BEST PRACTICES FOR SPECIFYING, DEPLOYING, AND OPERATING WASTEWATER RECYCLING SOLUTIONS

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Abstract

A global water crisis driven by global heating and the climate crisis is affecting the entire planet. Among the most practical and accessible of solutions to addressing that shortage is by implementing wastewater recycling technologies wherever possible. This white paper explains how to get started in identifying requirements for your own wastewater recycling system.

Overview

The global water crisis has deeply infiltrated almost every major population center, driven by the ever more aggressive global heating pattern across the world.

The droughts, famines, and floods that were once sporadic have now turned into recurring phenomena. Heat waves now dry up aquifers we have relied on since the beginning of time. Along the coasts, that drying phenomenon is drawing in saltwater, causing further damage to the freshwater which used to be plentiful

These impacts of climate change have antagonistically impacted and reduced the available water

The world is far behind the schedule of the UN's Sustainable Development Goal 6, which ensures availability and sustainable management of water and sanitation for all. Although the water reserve cannot be reverted, by adopting several sustainable water recycling techniques, a large portion of the water insecurity can be solved. Water recycling techniques have grabbed the attention of many, due to their simplicity and ease of installation. The recycling systems treat and reintroduce the wastewater into the water supply system, to be reused by the users. The greywater and blackwater recycling systems are separated and are treated differently. For achieving the best results of recycling systems having minimum health hazards; higher treating efficiency; economically feasibility, several best practices for specifying, deploying, and operating the systems must be adopted.

Keywords: Best practices, greywater, blackwater, recycling systems, constructed wetlands, biodigester.

1 Introduction:

We are now at the peak of the climate crisis with no point of return. Frequent natural calamities and anthropogenic activities have intensely impacted the freshwater reserves. The freshwater reserves constitute only 2.53% of the total water present on the surface of the earth, out of which ~ 1.77% of water is trapped in polar ice, ~ 0.76% forms the groundwater and only 0.03% is available as surface water.

The climate crisis has exposed many nations to famine and droughts, aggravating the issue of water scarcity. In 2050, about 52% of the projected population of 9.7 billion people globally will reside in water-stressed areas. The freshwater reverses are dwindling on daily basis owing to overpopulation, urbanization, and industrialization. There is an urgent need for conserving freshwater and safeguarding it for future generations.

Conventionally treated sewage wastewater is discharged into aquatic bodies such as rivers and the oceans, which leads to the loss of water forever. Even untreated wastewater is unfortunately dumped in many parts of the world into sewage systems, freshwater streams and lakes, and oceans. This leads to the formation of harmful algal blooms and aquatic dead zones. The only solution to mitigate the water insecurities caused by all of this is to adopt and embrace several recycling techniques. The recycling techniques majorly involve treating the wastewater and its reuse. The wastewater generated could be a promising source of freshwater and will become the major source of water very soon.

The wastewater generated in homes on an everyday basis comprises two chief streams of water. One is referred to as 'black water' and the second is the 'grey water'. A comprehensive system for recycling wastewater comprises efficient recycling of both mentioned streams. However, the course of treatment varies for both streams of water. 'Grey water 'is the wastewater generated in the bathroom, laundry, and kitchen. Greywater is a component of domestic wastewater, which has not been originated from toilets or urinals. The wastewater from the toilet or urinals is collectively referred to as 'black water'.

2 Grey water recycling solutions

The recycling and reuse of greywater include a series of steps for treating the greywater to a level that is safe for its further reuse in varied applications. An efficient and customized plumbing system allows an appropriate collection of greywater from different sources such as showers, laundry, kitchen and holds it into a surge tank. The primary aim of the surge tank includes the storage/holding of greywater before its treatment at the times when the input of greywater is relatively high, such as during the morning times when inmates of the house are bathing and washing at the same time.

