Greywater Environmental Management: A Review

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Abstract. The growth in population leads to significantly increasing the water demand. Thus, the disparity between demand and supply for water has become an important problem in human life. One of the most effective solutions to overcome this disparity is to manage urban water. Greywater, a significant part of domestic wastewater or sewage, can play an essential role in the urban environment. To address this role, the current paper aims to provide families with some efficient, affordable and sustainable systems to treat greywater. For non-drinking services, treated greywater may be used in various applications such as irrigation, toilet-flushing, car-washing, etc. Around the world, there are several types of greywater treatment systems. A study of these processes has been undertaken to assess the most appropriate activities at the family and community level. The best techniques for treating greywater in this study, constructions wetland (C.W.) instead of other techniques, as this is a sustainable, low-cost and easy-to-apply technology. The use of grey water is important because it decreases the demand for fresh water and decreases treatment stress.

Keywords: Greywater; Reuse; Environmental management; Impact; Sustainable.

1. Introduction

Domestic wastewater or sewage generated from households can be categorized into two types, black water and greywater [1][2]. Blackwater originates from toilets and kitchens having high concentrations of organic solids. Greywater originates from bathrooms and laundries. The general characteristics of greywater can be significantly varied depending on several affecting factors [3]. These factors can affect the quality of greywater in terms of chemical and biological.

In terms of chemical quality, several factors such as pH, chemical oxygen demand (COD), biological oxygen demand (BOD), electrical conductivity (EC); fats, oil and grease, solids and pathogens can affect its quality [4][5]. In terms of biological quality, this quality is dependent on the presence of faecal contamination.

2. Characteristics of greywater

Greywater's composition differs widely depending on its origin (i.e., bathroom, laundry or kitchen greywater) and the locality's water quality is affected [6][7]. A selection of acidic, alkaline, suspended and dissolved liquids, fats, toxins, oil and greases are heavy metals, synthetic chemicals and pathogens [8][9]. (Releveled and Zeeman) reported that the organic fractions in greywater are around 30 percent, while nutrient fraction constitutes 9-20 percent [10].

2.1 pH

Greywater pH depends largely on the water supply's pH and alkalinity [11][12]. The pH of greywater is directly related to some chemicals such as fabric cleaners, bleaches, and disinfectants [13]. Braga and Varese reported acidic pH (5.6) in greywater [14], but Friedler reported that the maximum alkaline pH was reported (10) in the greywater [10]. In general, as there is a large variation in pH, ranging from 6.4 to 8.1 in greywater [15].
2.2 Chemical oxygen demand (COD)
The reported COD values ranging from 254 to 618 mg L$^{-1}$ in greywater. By contrast, stating that greywater tends to contain fewer than solids, as their pollutants are dissolved, keeping the COD: BOD ratio around 4:1 in the greywater [16]. Differences in COD were observed [14], where they recorded COD values of 4800 mg L$^{-1}$ in Brazil of greywater for commercial washing.

2.3 Pathogens
Pathogens in greywater are common. Winward et al. reported that it creates risk from a range of fecal-borne pathogens [17]. Coliform clusters from 3x10^3 to 2.4x10^7 CFUs per 100 mL were reported by [13]. Rose et al. [18] reported that families with children had a higher number of coliforms (3.2 x 10^5 and 1.5 x 10^3 CFUs per 100 ml) in greywater compared to families without children (6 x10^5 and 80 x10^3 units). (Formation per 100 ml). In a study conducted in London, Birr et al. stated that fecal enterococci were found in at least 70% of tested greywater [19]. Bacterial pathogens are observed and the pathogen, Cryptosporidium sp. as mentioned in [20]. Intestinal pathogenic bacteria, such as salmonella and campylobacter, can be introduced by handling food in the kitchen [21], in addition to materials derived from faces. Other pathogenic bacteria have also been reported in greywater. Friedler et al. found dermatophytes (Pseudomonas aeruginosa), respiratory pathogens (Legionella pneumophila) and intestinal pathogens (Escherichia coli) in greywater [22].

