IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

GREYWATER REUSE: A SUSTAINABLE SOLUTION FOR WATER CRISIS

[1] Aniket Vijay Pingale, [2] Mayur Manoj Deore, [3]Dipali Ghanshyam.Bagul

[1]Student, [2]Student, [3]Professor Civil Department, RSCOE,JSPM Tathawade,Pune

Abstract: a sustainable greywater filtration system for residential-scale water reuse. Recycled greywater can be used in toilet water, outdoor irrigation, car washing, and clothes washing, reducing the demand for potable water. Although pilot-scale systems have been demonstrated for greywater recycling, residential-scale applications remain unexplored, as treatment options on a residential scale are limited. It used several filtration methods, including micron, mineral sand, activated carbon, and ultraviolet disinfection. Multi-phase water testing was conducted to evaluate pH, turbidity, chemical oxygen demand, total organic carbon, and total nitrogen. The prototype proved capable of functioning in a real-world setting and filtering water to meet several non-potable urban reuse standards. This survey intends to discover the different treatment for grey water by breaking down the grey water attributes, reuse gauges, execution and cost.

Keywords:Greywater,Reuse,Standards,TreatmentTechnologies,Waterscarcity

I. INTRODUCTION

Due to global fresh water shortage, managing supply and demand for fresh water has always been a difficult task. Maharashtra is India's most densely inhabited state. Recycle and reuse are becoming increasingly important as the world's population grows. Grey water and monsoon rainfall collecting are important solutions for conserving fresh drinking water. Grey water is a combination of waste water from the kitchen, laundry, and bathroom, and filtration plays a crucial part in filtering this greywater. Fine sand, course sand, gravels, coal, and brick fragments were employed in the filtering system.

A vertical sand filter is the simplest greywater filter. Greywater should be subjected to physical and chemical tests. Material layer heights of 200mm, 400mm, and 600mm vary attributes and properties. The phrase "grey water" comes from its foggy appearance and the fact that it is neither fresh nor badly contaminated. Because fresh water is in short supply all around the world, balancing supply and demand has always been a difficult task. India is a country in the process of evolving. Maharashtra is known for being one of India's most densely inhabited states. Water demand is often increased by population expansion in all sectors of the economy: agricultural, industrial, and home. Rapid population increase, unplanned urbanization, surface water contamination, and ongoing ground water extraction are all contributing factors.

II. METHODOLOGY APPROACHES FOR GREY WATER TREATMENT AND REUSES

2.1 Background

Greywater can be viewed as an important resource which could be diverted for variety of application to water starved areas. With the increased challenges of freshwater availability, reliable alternatives like treated greywater need to be searched upon. Its constant availability throughout the year with low organic content makes it quite suitable and cost feasible for recycling and also a good source of water for augmenting water supply. Various Greywater treatment methods such as physical, biological, chemical, constructed wetland and combined treatment have been analyzed in this paper for both Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) removal efficacy. Also, the feasibility aspects of these technologies in terms of effluent generation, space consumption, financial viability, expertise required have been analyzed with reuse perspective and it was found that the relatively simpler technologies like physical treatment and constructed wetlands are cost effective in treating greywater and are suitable for reuse in landscaping and flushing. Complex technologies like chemical and biological treatment technologies generate related effluent suitable for stringent reuse applications. Social acceptance and awareness are some of the other aspects which need to be considered for enhancement of usage of such technologies.

- **Graywater Constituents**

The potential to reuse graywater needs to be balanced with the intended end use and the graywater composition. Constituents commonly found in graywater may pose a threat to the environment or human health. Graywater constituents include salts, pathogens, household pharmaceutical and personal care products and organics/nutrients (detergents are main source). When graywater is compared to domestic wastewater, graywater has lower contaminant concentrations of organics, solids, nutrients and pathogens. A number of studies have identified levels of pathogens in graywater that exceed regulatory limits for reclaimed wastewater and recreational water. The presence of indicator organisms is generally taken as confirmation of fecal contamination and subsequently the presence of pathogens and viruses which pose a threat to human health.

