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Grey-Water Treatment and Reuse: A Review

R. Prashanna Rangan[1] and K. Heenalisha[2]
[1&2]UG Student, Department of Mechatronics Engineering, Kongu Engineering College, Tamil Nadu, India
E-Mail: prashanna098@gmail.com

***Abstract* - Globalization as well as Rapid industrialization had made an evil impact and led to the over usage of water, since it has been raised drastically in the last decade. This increase in water demand has led to a situation at which humans find difficulty in availing the water for their needs. There has been a great technological research been conducted on waste water recycling methods. Grey-water is a form of waste water, consisting of kitchen water, bathrooms, dish and cloth washers. Reusing of Grey-water has become a better choice, but since the amount of dissolved contents are unknown, it is mandatory to recycle before reuse. Since Grey-water is less in organic and BOD content and free from faecal matter for reproduction of bacteria, it could be recycled easily by adapting various techniques. The recycled water may be used for many regenerative purposes, say irrigating the agricultural lands, toilet flushings, home garden watering, etc. this paper aims in revolving the possible techniques that can be utilized for recycling the grey-water.**
Keywords: **Grey-Water Recycling, Waste Water Control, Reuse Techniques, Water Scarcity, Urbanization, Treatment Technologies, Water Sustainability**

I. INTRODUCTION

Water is been widely used by all the people, around the world for various purposes from washing to planting crops and from drinking to cleaning. Nearly three fourth of the world is covered by water, yet the amount of freshwater being available for human need has been drastically reduced in the recent years.

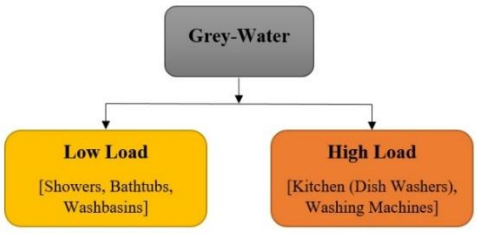

Fig. 1 Grey-Water types

The household water is generally divided into two main categories namely, potable water and waste water as sewerage water and mostly around 50-80% of the sewerage water are from kitchen sinks, bathing, showers, washing machines, dish washers etc., are they are generally referred as grey-water. They may also contain a complex mixture of organic matter and suspended solids. Around one third of sewerage water is the black water from toilet drains, containing of human wastes. In comparing the above two, grey-water can be used for recycling purposes, since it does not have any fecal matter for reproduction of bacteria. Hence can be recycled and utilized for other regenerative purposes, other than potable uses. If the waste water in the form of grey-water is recycled in a proper manner, it could lead to the elimination of the use of potable water of about 70 Liters per person per day. Since the potable water is reduced, according to a survey carried out by Aarhas University [6], it is estimated that by the year 2020, around 30-40% of the world nations will face water deficit and researchers have also expressed that climatic changes also worsen the situation. Surveys states that usable domestic Grey-Water could meet up to 35% of the demand for water for various non-potable uses. Fig.1 clearly depicts the major two types of sources for Grey-Water.

In the near future, the most costliest thing will be the Water and as per the prediction, it is stated that Third World War may arise due to water shortage. There are huge gallons of water in the Ocean and yet it cannot be directly consumed as it involves huge processes for human consumptional purposes. Thus recycling of Grey-Water is considered as one of the viable solution of the present to meet up with the increased water demand. The basic cycle of life is the Water cycle and hence it has become mandatory to keep it balanced.

At many places around the world, digging of huge bores is made to extract the fresh water, which has also started depleting as the fresh water content available beneath the Earth is reduced. Desalination is yet another major methodology, carried out by most of the Leading World Countries but it is quite costlier in production. Rainwater harvesting can also be a good alternative for meeting the increased demand for freshwater, but it has some limitation as only the regions receiving high amount of rainfall will owe the benefits of it. Hence recycling the Grey-Water proves to be a very friendly approach for meeting the huge demands at the present for water. It is a mandatory step to recycle the Grey-Water before reusing it, since the amount of dissolved content may harm the user. This paper aims to put forth the possible recycling methodologies that are adapted at the present for reuse of Grey-Water.