2.1 Overview of Greywater treatment system:

The entire greywater treatment system can be easily divided into three stages, which include a) primary treatment, b) secondary treatment and c) tertiary treatment.

2.1.1 Primary Treatment:

The goal of the primary treatment involves the expulsion of coarse particles like hair, food particles, lint, etc. (by a screen), followed by the maximum removal of oil and grease (by oil trappers).

Relatively smaller particles of the greywater get subsequently removed by allowing the greywater to pass through the settling tank. The velocity of incoming greywater is reduced to allow the settling and separation of various particles. Generally, baffles can be provided in the settling tank to increase the aeration, mixing, and prevent the solid deposition (Devott, Wate, & Godfrey, January 2007). Natural coagulants such as ground seeds and drumsticks can be added to the tank. However, the settling tank fails to remove the fine flock particles, colour, and microbes, which are subsequently removed by filters.

The selection of filters utilized in the greywater treatment system predominantly depends upon the amount of greywater to be filtered, the type of contaminants present, and its end-use. During filtration, the turbidity, protozoan cysts, and helminth eggs are also removed. It's been observed that the protozoa are filtered by the gravels, bacteria by the medium gravels, and viruses by sand. Several filters include, (a) Up-flow - downflow filter (b) Multi-media filter (c) Slow sand filter, and (d) Horizontal Roughing filter. However, the upflow-downflow filter illustrates high efficiency. It largely comprises 4 columns *refer to figure 1.*

As the name suggests, the water is added at the bottom of the first column of the filter and collected at the top of the second column of the filter. This water is again fed at the bottom of the third column of the filter and collected from the top of the fourth column of the filter. The filter media differs in each column. Each filter column consists of:

- First filter column (near the inlet of greywater) – gravel 40 – 60 mm size.
- Second filter column – gravel 20- 40 mm size.
- Third filter – coarse sand (1-5 mm)
- Fourth filter column (near the outlet of greywater) – fine sand (0.1-1 mm)

This arrangement of different filtering media allows a thorough removal of odor, color, and microbes.

2.1.2 Secondary treatment:

Constructed wetlands are a simple system that can be easily managed and its most cost-effective biological greywater treatment system. They are sealed basins/beds with porous substrates of sand and gravel. The different regions of the constructed wetland with the varied substrate are depicted in figure 1. They utilize wetland plants, soils, and the associated microorganisms to mimic the natural ecosystem. The water passes through a filter bed and gets mechanically filtered. The pollutants in the water are consumed by the microorganisms present in the soil particles and root system of the wetland plants, thereby filtering the water. The local wetland plants are utilized. Some of them include cattails (Typha), sedge (Cyperus), rushes (Juncus), soft stem bulrushes (Scirpus) and common reed (Phragmites). Decorative and flowering plants can be used at the edges of the bed. The sources of the plants to establish the wetland includes seeds, seedlings, entire plants, or parts of plants (rootstocks, rhizomes, tubers, or cuttings). (Bastian & Boyd, 2019).

2.1.3 Tertiary treatment:

Disinfection of water forms the basis of greywater, which includes chemical disinfection by chlorination or ozonation, physical disinfection by filtration, and radiation disinfection by UV irradiation. (Al-Gheethi, et al., 2019)

The image below depicts the overview of the greywater recycling system with its main components.

