Design and Economical Performance of Gray Water Treatment Plant in Rural Region

Bhausaheb L. Pangarkar, Saroj B. Parjane and M.G. Sane

Abstract**—**In India, the quarrel between the budding human populace and the planet's unchanging supply of freshwater and falling water tables has strained attention the reuse of gray water as an alternative water resource in rural development. This paper present the finest design of laboratory scale gray 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. The economical performance of the plant for treatment of bathrooms, basins and laundries gray water showed in terms of deduction competency of water pollutants such as COD (83%), TDS (70%), TSS (83%), total hardness (50%), oil and grease (97%), anions (46%) and cations (49%). Hence, this technology could be a good alternative to treat gray water in residential rural area.

Keywords**—**Gray water treatment plant, gray water, natural technology, pollutant.

I. INTRODUCTION

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 gray 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 gray water by economical way. Gray water is non-industrial waste water generated from domestic processes such as washing dishes, laundry and bathing. Gray 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 [1], [2].

Gray water treatment is an environmental friendly process as a control of water pollution. Many people have investigated the various waste water treatment methods extensively on the international and national levels and many researchers tried to reduce the cost for recycling of the water. The household gray water can be reused for other purposes, especially landscape irrigation, floor washing, car washing and toilet flushing. Grey water has some pollutants that are considered as fertilizer for the plants. Phosphorous, nitrogen, and potassium are excellent sources of nutrients when reusing gray water for irrigation of landscaping and gardens. Benefits of grey water include using less fresh water, sending less waste water to septic tanks or treatment plants, less chemical use, groundwater recharge, plant growth, and raises awareness of natural cycles [2] – [4].

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 [5]. Our designed gray 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 gray 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 [6].

Experiences of treating gray water by natural treatment systems have not been widely reported. In general terms, gray water has lower concentration of organic matter, nutrients and microorganisms. The concentration of phosphorus, heavy metals and xenobiotic organic pollutants are around the same levels [7] – [9]. The pollutants of gray water are reduced by a natural treatment system (laboratory scale) was the aim of this study. This is a socio-economical treatment method gives the wide significant in the rural development.

II. MATERIALS AND METHOD

Laboratory scale gray water treatment plant was designed for 180 lit/hr capacity restricted four stage physical operations 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 gray 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

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feed raw water was controlled by the manual control valve. The laboratory scale gray water treatment plant is explained in figure 1(a) contained the operation of primary settling tank with cascade flow of water as shown in figure 1(b), aeration as shown in figure 1(c), the agitation as shown in figure 1(d) 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 gray 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.

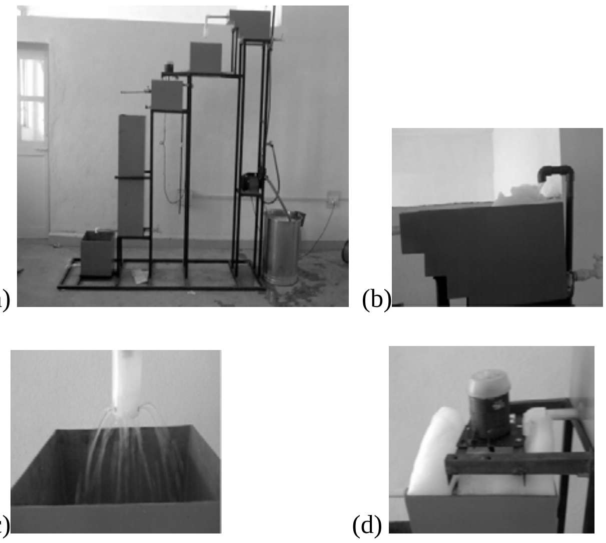

Fig. 1 Experimental set up: (a) Lab scale gray water treatment plant, (b) Primary settling with cascade system, (c) Aeration and (d) Agitation.

III. RESULT

A. pH test for filter bed height calculation

The natural materials such as sand, bricks, charcoal, saw dust and coconut shell covers were used as an adsorbent in the filtration unit. The sample of water was taken before and after filtration with varying bed height of each filter bed and found the positive effect on pH level at 2 lit/min (LPM) of water flow rate as shown in figure 2. The filter bed of coconut shell cover and charcoal were given the maximum effect on pH level from 8.23 to 7.88 and the minimum effect found for bed of bricks. The bed of sand and saw dust material were found the fair change in pH level 8.23 to 8.16. The deviation in pH by each filter bed was found because each filter bed having the different capacity of adsorption of ions.

