. The traces of potassium, magnesium and calcium were found and removed fully from grey water.

3.2. Performance of Grey water plant in three seasons

The performance of the grey water treatment plant was determined for 03 seasons such as winter, spring and summer. The grey water samples of the residence hostel were collected in each month and calculate the average percentage removal of the grey water parameters. All these data reported in **Table 2.** From the presented data, it was found that the performance of the plant is better in the winter season and less in the spring season. Because in the spring season, the pollutant are more dissolved in the surface water and ground water. The traces of the potassium, magnesium and calcium were found and removed fully from grey water in summer and winter season and some traces was found in spring season.

Fig.1. Laboratory scale grey water treatment system

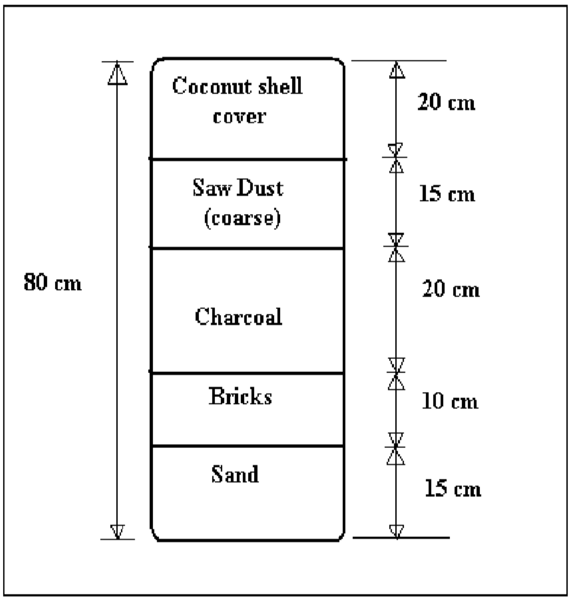

Fig.2. Arrangements of the filter media in the filtration tank.

Table 1: Average characterizes of bathrooms, basins of grey water from a residential college. campus located at Sinnar rural area in Nashik city, India (August 2009)

Sr. No.	Parameters	Raw water	Filtered water
1	pH	8.12	7.43
2	Total Hardness (mg/lit)	374	187
3	COD (mg/lit)	327	58
4	TDS (mg/lit)	573	172
5	TSS (mg/lit)	184	32
6	Oil and grease (mg/lit)	7.2	0.24
7	Fluorine (mg/lit)	0.82	0.43
8	Chlorine (mg/lit)	37.9	21.47
9	Nitrites (mg/lit)	0.08	00
10	Nitrates (mg/lit)	0.67	0.21
11	Phosphates (mg/lit)	0.012	00
12	Sulphates (mg/lit)	21.3	10.66
13	Sodium (mg/lit)	32.28	17.11
14	Potassium (mg/lit)	4.52	1.98
15	Magnesium (mg/lit)	0.11	00
16	Ammonia- nitrogen (mg/lit)	0.79	0.21
17	Calcium (mg/lit)	0.13	00

Table 2: Performance of the grey water treatment plant in 03 seasons

Sr. No.	Parameters	Percentage removal of parameter		
		Winter	Spring	Summer
1	Total Hardness	60.5	49.3	56.2
2	COD	90.8	82.1	89
3	TDS	80	71.9	81.2
4	TSS	89.9	85.3	89.2
5	Oil and grease	97	95	97
6	Fluorine	52.9	48.8	51.3
7	Chlorine	49	45.4	47.6
8	Nitrites	99.9	96	99.9
9	Nitrates	74.8	67.9	71.6
10	Phosphates	99.9	92	99.8
11	Sulphates	80.2	48.7	71.3
12	Sodium	72.2	51.7	69.1
13	Potassium	70.3	59.4	62.5
14	Magnesium	100	98.1	100
15	Nitrogen	82.8	76.1	83.5
16	Calcium	100	91.2	98.5

3.3. Comparison of the present grey water treatment plant with other treatment plants

The comparisons of the plant with other treatment plant were done in the **Table 3**. It seems that the performance of the grey water treatment plant was better as compared to other treatment methods. Hence the present study found the better application in the grey water treatment in rural region by the economical way. The cost performance of the residence hostel was done in the next section.