2.4 Fats, oil and grease
The oil and grease lead to an oily layer in the water to reduce light penetration, oxygen diffusion and photosynthesis by submerged plants [23]. Oil and grease concentration in the untreated household wastewater was 50 to 100 mg/ L [24]. It prevents the filter units and hinders processing efficiency. Oil and grease are other important factors in greywater, as kitchen sinks and bathroom showers contribute to this pollutant. Some common conventional methods for treating oily wastewater include chemical treatment, biological flotation, gravity flotation methods, dissolved air flotation (DAF) and membrane use [25]. The effectiveness of gravity separation and dissolved air flotation was studied for removing oil and grease from domestic and industrial wastewater, and removal efficiency of about 85% was achieved in removal as an emulsified oil from wastewater. Wastewater containing fats and oils was naturally treated, which is currently considered insufficient if the fats are in a dispersed form [26].

2.5 Electrical conductivity
reported that the conductivity values range from 0.52–1.27 dm$^{-3}$ in greywater [27]. These differences were due to laundry's varying emptying, kitchen washing, and floor washing at different times. Detergents contain phosphate, sodium and potassium in their raw materials, which leads to the enrichment of the dissolved solids in the detergent, which leads to an increase in electrical conductivity. They also recorded ranges of electrical conductivity in greywater between 14 and 3000 μs / cm [28]. Bad or outdated plumbing materials also contribute to increased electrical conductivity due to water sources.

2.6 Solids
The suspended solids content ranges from 15 to 800 mg L$^{-1}$ [29], [ 30]. While Abinaya and Loganath reported TDS values from 712 to 990 mg L$^{-1}$ in greywater. The source of suspended solids is body care products, toothpaste, shaving residues, skin and hair, body fats, food particles, and fibers from various textiles [31]. The values of suspended solids are much higher in toothpaste, body care products, skin, hair, shaving residues, body fats, food particles, and various textiles [31]. The solid greywater content is generally low, indicating that a large fraction of contaminants is in the dissolved image [32].

2.7 Biological oxygen demand (BOD)
The BOD in greywater has very wide variations (5 to 431 mg L⁻¹) [33]. The BOD refers to the oxygen requirement in greywater for the organic compounds microbial degradation at a constant temperature. Lazarova et al. estimated that greywater from residential apartments accounts for 50–70 percent of wastewater generated [9]. World water shortages have made the reuse of wastewater a must [1]. Except greywater uses 65% of domestic wastewater, making it the key to domestic water recycling [2]. Greywater means bathrooms (laundry and bathroom). It is not allowed to use wastewater from the kitchen as it is not gray water. It is considered black water. Water can be reused following treatment, but it should mainly come from the bathroom and washing facilities because bathrooms and laundry are relatively unconstrained compared with kitchen water and can be created in larger quantities [3]. Greywater consumption per capita of (135) liters/day. The world's per capita surface availability of water is 1588 m³, which is projected to reduce further down to (1401 and 1191) m³ by (2025 and 2050) [4]. The domestic water consumption the world accounts for about 17 m³ [5][6].

3. Greywater Environmental Management Plan (EMP)

Such a project's environmental management plan consists of mitigation, monitoring, and institutional measures to be taken during implementation and operation to eliminate adverse environmental and social impacts, offset them, or reduce them to the acceptable levels. The plan also includes the actions needed to implement these measures [34] [64]. The most common way to use greywater environmental management (GWEM) applications Reuse/recycling domestic light greywater is adopted worldwide as an emerging eco-friendly and economically feasible water-conservation means. It is most commonly used in toilet flushing and landscape subsurface irrigation. Irrigation methods used. Irrigation may create water spray (aerosols) or retain water at the soil surface and runoff. Furthermore, Proper planning of greywater reuse, as described in, will significantly decrease potential hazards to public health and the environment. This study aims to provide that greywater must be managed properly to avoid exposing people to pathogens, damaging plants, clogging the irrigation system, and creating unpleasant odors. Management options used to address the risks associated with greywater reuse include using a hierarchical risk management framework [35]. The potential risks can be reduced by organizing the following:

1. Limiting the use of direct greywater guidance to sources of lower risk.
2. Limiting the volume of greywater permitted for direct orientation of the irrigation system.
3. Ensure that the untreated greywater does not flow into the surface or groundwater.
4. Ensure that the grey water remains below the surface by selecting the correct covering material.
5. Limit storage of untreated grey water in less than 24 hours.
6. Not to allow dangerous chemicals to empty the drain and recommend using grey-water-tolerant plants and planet-friendly cleaning products [36]. Table 1 shows the impact of greywater on the environment.
Table 1: Impact of greywater on the environment [36] [65].

| Item            | The adverse impact of greywater                                                                 | Mitigation measures                                                                 |
|-----------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Soil            | ● A lowered soil absorption and water retention capacity;                                       | ● The gypsum application (calcium sulphate) in the soil before irrigation salts and other soil pollutants dilutes grey water with fresh water. |
|                 | ● Lower alkalinity due to the presence in greywater of sodium, potassium or calcium salts, especially detergents; a reduced soil dilution absorption and water retention; Washing. | ● Do not allow the soil to dry because it leads to salt concentrations in the remaining water to reduce pH. It helps purify the ground from the build-up of excess sodium. Choose garden detergents that are phosphorous, sodium, boron, and chloride degradable and uplift. |
| Groundwater     | ● Groundwater contamination                                                                    | ● Water quality and irrigation nutrients must be regulated and applied at a sufficient pace to satisfy greywater vegetation demand. |
| Plant health    | ● The plant harm sign appears                                                                  | ● The use of greywater must be prevented or decreased.                                |
|                 |                                                                                                 | ● Greywater can only be used on well-developed plants, not plants or young plants because they are more susceptible to greywater impurities. |

4. Greywater Treatment Technologies

Untreated greywater discharged into any ecosystem is considered unsafe [37] [38]. Greywater needs to be treated to reduce the contamination in terms of organic load, nutrients and strong pathogenic microorganisms before using various purposes. In literature, many methods are used to treat greywater effectively [39]. Among these methods can be summarized below:

4.1 Aeration

Aeration helps to provide oxygen from atmospheric air for the biological treatment of greywater. An improved aeration system such as the aeration of micro-bubbles is an excellent way to improve oxygen transfer efficiency [40]. Ventilation allows deep exposure to water and air by mixing air and water intensively so that chemical reactions occur between them to remove odorant compounds such as hydrogen supplied and carbon dioxide [41]. Various types of diffuse aerators are used, such as submersible jet aerators, coarse bubble diffusers and micro-bubble diffusers.

4.2 Adsorption

Adsorption using activated carbon can be used as an effective method for treating greywater. A typical surface area of activated carbon is about 1,000 square meters per gram (m²/g). The performance of activated carbon in removing pollutants from greywater and concluded that the activated carbon has a superior performance in reducing organic matter (reduction of 97% in COD and 94% in BOD); As well as the surfactants are considered (reduction by 99%), removal rate and total phosphorous (reduction by 91%). They were reducing total nitrogen by 98% [43].

4.3 Filtration

It is a process used to separate solids from liquids or gases using a filter medium that allows the passage of a liquid but not a solid. The term "filtration" applies whether the filter is mechanical, biological or physical. A filter system consisted of shallow layers of stone, medium gravel and pea gravel under a deep layer of sand and multimedia filters. In contrast, the fine filter achieved 31±17% and 13±11% or
±10% total organic carbon removal (TOC) and 1±7% turbidity in coarse filters, reduction in total organic carbon and turbidity, respectively [44].