Ref [1] is a review paper which speaks about the various recycling and reusing techniques that can be adopted for treating grey-water. It also adds a point related to recycle of grey-water is completely encouraged the most by the

Ministry of Environment and Forest, since the fresh water available has been reduced drastically. [2] Is a research article, which speaks about the availability of pe-capita freshwater that is, being available to the common man in various countries and its impacts by the change in climatic condition and population. It also speaks about the amount of Fresh water availability around the World by using Z-Scores and CCSM-3 based calculations. It gives out a decadally averaged data for the decade 2000-09. [3] Speaks more about the reuse of Grey-water and it compares between the use and utilization of Rainwater, Desalination and Grey-water and finds Grey-water to be more suitable at the present, as Desalination owes pollution related problems and Rainwater is not dense in all areas. It also explains the advantages and disadvantages of reusing the Grey-water. [4]

Is a review work, which describes in detail the available Physical, Biological and Chemical methods for treating the Grey-water and discusses about the various methods that are currently carried out in India [5]. Is an intensive review paper, which aims in providing a treatment technique to Grey-water, based on the characteristics, reuse standards, technology being adapted and the overall cost incurred for the setup. It also speaks more about the treating system and the qualities that are to be inherited by them [7]. Creates a financial model, which helps in explaining the utilization of Grey-water for non-potable purposes. It also explains about the Capital cost, operational cost and Net Present Value (NPV). It compares two different methods and finally concludes that Membrane Bio Reactor (MBR) water treatment was much better than Vertical Flow Constructed Wetland (VFCW) for shared systems. [8] Says about the construction of an onsite Grey-water recycling system for Qom province, located at Iran. Due to the presence of two major deserts, adjacent to the city, water scarcity has become a major issue and hence recycling of Grey-water is bee carried out there.

The recycled Grey-water is used for irrigating the University's green space. The average flow rate of the water is around $0.012 m^3/s$. [10] Develops a mathematical model forinvestigate the performance and treatment capability of Rotating Biological Contactors (RBC) for treating Grey-water. [11] Elucidates the necessity of treating Grey Water before recycling it and also developed a model for recycling the Grey Water and proposes it to be used for agricultural purposes.[12] Speaks about the construction of a pretreatment system and a mini-wetland in the Village dwelling to avoid the contamination of water bodies. It also measures the effectiveness of the Grey Water wetland treatment system.[13] Made a detailed analysis on the water availability and states that nearly 150 million people live with inadequate perennial water availability. It also predicts that by the year 2050 this will be raised to 1 billion if the current scenario continues. Climatic changes will also lead to water shortage to an additional 100 million urbanities. This article focuses mainly on water availability component and depicts about the perennial and seasonal water shortage for the year 2050 and compares with that of 2000. [14] Speaks about the reuse of Grey-Water for agricultural purpose. A survey was conducted for 47 respondents over 18 years of age from various socio-economic background and found that about 85.1% relied on public water resource as the primary and 57.4% on private water tankers as second most important resource and 6% relied only on private resources.

The survey also gives results that rural communities are ready to accept reuse techniques for Grey-water and to implement it for irrigation purposes. [15] Is a quality study paper that focuses on the treatment systems that could possibly carried out for treating Grey-Water. It also proposes 5 treatment methods and shares the best method in regard to the average suspended solids after treating was the water hyacinths, copper ion, and sand filtration system and for best average turbidity it was found as copper/silver ion generating unit with sand filtration. [16] States that the major pollutant of Nitrogen is the household waste water. It shares in brief about the amount of Nitrogen that will be emitted by carrying out various methods for waste water treatment. It also describes about the cost effective and the most costliest methods that are carried out in Nitrogen mitigation during waste water treatment. It states that the centralized plant for Waste water treatment is the most costliest one with less effectiveness in cost for all the cases [17]. Speaks about the reuse of Grey-Water and explains the problem that may arise due to non-proper management. It made a case study of Grey-Water that arises in Rajupura village near Vasad (22.473 N, 73.085 E) and tries to reduce the load to WSSB.

In this case study, the Grey-water is directly drained into roads, which caused mosquito nuisance as well as polluted the river water. The total amount of Grey-water produced in that particular village was 72900 litres, which is about 60% of the total fresh water supplied. It explains clearly the layout and puts forth a design that could be viable for the village. The paper also made some calculation by forecasting the population growth by 2030 and designs a sedimentation tank and filter that is used to recycle Grey-Water [18].