3.4. Study the effect of treated grey water on plant growth

The grey water contains harmful chemicals. Sodium, potassium and calcium are alkaline chemicals. Because of the presence of these chemicals in laundry detergent, grey water use tends to raise alkalinity of the soil. Slightly alkaline soils will support many garden plants. Even most acid-soil loving plants will be happy with slightly alkaline soils that are generously amended with organic matter. The pH of an acid soil is 6.9 or lower while that of an alkaline soil is 7.1 or higher. If a simple pH test indicates that the pH reading is over 8.0, the pH should be reduced. A sandy, well-drained soil will be less affected by the application of grey water than a poorly drained clay soil. To correct these problems and keep soil healthy, the treatment before irrigation of grey water is necessary.

To study the effect of treated water on plant growth, we have applied the treated water to the garden plants continuously for one month. It is observed that:

- Plants grow normally by applying treated water.
- There is no effect of treated water on plant
- The concentration of salts, detergents and minerals are reduced, so there no potential for adverse impacts on the soil and plants.
- There is sufficient level of phosphorous present in treated water which is good for plant growth.
- pH of the treated water reduces up to 7.3 to 7.5, so alkali loving plant are not affected.

Table 3: The performance parameters comparison of the present work to other literature data in terms of the parameter removal efficiency

Sr. No.	Author and year	Treatment method	Parameters removal efficiency
1	Gross et al. (2007) [15]	Physical (Recycled Vertical Flow Constructed Wetland)	TSS(98%), BOD(100%), COD(81%), TP(71%), TN(69%), Fecal coliform(99%)
2	Gross et al. (2007) [16]	Biological (Recycled Vertical Flow Bioreactor)	COD(89%), NO_3-N(50%), TAN(16%), TSS(95%), Boron, Anionic Surfactants(100%)
3	Seo et al. (2007) [17]	Biological (Activated Sludge) Physical (Coarse pore filtration)	Organic-TOC & BOD(95%), TN(50%), TP(85%), SS
4	Gual et al. (2008) [18]	Physical (Sand filtration) Chemical (Chlorination)	pH, SS(28%), Turbidity(18%), TOC(20%), TN, COD(25%)
5	Kim et al. (2009) [19]	Physical (MF), Chemical (Oxidation)	pH, color(98%), turbidity(99%), COD(99%), SS(99%)
6	Colmenarejo et al. (2009) [20]	Physical (Extended aeration), Biological (Activated Sludge)	Ammonia, TSS(82%), COD(64%), BOD(55%)
7.	Present study	Physical (sedimentation, clarification and filtration) Chemical (oxidation)	Hardness (60%), COD (91%), TDS (81%), TSS (90%), oil and grease (98%), Nitrates (75%), Nitrites (100%), Cations (49%) and anions (46%)

Table 4: Cost analysis of grey water treatment plant of 20000 l/day capacity

Sr. No.	Parameters	Cost
1.	Capital cost (Rs) (Fixed cost)	300000
2.	Energy cost (Rs /year) [Electricity]	10000
3.	Operational and maintenance cost (Rs/year) (labor, consumables, replacements etc)	65000

Table 5: Cost Benefit Analysis of the grey water system

Parameter	Before construction of Greywater system	After construction of Greywater system
Water source between July and December	Dug well (30000 l)	Dug well (12000 l) and Greywater Reuse (18000 l)
Water source between January and May	Dug well (12000 l) and Water tanker (18000 l)	Dug well (12000 l) and Greywater Reuse (18000 l)
Annual cost of water	• Monthly expenditure on purchase of water is Rs.48000 since Jan. • Annual expenditure of Rs.240000	• Interest on Capital expenditure is Rs. 29000 • O&M and energy cost is Rs.75000
Annual cost saving	--	Rs. 136000
Payback period of the system	--	≈ 2.2 years

3.5. Cost Analysis

The cost effective grey water treatment plant is a very important in the rural region. The capital cost, energy cost, operating cost and maintenance cost of the pant are considered in economy of the plant. The cost is determined on the basis of the large scale capacity of the treatment plant. The total grey water generated in the college campus is 20000 l/day. For this large capacity the cost of the plant was analyzed.