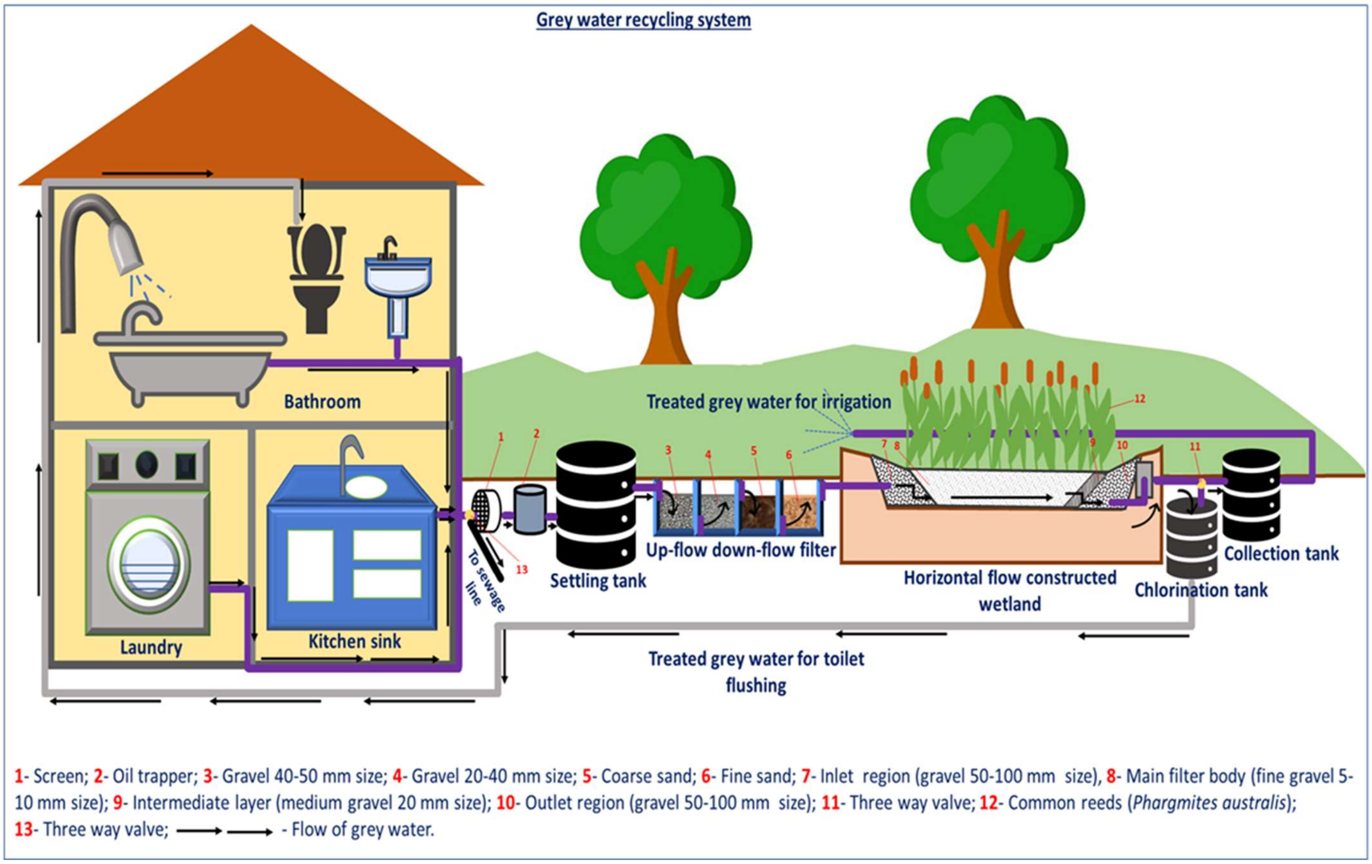

Figure 1 Greywater recycling system overview

Applications of recycled greywater can be categorized into outdoor and indoor use. Outdoor uses include, irrigation, watering the domestic garden, lawns on a college campus, athletic fields, cemeteries, parks**,** golf courses, washing vehicles, and windows, extinguishing the fire, feeding boilers, developing, and preserving wetlands. Indoor uses include flushing toilets and washing clothes.