- **Gray water Regulations**

Graywater is characterized as a low-strength wastewater due to the absence of toilet effluent and dishwasher/kitchen sink discharges, however still contains the presence of organics from food particles and pathogens measured in the form of indicator organisms from fecal matter. Graywater quality, just as the quantity, is variable from location to location depending upon the sources, personal hygiene habits, and season. Pathogenic presence in graywater is due to human contact and a function of human health and behavior, and therefore requires disinfection as a means of pathogen inactivation during the treatment process. For graywater applications that require secondary treatment due to the likelihood of human contact, there are multiple treatment technologies available. Treatment can be based on biological processes (membrane bioreactors, rotating biological contractors, and constructed wetlands), or chemical/physical processes such as a simple combination of filtration and disinfection.

- **Graywater System Configurations**

The components integrated into residential graywater systems vary depending upon the characterization of graywater sources, the residential application and local regulatory requirements. All of these factors contribute to the graywater reuse system design which can be extremely basic to highly complex. More basic designs include storage and often filtration before application. More complex designs have been seen to replicate domestic wastewater treatment on a small scale with the inclusion of expensive disinfection systems. Alkhatib et al., (2006) presents a comprehensive overview of graywater collection and treatment systems which includes a wide range of proprietary and individual homeowner design configurations.

2.1.1 Gray Water Treatment And Reuse In India – Why?

Water shortages are emerging as major issues brought about by factors such as urbanization, pollution of water bodies, human lifestyle needing higher water demands, industrial growth increasing water use and higher water consumption due to urbanized lifestyles. As new water sources are unlikely to be found, these shortages can be overcome by recycling of wastewater. Although attempts to collect new water sources are being tried out such as rainwater harvesting, desalinating seawater, dew harvesting, etc. wastewater treatment and recuse can give the best and fastest relief to the emerging water shortages. Primary water costs can vary from |25 to 100 in Water scarcity is emerging as a major issue in the urban and peri-urban regions of India which is caused by a high population density, low rainfall and high groundwater extraction. Grey water (GW) treatment and reuse within the same house is an easy option to overcome short-range water shortages (>50%) but requires overcoming social barriers. Biological treatment of GW is challenging due to low fermentable C, complex chemicals such as surfactants and xenobiotics and highly variable loads on treatment systems. Commercial GW treatment technologies are nascent and need to overcome techno-economic bottlenecks as well as enable social integration.

2.1.3 WHO Guidelines for agricultural use of wastewater

Standards developed 10-20 years ago (1969-1979!) tended to be very strict, as they were based on an evaluation of potential health risks associated with pathogen survival in wastewater, in soil and on crops, and on technical feasibility. The technology of choice for pathogen removal at that time was effluent chlorination. Evaluation of the credible epidemiological evidence – that was, an appraisal of the actual, as opposed to potential, health risks – indicated that these standards were unjustifiably restrictive. As a result of those considerations, a meeting of experts held in Engelberg, Switzerland, in July 1985, The irrational application of unjustifiably strict microbial standards (as mentioned above) for wastewater irrigation had led to an anomalous situation. Standards were often not enforced at all and serious public health problems resulted from totally unregulated illegal irrigation of salad crops with raw wastewater as it is in fact widely practised in many developing countries. The WHO approach called for realistic revised standards which were stricter for helminths removal but more feasible regarding bacterial levels (WHO, 1989b). For developing countries, it is therefore more feasible to rely on the WHO guidelines for their own legislation than on the following USEPA guidelines

- **Irrigation of food crops**

The use of reclaimed water for irrigation of food crops is prohibited in some states, while others allow irrigation of food crops with reclaimed water only if the crop is to be processed and is not to be eaten raw.