Grey water treatment technologies adopted in these systems are economically feasible which make these systems more attractive like the development of the other utilities; the implementation of grey water reuse facilities generally requires a substantial capital expense. In addition to capital costs associated to grey water reuse facilities, there are also additional operations, maintenance and replacement (OM and R) costs. The main objective of the grey water reuse system is to satisfy the water related needs to the community at the lowest cost to the society whilst minimizing the environmental and social impacts. Thus the financial aspect focuses on two types of the costs mentioned below:

- Capital costs of grey water reuse system
- Operation and maintenance cost of the grey water reuse system

The cost of 20000 l/day capacity of grey water treatment plants is presented in Table 4. The capital cost required for the construction of the system is Rs. 30000. In the calculation of the energy cost, power required for the motor of agitator and pump for reuse of grey water from the collection tank.

The Cost Benefit Analysis (CBA) considers the capital cost, maintenance and operating costs of grey water reuse systems against the savings in particularly potable water uses for such purpose. Cost savings for the Cost Benefit Analysis (CBA) were benchmarked against the calculated potable water cost savings of reusing Grey water for the college campus applications such as toilet flushing, garden watering and floor washing. Finding the CBA is presented in Table 5. From this the payback period was found nearly 2.2 years. The following input parameters were considered while undertaking CBA for Grey water reuse system:

- 300 students and teachers in the residence hostel
- College period July 1st to May 31st
- Daily water requirement of 30000 lit.

4. Discussions

The results presented in this study establish the potential applicability of the developed methodology. This laboratory scale grey water treatment plant is a combination of natural and physical operations such as settling with cascaded water flow, aeration, agitation and filtration, hence called as hybrid treatment process. All the natural and easily available low cost materials were used for the treatment process. The coconut shell covers are the waste materials, which can be easily procured and used as an efficient adsorbent in water treatment process for the removal of water pollutants and heavy metal ions from waste water.

In economy of the plant, the power supply, which is an important part of the operating cost of the conventional system and it is a today's major issues of India, was required a minimum, because system works on the natural force for flowing of water from first to last stage. The easily explicable operation, less maintenance of the plant and hence does not required the highly skilled personnel. After the investigations, due to the low energy demand, low operation and maintenance cost, lesser time consuming operation, this gives a significant and efficient method for rural communities and small industrial units for treatment and reuse of grey water.

The laboratory scale model shows the better and effective performance by the experiment and balances the advantages and disadvantages of the system. As per the Indian standard, the treated water is used for landscaping, gardening, toilet flushing, floor washing, car washing and irrigation. Hence on the large scale grey water treatment plant is more beneficial and economical for the college campus development.

5. Conclusions

The present study demonstrate the reuse and treatment of residential bathrooms, basins waste water called as grey water for the purpose of landscaping, gardening, irrigations, plant growths and toilet flushing. Based on finding of this study, this treatment technology can be considered as a viable alternative to conventional treatment plants in rural region since they are characterized by high potential for COD, TDS, TSS, total hardness, oil and grease, anions and cations removal. The benefits found are low energy demand, less operating and maintenance cost, lower load on fresh water, less strain on septic tank, highly effective purification, and ground water recharge. Hence, this is an environmental friendly, without chemical operation, cost effective and resourceful plant for rural development.

References

[1] Eran Friedler, Yael Gilboa, Performance of UV disinfection and the microbial quality of greywater effluent along a reuse system for toilet flushing, Sci. of Total Environ., 408 (2010) 2109-2117.

[2] Intizar Hussain, Liqa Raschid, Munir A. Hanjra, Fuard Marikar, Wim Vander Hoek, Wastewater use in agriculture: Review of impact and methodological issues in valuing impacts, working paper 37, Colombo, Shri Lanka, International water management institute (2002) 1-3.