2.2 Best Practices/ General Consideration for a greywater recycling system

1. The plumbing system plays a major and imperative role in the successful deployment of the greywater system. The plumbing system may be varied depending upon the need, use, and existing plumbing system. A decent alternative of capturing the greywater is by using dual plumbing with the provision of a valve aiding the greywater into the sewer when the garden to too wet to receive it.
2. A local/State accredited greywater treatment system should be installed.
3. Any pipe diameter less than or equal to 2” should have a slope of ¼” fall/foot run. Any pipe diameter greater than or equal to 3” should have a slope of 1/8” fall/foot run (a slight variation is anticipated depending upon the existing plumbing system and convenience of the user).
4. The pipe carrying the greywater and black water must be prominently separated by colour codes.
5. Ideally, the screen mesh (used in the primary treatment) should be less than 10 mm for the efficient removal of coarse particle

6. The ideal size of the surge tank depends upon the daily input of the greywater. The quantification of the greywater can be done easily by the bucket method. (where the amount of greywater generated daily is measured in buckets with known volume).
7. Several different types of pumps should be utilized for lifting the water in the greywater recycling system. These pumps can be electrical, mechanical (in the case of rural areas with power shortages), or solar.
8. The oil and grease trappers should be ideally placed before the settling tank. The trappers remove most of the oil and grease, which may otherwise adversely impact the sedimentation process.
9. As a rule, the greywater system should be at least 50 feet from the open water system, to avoid contamination.
10. The constructed wetland must be safe from flooding and should be integrated into the landscape as much as possible.
11. The permeability of soil is to be determined. If the soil permeability is $< 10^{-8}$ m/s, no artificial sealing layer is required. Constructed wetlands with higher soil permeability will require sealing of the bottom and sides to avoid the infiltration of the partially treated greywater into the groundwater.
12. Sealing can be done by a plastic liner (thickness ≥ 1 mm preferably from polythene), clay sealing (thickness ≥ 30 cm), or a mixture of soil with bentonite or very fine clay (two layers of 20 cm each, blended and compacted separately). The liner should be covered with 3-4 inches of soil to avoid the roots of vegetation to penetrate the liner. (Bastian & Boyd, 2019).
13. Ideally, the bed of wetlands should be constructed 30-60 cm deep with an additional 15 cm freeboard for additional water accumulation (Platzer, Winker, & Winker, 2011).
14. Natural slopes must be created in the system to minimize the use of pumps.
15. The wetland species are directly planted into the gravel on the surface of the bed with a spacing of approx. 1-foot between them. Initially, the plants should be kept well-watered but not flooded. Once the shoots are well-developed, the growth of the weed can be suppressed with occasional flooding.
16. The disinfection of the greywater is effectively done by using chlorine in the chlorination tank.
17. Chlorine is available in household bleach, solid tablets, or liquid form.
18. Chlorine is cheap and can be stored for longer periods without getting degraded.
19. The chlorine dose and the contact time required for adequate disinfection of the greywater depends on the characteristics of greywater (e.g. pH, BOD, and TSS), the chlorine demand, and the final uses of the treated greywater.
20. Chlorine is toxic to garden plants as chorine obstructs the normal metabolic processes acting as the substitute for similar nutrients in the soil.
21. Disinfection is not essential if the greywater is to be utilized for garden irrigation.
22. Greywater should be used in a way that guarantees no human contact, e.g. sub-soil irrigation.
23. Greywater collected for irrigation purposes should be used immediately.
24. If the greywater is to be used for toilet flushing it must be disinfected.
25. The untreated greywater can spread disease by splashing, human contact, and cross-contamination with the main potable water supply.
26. Use garden-friendly detergents that are biocompatible and low in phosphorus, sodium, boron, and chloride. The use of liquid detergents should be encouraged, as they have comparatively low salt content.

2.3 Maintenance and Operative Consideration:

Constructed wetlands are a 'Low Tech' system. They still, however, require a trained and skilled professional for its operation and maintenance. The efficiency of the pre-treatment units should be checked regularly. The sludge of the pre-treatment systems must be removed regularly. De-sludging of the settling tank is to be done weekly. Cleaning of the filter media into up flow-downflow filter also must be done on weekly basis. This would help to overcome the choking issue. Frequent checks and inspections of the valves and pumps need to the carried out to ensure the absence of any bubble in the pump and proper functioning of the valves. The pumps should be supplied with uninterrupted electricity (in the case of electrical pumps).