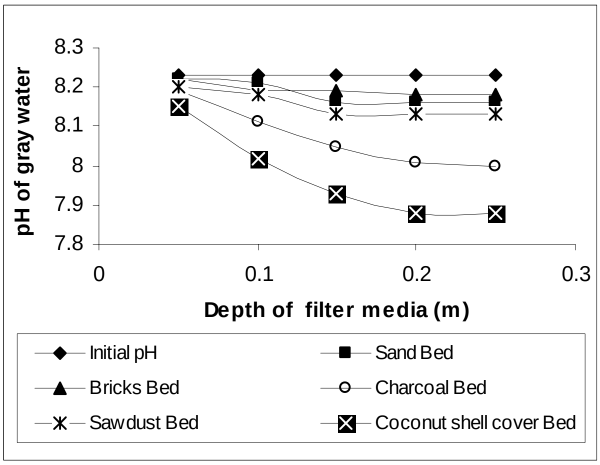

Fig. 2 Effects of filter bed heights on pH level change

For the further experiment 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 pH level effect. The maximum pH effect found by coconut shell covers bed was kept at top in the filtration unit.

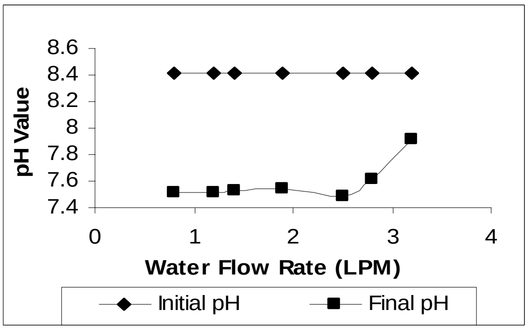

Fig. 3 Effect of water flow rate on pH level

B. Effect of flow rate on removal of gray water pollutants

The samples of raw gray water i.e. before cascade stage and final filtered water i.e. after filtration stage were taken with varying flow rate of water. Figure 3 shows the effect of flow rate of gray water on pH level and the resultant pH were nearly constant i.e. 7.51 (average) up to 2.5 lit/min, while increases pH level for further increase in flow rate. The characteristics parameters of gray water such as TDS, TSS, COD, total hardness, oil and grease were determined and all these are pretentious by flow rate of water after flow rate of 2.5 lit/min as shown in figure 4. The gray water average organic load removal was found 84 % at the water flow rate of 2.6 lit/min. The removal capacity of organic load of gray water was decreased by raising flow rate of gray water. The results show the 100% removal of oil and grease from the gray water only up to the 2.5 lit/min water flow rate.

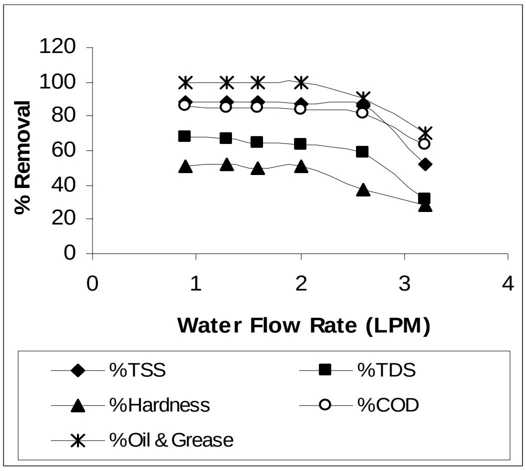

Fig. 4 % removal of pollutants with water flow rate

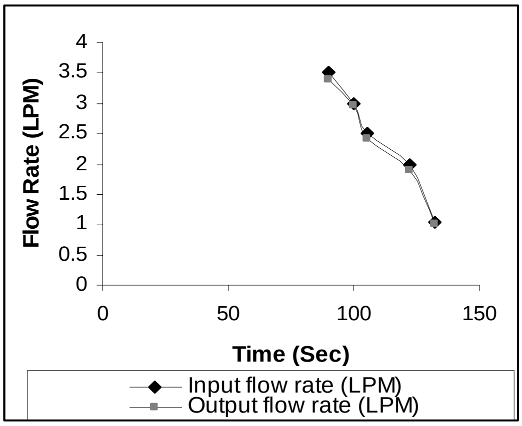

Fig. 5 Time effect on plant operation

C. Time effect on flow rate of gray water

Figure 5 shows the time required to flow the water from initial stage to final storage tank at various water flow rates. The input and output flow rates of water were nearly found the equal rates because there were no accumulations of gray water. The time required for 2.5 lit/min flow rate was 105 sec from input to output of the plant which was departed time of plant operation.

D. Performance of each stage of the system

The pH of gray water was changed by each stage of system as shown in figure 6. The aeration, agitation and filtration stages were found the involvement for change in pH of gray water. The pH level was changed mainly between 8.4 to 8.1 in agitation and 8.1 to 7.52 in filtration stage.