- **Irrigation of non-food crops**

The use of reclaimed water for agricultural irrigation of non-food crops presents a reduced opportunity of human exposure to the water, resulting in less stringent treatment and water quality requirements than other forms of reuse. The recommended maximum concentrations for "long-term continuous use on all soils" are set conservatively to include sandy soils that have low capacity to leach (and so to sequester or remove) the element in question. These maxima are below the concentrations that produce toxicity when the most sensitive plants are grown in nutrient solutions or sand cultures to which the pollutant has been added

2.2 Grey Water Treatment Technology

Grey water treatment methodologies range from simple low-cost devices that divert grey water to direct reuse, such as in toilets or outdoor landscaping, to complex treatment processes incorporating sedimentation tanks, bioreactors, filters, pumps, and disinfection. Some grey water plants are home-built, do-it-yourself style through piping and storage systems. On the other hand, there are also a variety of commercial grey water systems available that filter water to remove hair, lint, and debris, and remove pollutants, bacteria, salts, pharmaceuticals, and even viruses from grey water.

2.3 Research Work done On Gray Water Treatment in India

A lot of research work has been carried out on treatment and reuse of gray water at different institutes and R & D sectors in India to get suitable methods for conservation of water. Shegokar et al studied and designed a laboratory scale gray water system. They concluded that only physical operation such as gray water collection, sedimentation and filtration using nylon rope and storage system could be taken as a viable alternative method to conventional treatment system in rural areas (12). In Nashik, Maharashtra the design of lab scale gray water treatment plant was suggested by the researchers. They developed the system for small college campus in rural areas (1). A training course was carried out under Innovative Ecological Sanitation Network India (IESNI) on Small-Scale Constructed Wetlands for Graywater and Total Domestic Wastewater Treatment in Pune, Maharashtra (13). David Prashant Asirvadam et al worked-on treatment of gray water using constructed wetland system with Canna Indica plant. They compare the characteristics of gray water before and after treatment and concluded that constructed wetland system would be a better solution for treatment of low organic gray water due to its simple, low operational and maintenance cost (14). Gorky S. S. from Tamilnadu, India worked on treatment of gray water using constructed wet lands. They used this natural system to treat the water on laboratory scale. Researcher concluded that sub-surface vertical flow constructed wet land could be used effectively for treatment of gray water (15). Edwin et al reported that natural treatment systems are the better alternative for treatment of waste water, especially in developing countries

2.4 Evaluation of Different Available Systems for Grey Water Treatment

There is a great number of grey water recycling systems available which vary greatly in complexity, performance and cost. These systems range between simple one house systems to very advanced treatment processes for large scale reuse. It can be generally stated that the expense of a system is related to the final quality of treated waste water. It should also be noted that different reuse applications require different water quality specifications which demand different treatments which account for the range in complexity of available systems.

The evaluating strategy

Our strategy was built on evaluating the different grey water treatment systems that already applicable in different countries. The evaluation process was carried out according to a specific grading and ranking system developed by R&D TECH team. Table 6 describes this system, in which the most important parameters for evaluation were given weighing based on ranking points starting from one to ten. The evaluating parameters were:

•**The scalability:** This parameter gives indication about the easiness of the scaling up procedure of the selected system.

•**The mode of operation:** This parameter gives indication about whether the operation will be done manually, partial automatic or fully automatic.

•**The system running:** This parameter gives indication about the periodic interaction to the system to maintain a safe running.

•**The periodic Maintenance:** This parameter gives indication about the maintenance of the different systems.

2.5 Grey water reuse guidelines

The reclaimed grey water should fulfill four criteria (hygienic safety, aesthetics, environmental tolerance and economic feasibility) for reuse. However, the lack of appropriate water quality standards or guidelines has hampered appropriate grey water reuse. One shall also keep in mind that different reuse applications require different water quality specifications and thus demand different treatments varying from simple processes to more advanced ones. There has been no uniformly enforceable international water reuse guideline to control the quality of the reclaimed wastewater. In many cases, the national water reuse guidelines vary from states to states. There is considerable variation among these guidelines, particularly regarding identifiable values and the limited parameters. The differences observed between published reuse criteria reflect differences in need, applications and social factors (Pidou, 2006). Very few reuse guidelines are particularly made for grey water recycling. Regulations and guidelines for grey water reuse mainly focus on the healthy and environmental impacts and are often established by local authorities. In 2006 the World Health Organization (WHO) released a guideline for grey water reuse for restricted and non-restricted agricultural irrigation.