The operational tasks required for the constructed wetland include the checking of the following parameters (Platzer, Winker, & Winker, 2011).

- Pumps.
- Inlet structures for any clogging and the water level.
- Outlet structure for water level.
- Influent and effluent concentration of BOD (biological oxygen demand) and SS (Suspended Solids) as well as influent flow rate.
- Protection of wetland vegetation from weed and predatory plants.

Wetlands should be cleaned every 2 months by removal of any unwanted plants and grass. The settling tank should be inspected weekly and cleaned monthly or as required. The chlorination tank should be cleaned every day to maintain the proper dose of chlorine**.** The collection tank should be cleaned every 2 days to maintain a good quality of greywater. Likewise, Oil and grease trappers should be cleaned weekly or as required.

2.4 Health considerations

The treated greywater should be utilized at its production site or far from the sites often visited by children or pedestrians. The users should avoid the storage of greywater before or after treatment for more than 24 hours to prevent bacterial growth and odor generation (Assayed & Hazaymeh, 2018). An installation of a ventilation pipe is highly recommended to allow the odor to escape. In the regions with freezing temperatures, care should be taken to prevent the freezing of greywater into pipes and tanks, which can be attained by keeping the pipes and tanks completely drained off (Alexander & Clark, , 2016). Clear warning signs should be placed on pipes and tanks stating the presence of non-potable water within, which may be a health hazard upon exposure. The greywater must not be used for irrigating the plants that are intended to eat raw and the pet must be refrained from drinking the greywater. Drip irrigation system proves best for garden irrigation and sprinkler should be avoided. In an epidemic condition, the utilization of treated greywater should be avoided.

2.5 Financial Considerations

The greywater system, though a simple wastewater recycling system with low capital inputs, has several financial considerations as listed under (but not limited to):

- The initial cost of installation of the greywater recycling system and the greywater separation system (plumbing system which separates the greywater from the total wastewater stream).
- The cost of labor and technicians for installing the system and site preparation.
- The initial cost of pipes, extensions, connectors, and pumps.
- The operational costs include costs of energy, electricity, operation, and maintenance.

The greywater system also provides several financial benefits as listed under:

- Reduction in water bills.
- Availability of additional garden plants for individual utilization or sale.
- Reduction in cesspool emptying periods due to reduction of wastewater discharge saves money.

3 Blackwater recycling system:

Blackwater, which is so named because it includes human fecal matter, is step-wise treated in the conventional sewage treatment plants. However, these plants are energy-intensive, with relatively lower efficiencies.

The recycling of blackwater transforms it into a desirable resource. Blackwater can be treated and recycled at a community level as well as for a single dwelling unit. On average a person generates only 1.5 liters of black water per day, however, this value shoots up to 25 to 50 liters per day due to the additional flush water, which varies with the flush system used. The treatment of blackwater is crucial due to the presence of several microbes in the fecal matter.

The imperative role in the blackwater recycling system is played by “biodigesters”. Biodigesters are bioreactors that allow the treatment of blackwater by several specific microbes. Biodigesters provide a conducive environment for the growth of microbes which degrades the organic matter of the wastewater, thereby, treating it. These digesters not only treat the wastewater but offer a highly valuable resource – the biogas. Biogas is further utilized for power and energy purposes.

3.1 Overview of Blackwater treatment system:

The black water from the household is collected into the primary treatment (screening, settling, etc.) which then enters the biodigester for further treatment. Additionally, cow dung (source of specific microbes – the methanogens), kitchen waste, agricultural waste are added into the digester. The digester provides an anaerobic environment for the growth of the microbes. These microbes facilitate several reactions to yield methane. Methane (55-60%) along with carbon-dioxide (35-40%), hydrogen (2-7%) hydrogen sulphide (2%), ammonia (0-0.05 %) and nitrogen (0-2%) forms the biogas.