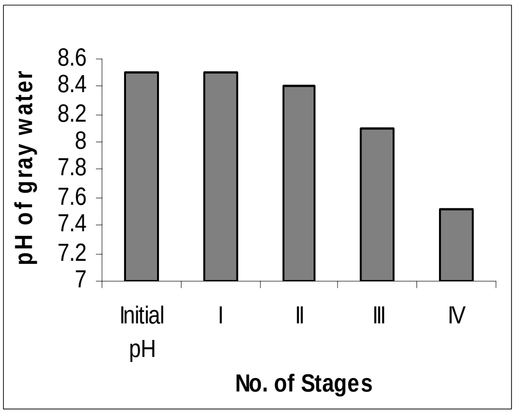

Fig. 6 pH level of gray water change in each stage of plant at 2.5 LPM water flow rate (I- Cascade stage, II- Aeration, III- Agitation, IV- Filtration)

Figure 7 explains the removal of gray water pollutants in each stage of the gray water treatment plant. Due to cascade, the course size and fine solid particles are settled down by gravitational force and only clear water flows towards aeration stage of the plant and found 11% of TSS was removed in the cascade stage. The major role of aeration was controlled the TDS and COD of gray water. The soap, detergents, oil and grease contained in gray water were removed by agitation operation. From the investigation, average pollutants removal efficiency of agitation operation was found up to 26 %.

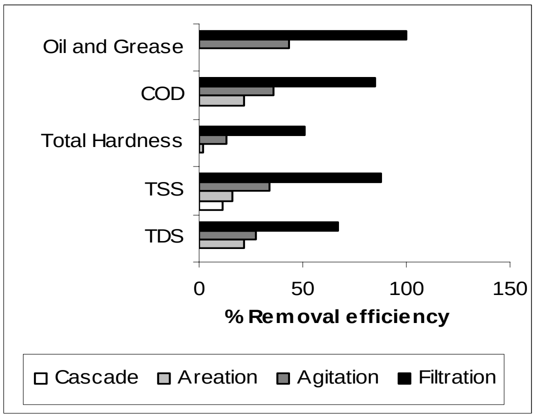

Fig. 7 % Removal efficiency of gray water pollutant in each stage of plant at 2.5 LPM water flow rate

All pollutants removal efficiency was increased by the filtration stage and found 36 % to 85 % of COD, 33 % to 87 % of TSS. The average removal efficiency of all pollutants for filtration stage was increased from 26 % to 69 %. The filtration stage found major role in the system for removal of pollutants from gray water. Hence the filtration stage was studied here and data of removal of load of pollutants on gray water by each filter bed was investigated and is explained in figure 8. The result shows that, coconut shell covers and charcoal filter bed gives better performance while bed of sand and sawdust shows the same performance in filtration stage.

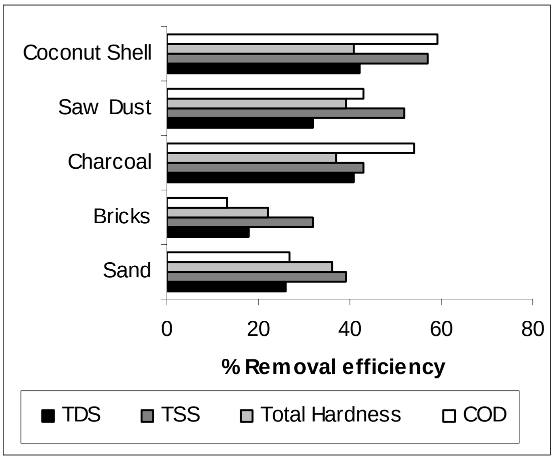

Fig. 8 % Removal of pollutants by each filter bed in the filtration operation

E. Performance of the laboratory scale system

The gray water was collected from bathrooms, basins of the residential area of college hostel located at Sinnar rural area in Nashik city, India. Total 08 samples of gray 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 gray water at steady state conditions and the average value data are summarized in table I. The average organic load in gray water found 327 mg COD/lit. The solids in gray water were found to have about 76% dissolved and 24% suspended particles. From table I, all the parameters found in gray water were reduced and found better performance of the natural system. The average 83 % of organic load was removed and 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 gray water.

IV. Discussion

The results presented in this study establish the potential applicability of the developed methodology. This laboratory scale gray 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 [11].

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 gray water.

The laboratory scale model shows the better and effective performance by the experiment and balances 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. Still, more research is needed about soil structure of the area which over applicable for irrigation and this will be presented shortly.

TABLE I
AVERAGE CHARECTERIZES OF BATHROOMS, BASINS OF GRAY WATER FROM A RESIDENTIAL COLLEGE CAMPUS LOCATED AT SINNAR RURAL AREA IN NASHIK CITY, INDIA

Parameters	Raw water (mg/l)	Filtered water (mg/l)
pH	8.12	7.43
Total Hardness	374	187
COD	327	58
TDS	573	172
TSS	184	32
Oil and Grease	7.2	0.24
Fluorine	0.82	0.43
Chlorine	37.9	21.47
Nitrites	0.08	00
Nitrates	0.67	0.21
Phosphates	0.012	00
Sulphates	21.3	10.66
Sodium	32.28	17.11
Potassium	4.52	1.98
Magnesium	0.11	00
Ammonia-Nitrogen	0.79	0.21
Calcium	0.13	00

V. Conclusions

The present study demonstrate the reuse and treatment of residential bathrooms, basins waste water called as gray 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.

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