2.6 Establishment of the guideline for grey water reuses

Based on the studies, a non-potable grey water reuse guidelines are proposed for both unrestricted and restricted reuses. Obviously, the restricted non-potable reuses have lower water quality requirements, compared to the unrestricted non-potable reuses. This guideline includes parameters like fecal coliform, total coliforms, TSS, Turbidity, BOD5, detergent, TN and TP.

2.7 Grey water treatment technologies

Technologies applied for grey water treatments include physical, chemical, and biological systems. Most of these technologies are preceded by a solid-liquid separation step as pre-treatment and followed by a disinfection step as post treatment. To avoid the clogging of the subsequent treatment, the pre-treatments such as septic tank, filter bags, screen and filters are applied to reduce the amount of particles and oil and grease. The disinfection step is used to meet the microbiological requirements.

2.7.1 Physical treatments: -

The physical treatments include coarse sand and soil filtration and membrane filtration, followed mostly by a disinfection step. The coarse filter alone has limited effect on the removal of the pollutants present in the grey water. The soil treatment system could remove organic pollutants and total phosphors partially. Due to the nitrification and de-nitrification reactions in the soil treatment system, nitrogen was eliminated effectively. Obviously, the soil filter applied in this study cannot be regarded as a single filtration but a combination of filtration and biodegradation Nevertheless, the relative higher residual organic substances in the treated grey water by membrane filtration often promote the re-growth of the micro-organisms in the storage and transportation system.

2.7.2. Chemical treatments: -

Very few chemical processes were reported for grey water treatments and reuses. The chemical processes applied for grey water treatments include coagulation, photo-catalytic oxidation, ion exchange and granular activated carbon.

2.7.3 Biological treatments: -

Several biological processes, including rotating biological contactor, sequencing batch reactor (SBR), anaerobic sludge blanket (UASB), constructed wetland (CW) and membrane bioreactors (MBR), have been applied for grey water treatment. The biological processes were often preceded by a physical pre-treatment step such as sedimentation, usage of septic tanks or screening). Aside from the MBR process, most of the biological processes are followed by a filtration step (for example sand filtration) and /or a disinfection step to meet the non-potable reuse standards.

2.8. Selection of appropriate technologies for grey water treatments and reuses

The characterisation of grey water reveals that the grey water shall be treated to a higher standard before reusing to avoid the health risk and negative aesthetic and environmental effects. The major target of grey water reclamation and reuses is to reduce the suspended solids, the organic strength and the micro-organisms due to its relationship with the aesthetic and health characteristics of the product water and directly through legislative requirements. A literature review of the reported physical processes for grey water treatment and reuses is summed up in Table 5. Obviously, coarse filtration and soil filtration alone are not able to reduce the physical, chemical and microbiological parameters to the values required by the non-potable reuse guideline. The micro filtration and the ultra-filtration membrane provide a limited removal of the dissolved organics but an excellent removal of the suspended solids, turbidity and pathogens.

III. RESULTS AND DISCUSSION

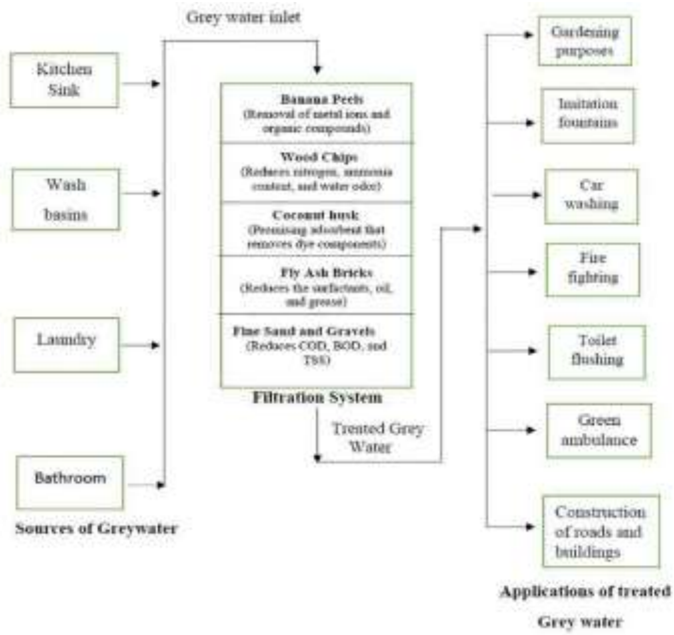

Fig. 01 - Filtration Assembly Fig. 02 - A schematic diagram of the mechanism of removing pollutants to supplement the system