The generated biogas is purified through scrubbers to obtain pure methane. The methane is thereby, used for several heating and power purposes.

The digestate (effluent of the digester) obtained from the digester undergoes further processing and is utilized as a valuable fertilizer. The biosolids or the sludge deposited in the digester act as an efficient substrate for mushroom cultivation.

Highly functional recycling and reuse channel of blackwater is created through the biodigester where the toilet waste finally ends up as important fertilizer.

The Figure 2. Depicts the overview of blackwater processing.

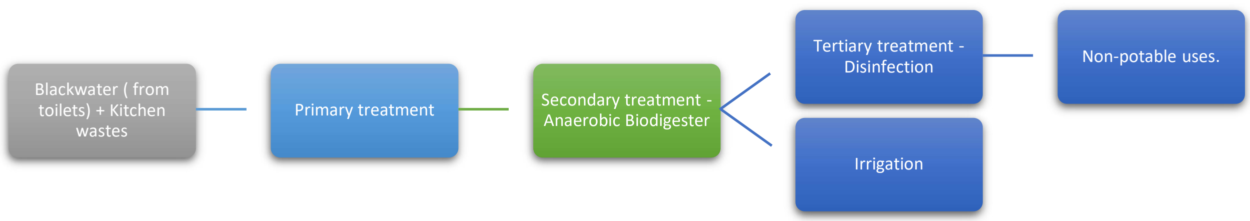

Figure 2 Blackwater processing overview

Note: The process comprising several intermediate processes, which are not depicted in the image for the ease of understanding.

The designs of biodigester vary globally, depending upon the geographical location and the need. Some of the biodigester designs that are operative at the mesophilic range are (a) the fixed dome digester, (b) the floating drum digester, and (c) the tubular digester.

However, the most commonly accepted and utilized design of biodigester, in Fixed-Dome Biodigester.

Figure 3. Given below illustrates a Fixed-Dome Anaerobic Biodigester, utilizing human waste as the substrate along with several steps involved in the functioning of the biodigester.