[3] Emerson G., Every drop is precious: Grey water as an alternative water source, Queensland Parliamentary Library, Research bulletin no. 4 / 98 (1998).

[4] Diana Christova-Boal, Robert E. Eden, Scott McFarlane, An investigation into greywater reuse for urben residential properties, Desalination 106 (1996) 391-397.

[5] Kumar R., Singh R.D., and Sharma K.D., Water resource of India, Current science, v. 89/ n. 5 (2005) 794-811.

[6] Ministry of water resources, Integrated water resources development a plan for action, Report for the National Commission for Integrated Water Resource Development (1999).

[7] Laia Domenenech, David sauri, Socio technical transitions in water scarcity contexts: Public acceptance of greywater reuse technologies in the Metropolitan Area of Barcelona, Resources, Conservation and Recycling 55 (2010) 53-63.

[8] Gupta S.K., and Deshpande R.D., Water for India in 2050: first order assessment of available options, Current science, v. 86/ n. 9 (2004) 1216-1224.

[9] Fabian Deniz, J. Jaime Sadhwani, Jose M. veza, New quality criteria in wastewater reuse, Desalination, 250 (2010) 716-722.

[10] R. Ravindar Rao, R.C. Reddy, K.G. Rama RAo, P.S. Kelkar, Assessment of slow sand filtration system for rural water supply schemes – A case study, Indian J. Environ Health, v 45/ n 1 (Jan 2003) 59-64.

[11] F. Brissaud, Low technology systems for waste water treatment: Perspectives, Water science and technology, v 55/n 7 (2007) 1-9.

[12] Justin J. Henriques, Garrick E. Louis, A decision model for selecting sustainable drinking water supply and greaywater reuse systems fro developing communities with a case study in Cimahi, Indoneasia, J. Environ. Management 92 (2011) 214-222.

[13] Petter D. Jenssen, Tore Krogstad, Adam M. Paruch, Trond Maehlum, Kingra Adam, Carlos A. Arias, Arve Heistad, Lene Jonsson et al., Filter bed systems treating domestic wastewater in the Nordic countries – performance and reuse of

filter media, Ecological engineering 36 (2010) 1651-1659.

[14] B.L. Pangarkar, S.B. Parjane, M.G. Sane, Design and economical performance of grey water treatment plant in rural region, Int. J. Civil and Environ. Engg., 2(1), (2010) 1-5.

[15] A.Gross, O. Shmueli, Z. Ronem, E. Raveh, Recycled vertical flow constructed wetlans – a novel method of recycling greywater for irrigation in small communities and households, Chemosphere 66 (2007) 916-923.

[16] Amit Gross, Drora Kaplan, Katherine Baker, Removal of chemical and microbiological contaminants from domestic greywater using a recycled vertical flow bioreactor, Ecological Engineering 31 (2007) 107-114.

[17] G.T. Seo, B.H. Moon, Y.M. Park, and S.H. Kim, Filtration characteristics of immersed course pore filters in an activated sludge system for domestic wastewater reclamation, Water Sci. and Tech., 55 (1-2) (2007) 51-58.

[18] M. Gual, A. Moia, J.G. March, Monitoring of an indoor pilot plant for osmosis rejection and greywater reuse to flush toilets in a hotel, Desalination 219 (2008) 81-88.

[19] Joonkyu Kim, Insang Song, Haeseok Oh, Jisun Jong, Joonhong Park, Younkyoo Choung, A laboratory –scale greywater treatment system based on a membrane filtration and oxidation process- characteristics of greywater from a residential complex, Desalination 238 (2009) 347-357.

[20] M.F. olmenarejo, A. Rubio, E. sanchez, J. Vicente, M.G. Garcia, R. Borja, Evaluation of municipal wastewater treatment plants with different technologies at Las Rozas, Madrid (Sapin), J. Enviro. Management 81 (2006) 399-404.

*****
*****