Reviews the low carbon technique and states that produced excellent analytical results as well as consistency in performance. It also made a questionnaire to the common public and asked them 135 questions out of which 95% accepted the Grey-Water by considering one or more attributes [19]. Proposed a technique where vegetated wall could be used for consuming the Grey-Water. [20] Is a review paper that focuses on a survey that is carried out with the general public for the acceptance of Grey-Water. It also pose the regulation for Grey-Water recycling in the U.S. [21] Points out the various techniques and compares with each other. It says that the filtration has only a limited effect on Grey-Water while biological methods prove to be comparably useful in treating the wastewater. [22] Proposes some useful techniques that could be adapted for treating Grey-water.

II. CHARACERISTICS OF GREY-WATER

TABLE I US EPA GREY-WATER REUSE STANDARDS FOR DIFFERENT USES

	pH	BOD (mg/L)	Turbidity (NTU)	TSS (mg/L)	Fecal Coliforms (CFU/100ml)	Residual Chlorine (mg/L)
Landscape Irrigation	6-9	10	2	-	0	1
Agriculture	6-9	30	-	30	200	1
Toilet Flushing	6-9	10	2	-	0	1
Ground Water recharge	6.58.5	-	2	-	0	1

The characteristics of the Grey-water vary greatly depending on the place and type of uses. Sometimes the grey-water is found with stains of oil or grease from kitchen sinks and some surfactants in the laundry water from washing machines. These mixtures could reduce the efficiency in treating the water. The properties that should be possessed by the Grey-water for various recycling purposes are mentioned in the Table I. For the various usages, the recycled Grey-water must possess some characteristic features, in order to be harmless for usage, as mentioned in [8, 9].

III. GREY-WATER TREATMENT TECHNIQUES

Based on the contamination level, various treatments are carried out to purify the Grey-water. The intensity of purity decides the number of steps involved in the treatment. Reuse of Domestic Grey-Water for potable uses requires very high levels of recycling processes and hence it is majorly used only for on-potable purposes namely landscape irrigation, agriculture, flushing of toilets etc,. The treatment involves the treatment methodologies like physical filtering, chemical and biological treatments.

A. Physical Treatment

Ref [8] uses a 1CM mesh to screen the suspended solids that are present in the Grey-water. The water is then stored to a septic tank buried underground and then passed through a trickling filter to settle down the suspended plastic media. The trickling filter is made of mineral Lika. The processed water is then made to settle at the settling tank, where the sludge gets settled at the bottom and is removed.

Ref [10] uses Rotating Biological Contactors experimental pilot plant system to analyse its mathematical model. The Grey-water is passed through a coarse screen and later to a 3mm mesh size screen before entering the RBC plant. The RBC plant consists of 36discs with 16.2m^2 of total disc area. The experiment was carried out for low, medium and high concentration of Grey-water for a period of 10 months. A flow rate of 400L/d was obtained. [11] Owes a plant layout Area of 12.5 m^2, Depth of 0.6 m and a slope of 1% at the bottom. Coarse screening for pre-treatment was developed with the Gravel specifications are Drainage layer of 30 cm on each other with Size of 15–25 mm, Transition layer of 15 cm on each other with Size of 5–15 mm and Filter layer of 4.1 m with Size of 2–5 mm. The setup also adds up a disinfection treatment by employing the passage of UV rays by lighting up 8 lamps of 50Watts each to the treat the water. System [12] consists of a pre-treatment layer of coal and fine sand (Dia<0.2 mm) sandwiched by Gravel on top (Dia 20-50 mm) and bottom (Dia <15 mm). The setup develops a mini wetland model and dumps the filtered Grey Water that consists of clay soil layer, beneath which the fine sand and gravel layers are laid. [15] Proposes a technique that uses sand filtration as the main filtering technique, followed by ion generating unit consisting of copper/silver based on the requirements. [17] Carries out a developmental setup of shared Grey-Water recycling system for their entire village that consists of a sedimentation tank and a filter as a result of which TDS count is reduced much. [19] Consists of a wetland in the form of green wall, which has a filter media consisting of sand and gravel as the primary layer that filters the solids. The top layer is left for vegetation to allow deep and wide roots. The system [22] consists of soil bed acting as a pre-treatment followed by soil-box planter, which is used for plantation of crops. The process flow starts from the septic tank, where the waste water is collected and is transferred to the sand filter, where the suspended solid gets filtered. It is followed by a pump pit and later the water is discharged into the planter bed.