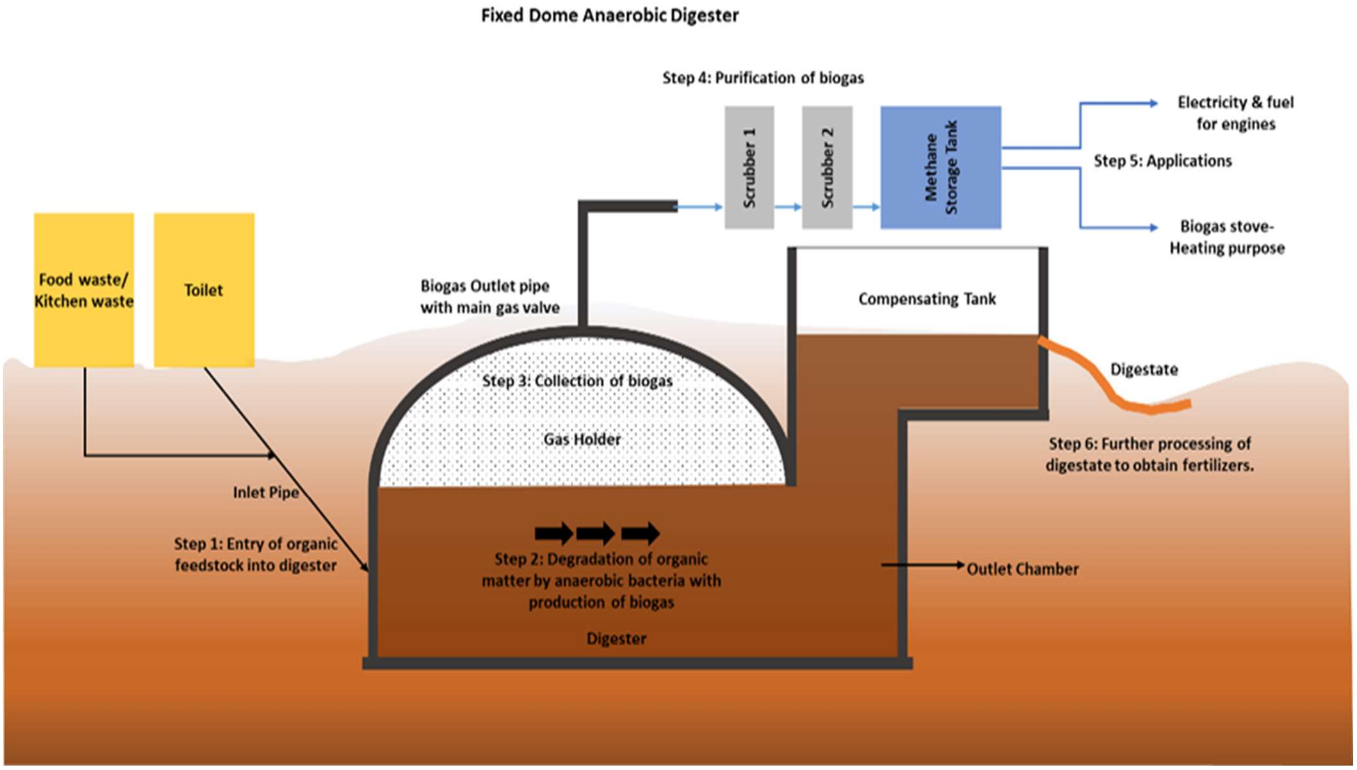

Figure 3 Fixed Dome Anaerobic Digester and its functional steps.

Note: The fixed dome digesters are mainly used for treating the waste of a large population as in the case of community, school, hostel, etc. However, for a small family/single house, horizontal and vertical tanks with special adaptors and attachments can be used as biodigester. Biodigesters are commercially available in several models, types, and sizes.

3.2 Best practices/General Consideration for deploying and specifying the blackwater recycling system:

1. A new plumbing system (or modification in the already plumbing system) must be done to prevent the blackwater from entering the general sewerage and directing it to the recycling system.
2. The pipes used for the system must be prominently labelled as “Blackwater.”
3. Several local regulatory permits and authorization should be gained.
4. The blackwater must not accidentally contaminate the freshwater inputs.
5. Installation of low flush/dry toilets.
6. 3”- 4” pipes are used for carrying the blackwater.
7. The size of the biodigester depends upon the input feed and the hydraulic retention time (It deals with the duration for which the substrate gets retained in the digester. It denotes the duration from the entry of the substrate into the digester to its exit) (Abbasi T, Tauseef S.M, & Abbasi S.A., 2019)
8. The blackwater should be immediately treated in the biodigester, and any storage of the blackwater must be avoided.

3.3 Maintenance and Operative Consideration:

- The blackwater recycling system uses biological treatment and requires regular desludging of the system.
- Monthly servicing of the installed system is required.
- Utilization of environmentally friendly products is highly recommended to prevent the failure of the system due to antibacterial soaps.
- The recycled system must have minimum human contact. The treated blackwater is neither intended for drinking purposes nor irrigating the vegetables that are eaten raw.
- The biogas generated in the system must be carefully used and processed.
- The chances of fire due to the gas must be minimized by the proper maintenance and functioning of the system.
- The inlets and outlets pipes should be unblocked on a weekly/monthly basis.
- The construction of a fence around the digester is essential, to forestall any harm caused by animals.
- The inner wall of the digester should be painted once in three years using white cement and synthetic resin mixture to seal any cracks if present.
- The bio-solids in the digester should be removed once in three years. Alternatively, if needed the bio-solids or sludge can be removed every 1-2 years.
- To eliminate the chances of foam entering the system, foam traps should be installed in the system.
- The gas piping should be checked for any leakage weekly/6-12 monthly.
- All the pipes of the system must be along the wall or post and must be secured firmly to evade any breakage.
- Underground pipes should be well protected to prevent the damage caused by animals, people, and vehicles.
- Regular maintenance is a mandate for the proper functioning of the system.