The ultrafiltration membrane system treats greywater from all household sources (including dishwashers, washing machines, and kitchen sinks in addition to bathrooms, hand sinks and showers) and the performance is fair. The filtration removes solids such as cutting, cloth, hair, and food particles from greywater. Ludwig suggested using a natural mulch tank filled with organic stones and mulch (leaves, tree bark, etc.) to treat greywater [45]. The basic principle behind filtration is to prevent impurities from reaching downstream by absorption and uptake. Adsorption is when impure components are eliminated by bonding them physically or chemically to suitable absorbents' surface [46]. Hodgson recommended a mixture of coarse and fine filters to achieve 15 physical absorptions using locally available filter media as an effective method. To remove ammonia, phosphorous, cations and even partial bacterial load from greywater [47].

4.4 Zeolite
Zeolite refers to aluminum silicate minerals porous in nature, which can absorb cations by holding or exchanging them in their active sites. Both natural and synthetic zeolites are porous and capable materials to absorb particles of appropriate cross-sectional diameter. Because of this property, zeolite is used in various industrial and agricultural applications [49]. Zeolite is an excellent waste detector and heavy metal detector due to its specific chemical composition and mesh structure [48]. Assayed et al. assessed zeolite efficiency in treating greywater combined with a sand bed filter [50]. One of the unique properties of zeolite is that it is very selective towards cations and several experiments conducted on this aspect have proven positive for removing copper (Cu$^{2+}$), manganese (Mn$^{2+}$) and zinc (Zn$^{2+}$), which are common contaminants in water) pH, (COD), (BOD), Fats, oil and grease Solids. However, it has been indicated that zeolite filters have a high performance depending on the contact time, zeolite loading, elemental ammonium concentration, and pH value. [52]. The treatment efficiency as reported by them was 82-87% for COD. 85-100% for phosphates (PO$_4^{3-}$); 64-75% nitrate for (NO$_3^-$) and 58-89% for turbidity. The process efficiency for removing ammonium from greywater using zeolite was 97%, as reported by Widiastuti et al. [53].

4.5 Sand filters
Sand filtration purification is a proven method and is well suited for treating greywater and wastewater. Fine sand, coarse sand, river sand, beach sand, silica sand, etc., are some of the sands that scientists have tried to treat greywater. 0.3 mm fine sand filter with values of 1.82, 1.48 Mg m$^3$ and 0.4 each. Other tried sizes include 0.7, 1.3 and 2.5 mm, either in single or multiple layers. Percent for uniformity, density, specificity and porosity [54]. The sand filtration system's performance also depends on hydraulic loading, sand texture, and suitable depth chemistry 2-10cm. Suitable for effective performance, with BOD removal more than 80% [55]. Sand filters are not only used during primary treatment. Still, they are sometimes used as polishing materials for effluents during tertiary treatment to remove residual and bacterial suspensions of nitrogenous substances, including ammonia and nitrates, into nitrogen gas. Besides the physical filtration through sand, an active biofilm develops. They are attached to the surfaces of grains of sand that mineralize organic matter volume alone does not determine treatment efficacy [56].

4.6 Constructed wetlands
Natural greywater treatment systems use natural filter media that can be used to treat greywater, but a clearance phase is needed if a low flow of pathogens is required [57]. Some examples are horizontal wetlands, HFCW, vertical flow constructed wetlands (VFCW), anaerobic filters, and vertical flow filter (VFF). These systems combine physical processes such as filtration through a filter medium (such as sand, gravel, rock, cinder) with biological processes such as aerobic or anaerobic decomposition via microorganisms. Existing within the system (for example, biofilms, plant roots, mollusks, earthworms)
cultivated systems (such as VFCW and HFCW) help remove nutrients such as phosphorous and nitrogen. They are preferred, especially in low-income and middle-income countries (MICs), due to their low cost [58].