All the above filter layers were laid into the PVC container of 20 L, height 100 cm and width 30 cm, in a chronology as mentioned in Table 1, and the filter unit was prepared as shown in Fig. 1. Fig. 2 depicts a schematic diagram of the mechanism of removing pollutants to supplement the system. In between these filter layers, nylon meshes of pore size 1 mm were placed to hold these layers in place. The mesh was placed between the coconut husk and gravel layers and between the banana peel and subtle sand layers, The filter height and width were decided by a trial-and-error method wherein; similar filter units were prepared of different heights and width. The preliminary filter was ready in a 2 L coke bottle, and the filtration efficiency was checked by visual inspection of the input and output greywater. Subsequently, the filter height and width were increased using different sized containers, and their efficiency was checked. Three such filters were prepared, and finally, the filter unit with the above-said specifications was seen to give the best output, and thus it was selected for further investigations. At the bottom of the container, small holes of diameter 2 cm were made for the effluent. Sampling point P1 was provided for the influent and R1 for the effluent. The filter unit was placed at the height of 40 cm above the ground level over an iron tripod stand, and the effluent was collected from below into a collection vessel.

Parameter		pH	TURBIDITY (NTU)	Chlorine (mg/L)	BOD (mg/L)	COD (mg/L)
Kitchen Sink	Before	7.1	298	717	998	1038
	After	6.7	62	40	126.9	145.5
Laundry	Before	8.55	247	266	260	1590
	After	7.4	52	15	33.0	222.9
Wash basin	Before	8.1	102	181	252	424
	After	7.3	21	10	32.0	59.4
Bathing	Before	7.4	209	256	215	366
	After	71	44	14	27.3	51.3
Mixed	Before	7.4	133	216	245.4	831.6
	After	6.9	28	12	31.2	116.5

Table 1

Table 1 shows the various parameters before and after treatment. The parameters evaluated had high values before the application of the treatment procedure. There was a decrease in the investigated parameters' values, which proves that the filter layers were efficient in the treatment. It can also be seen that the generation and characteristics of greywater vary greatly depending upon its source. The variation in the parameters defining greywater also depends on the time of the year, i.e., the greywater parameters vary seasonally.

This study aimed to develop low-cost greywater recycle unit. And hence, most filter materials used were waste products generated in the house itself. These filter materials, therefore, are free of cost and readily available.

IV. SUMMARY AND CONCLUSION

From this study, it can be very well demonstrated that a filter unit integrating various filter layers proves to be a useful way of treating in-house generated greywater and using it then and there itself, which reduces the freshwater requirement and saves a significant amount of money and energy. The filter unit described in this study was found to have achieved a COD removal efficiency of 85.98%, BOD removal efficiency of 87.28%, and turbidity, which was reduced by 78.94%, and TSS were decreased by 94.44%. Removal efficiencies are higher than obtained in earlier studies. Even though this system proves to be efficient in treating greywater to levels permissible for its reuse in gardening, firefighting, etc. It is still not yet fit for human consumption and requires further treatment. This greywater reuse method by masses would ensure a reliable water supply to our future generations. It can be concluded from this study that greywater can be recycled and reused for purposes such as toilet flushing, gardening, car washing, firefighting, and this practice will lead to a significant reduction in the consumption of freshwater.

V. RECOMMENDATION

Grey water reuse is an important alternative for reducing potable water consumption in the different building occupancies.

•The review shows significant variations in quality and quantity of grey water in terms of time and sources, and that variability is largely the selection of the treatment system.

•The review also reveals that in recycled grey waters, heavy metals and organic micro-contaminants generally pose no threat to human health when properly treated.

•The results showed that the environmental advantage of the strategy is the use of water-efficient systems. This saves significant water and reduces wastewater.

•The environmental impact is low due to the reduced consumption of energy over the life cycle.

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