3.4 Health Consideration:

Blackwater is a potent source of pathogens and an easy mode of disease transmission. The treated, as well as the untreated blackwater, must be kept away from human exposure. The utilization of blackwater is majorly constrained to non-potable uses. The use of biodigester as one of the components of the recycling system increases the chances of health hazards due to the generation of biogas. Accidental exposure to biogas may cause nausea, headache, irritation in the eyes, lungs disorders, and even death (at significantly high levels of biogas). Sometimes, the blackwater recycling system also emits a foul odor.

3.5 Financial Consideration:

The utilization of a blackwater recycling system reduces the water bills and importantly conserves the freshwater. It reduces the load on the sewerage system and improves the shelf life of the system. The utilization of the digestate as the fertilizers saves the cost of buying the separate chemical fertilizers for garden plantations. Likewise, utilization of treated blackwater for green landscaping reduces the cost of beautifying the commonly visited places such as parks, streets, etc. However, like greywater recycling system the blackwater recycling system has several initial costs which majorly includes, plumbing cost, labor cost, maintenance & operative costs, and regulatory costs.

Note: Currently, utilization of blackwater recycling system involving biodigester is at its nascent stage, where several variables of the system need to be optimized.

4 Conclusion

Global freshwater reserves are rapidly dwindling and the only effective solution to mitigate that global water crisis is the recycling of wastewater. The recycling of daily generated wastewater opens several avenues of water conservation along with economic gains. The separation of the greywater and blackwater lowers the recycling time and improves the operative efficiencies of the system and both these wastewater streams comprise quite different chemical makeup and need to be treated differently. A user/house inmate may adopt the best practices for specifying, deploying, and operating the recycling systems.

The choice of best practice for utilizing the recycling system largely depends upon the chemical composition of the wastewater to be treated, ease of achieving the process parameters, capital inputs, and desired results. Both the mentioned recycling system requires local/national authorization for their installation and use. Soon, every house and community will have to adapt to recycling systems to overcome the intense water insecurities.

5 References

Abbasi T, Tauseef S.M, & Abbasi S.A. (2019). Biogas and Biogas Energy: An Introduction. In *Biogas Energy. SpringerBriefs in Environmental Science,* (Vol. 2). Springer, New York, NY.

Alexander, S., & Clark, , B. Y. (2016). The Benefits, Challenges, and Impediments of Greywater Use in EPA Region 5. *SSRN Electronic Journal*.

Al-Gheethi, A., Noman, E., Radin Mohamed , R., Talip , B., Mohd Kassim, A., & Ismail, N. (2019). Disinfection Technologies for Household Greywater. In R. Radin Mohammed, A. Al-Gheethi, & A. Mohd Kassim (Eds.), *Management of Greywater in Developing Countries.* (Vol. 87). Springer.

Assayed, A., & Hazaymeh, A. (2018). Guideline for greywater treatment and reuse and rainwater harvesting and collection at home - English Version.

Bastian, R., & Boyd, W. (2019). *A handbook of constructed wetlands.*

Devott, S., Wate, S., & Godfrey, S. (January 2007). *Greywater Reuse In Rural Schools - A Guidance Manual.* National Environmental Engineering Research Institute. United Nations Children's Fund UNICEF, Madhya Pradesh, India.

Platzer, C., Winker, M., & Winker, M. (2011). *Technology Review of Constructed Wetlands.* Eschborn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.