B. Biological Treatment

Ref [10] is made to pass through UV rays to filter the pathogens that may be present in the Grey-water. Speaks about the construction of Horizontal sub-surface flow constructed wetland (HSSF CW) reactor [11].

C. Chemical Treatment

Ref [8] uses chlorination technique to make the water disinfectant and thus making it viable for other uses. Uses some tests to analyse the quality of the recycled water [11]. It makes use of modified Winkler method, dichromate open reflux method, indophenol method, diazotization method, Kjeldahl mineralization for BOD, COD, NH_4^+-N concentration, NO_2-N, Total Kjeldahl nitrogen (TKN-N) respectively.

IV. MERITS AND DEMERITS OF GREY-WATER

A. Merits

1. Leads to less utilization of freshwater
2. Eco-balance

3. Replenish the ground water
4. Incurs less water bills
5. Reduces the water demand for irrigation purposes

B. Demerits

1. Detergent content in Grey-water may lead to increased base level of the water
2. May contain fatty substances, oils, detergents, lint, fabric softeners and other substances which may find harmful for plant growth
3. Cannot be stored, since it creates a bad odour due to breakdown of nutrients in it
4. Purification process is quite complex for small scale.

V. RESULTS AND DISCUSSION

Ref [10] by developing a mathematical model for RBC, it provides an efficiency of 83.6%, 92.8% and 94.8% for low, medium and high influent concentration for TSS removal and 94.2%, 95.5% and 95.9% for BOD removal. The total nitrogen removal was about 58.6% and 74.3% for medium and high concentrated Grey-water. [11] Has a quality checked for the water inlet Vs the outlet of the HSSFCW for every 100 days to ensure the water quality. Once every five days the Physico-chemical parameters like the pH, EC, BOD5, COD, TSS, TN, TP and once in a fortnight Microbiological Parameter (FC) is monitored. The process achieved 88% of removal of total Chemical Oxygen Demand and Suspended Solids from the Grey Water. Other parameters like turbidity, BOD5 and surfactants were about 88, 87 and 84% respectively. The mini wetland model [12] shows a high removal performance of about 81.42 % for Biological Oxygen Demand, 84.57 % for Chemical Oxygen Demand, 39.83 % for Ammonia Nitrogen, 54.70 % for Suspended Solids, and 45.01 % for turbidity. The entire setup is used to cultivate the crops. [15] The system was capable of removing fecal indicator bacteria, suspended solids, and turbidity from the Grey-Water by making use of the water plant Hyacinth along with ion generating unit and sand filtration. This process finds to be cost effective [16]. Elucidates in detail about the amount of Nitrogen that will be emitted by carrying out each recycling techniques for waste water. It describes about both Grey-Water as well as Black-Water in Septic tanks and concludes that a centralized waste water recycling plant is the least cost effective in all the cases. [17] As a result of the construction of the shared Grey-Water recycling system, the various parameters like pH, Turbidity, BOD, TS and COD have been reduced to a greater extent and is shown in the Table 2below. The system also proves to be simple yet effective method for treating Grey-Water, before it could get mixed with the river water.

Ref [18] made a detailed analysis by putting forth the questions to about 135 adults and found some common points that arised during Grey-Water reuse. These are some common questions like subsidies, smell that may arise, impact on the environment etc., but these are evident for implementing the system for real time use. [19] Shows a performance of about 90% efficiency for removal of BOD5, COD and TSS. System [22] proves to be simple and effective method for reusing the waste water for plantation of crops.

TABLE II RESULTS OF [17] FOR UNFILTERED AND FILTERED GREY-WATER

Parameter	Unfiltered	Filtered
pH	8.4	8.08
Turbidity(NTU)	81	15
BOD (mg/lit)	274	104
TS(mg/lit)	1080	104
COD(mg/lit)	560	240

VI. CONCLUSION

In comparing all the available technologies for recycling the Grey-water, physical methods like sand filters prove to be very less helpful in filtering the solid particles. Membrane technology is comparably better to sand filtering as it filters most of the solid particles, but biological substances are left the same. Extensive biological treatments are used to remove the dissolved bacteria to a limited extent. Membrane technology and limited biological treatments could be used for obtaining better results that could be most suited for irrigation purposes.

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