In terms of treatment performance and operating and maintenance costs, constructed wetlands can be considered the most environmentally friendly and cost-effective technology for greywater treatment and Reuse [59]. However, they also require a large area (0.5-3 m² person⁻¹) [60]. The systems achieved TSS removal rates of 90-98%, BOD> 99%, COD from 81 to 82%, Total N from 26 to 82%, B from 0 to 63%, K up to 67%. No clearance of Ca, Mg, and Na were observed. An increase in E.C. was found in all built-up wetland technologies [61]. Therefore, it is suitable for urban use. Treating wetlands, the construction wetlands mimic soil's natural processes to purify water for biological, physical and chemical use. The technology has recently been discovered widely in Africa, Asia, Europe, Australia and the USA. The wetland systems developed were shown to achieve an average deletion rate of 94% TSS, 99% BOD5, 82% COD and 54% total N. While this wetland has a far-reaching impact on soil enrichment and groundwater recharging, its large footprint may consider them to be impractical for many home applications. In this study, Arden & Ma established wetlands can be considered the most environmentally friendly and cost-effective technology for greywater treatment and Reuse [60].

Study shown greywater characteristics and various treatment methods to establish a proposal for a greywater recycling system specifically designed for restrained irrigation. Greywater volume varies from 50% to 80% of the wastewater volume of households. It has a high ability to remove nutrients and organic matter (COD, PO₄, Nₐ, E.C., SAR) and Heavy metals removal ratio of 70-90% of all greywater [59]. Studies shown showed that some efficient, cheap and sustainable greywater treatment systems should be suggested for households. For non-potable purposes, greywater may be used for drainage, toilets, laundry, car washing, dust control, and aquifers for recharging.

The disequilibrium between water demand and process analysis was carried out to evaluate the most suitable household and community processes. Septic tank, developed wetland and intermittent sands due to simple operation and maintenance systems and the cost-effectiveness of these systems, a wetland (CWS) has been described as the most suitable decentralized treatment method. Greywater use is becoming increasingly common, especially in areas of limited water supply. Greywater is also an ultimate alternative to conserve water. Gary water use is important as it decreases the demand for fresh water and reduces it [62].

Table 2 prefer to use method the common greywater treatment methodologies that each technology or method in terms of the advantages and disadvantages [63].

| Treatment Technique | Description | Advantages | Disadvantages |
|---------------------|-------------|------------|---------------|
| Sand filter         | Beds of sand or coarse bark or mulch trap and adsorb contaminants as greywater flows through uses | Simple operation, low maintenance, low operation costs | Simple operation, low maintenance, low operation costs |
| Activated carbon filter | Activated carbon has been treated with oxygen to open up millions of tiny pores between the carbon atoms. These filters thus are widely used to adsorb odorous or colored substances from gases or liquids. | Simple operation, activated carbon is particularly good at trapping organic chemicals and inorganic compounds like chlorine. | High capital cost, many other chemicals are not attracted to carbon at all – sodium, nitrates, etc. This means that an activated carbon filter will only remove certain impurities. It also means that an activated carbon filter stops working once all of the binding sites are filled. |

Table 2: Common greywater treatment methodologies [63] [55].
Table 2: to be contained

| Disinfection                      | Chlorine, ozone, or Ultraviolet light can all be used to disinfect greywater | Highly effective in killing bacteria if properly designed and operated, low operator skill requirement. | Chlorine and ozone can create toxic byproducts. Ozone and ultraviolet can be adversely affected by variations in greywater organic content. |
|-----------------------------------|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| Aerobic biological                | Air is bubbled to transfer oxygen from the air into the greywater. Bacteria present consume the dissolved oxygen and digest the organic contaminants, reducing the concentration of contaminants. | The high degree of operations flexibility to accommodate greywater of varying qualities and quantities allows treated water to be stored indefinitely. | High capital cost, high operating cost, complex operational requirements does not remove all pathogens. |
| Constructed wetlands (CWS)        | Natural greywater treatment systems are extended systems that use natural filter media that can be used to treat dark Graywater and biological degradation | Performance and low operating and maintenance costs, constructed wetlands It can be considered the most environmentally friendly and cost-effective technology for Graywater Treatment and Reuse. | Require a large area. |

5. Conclusion

The review of treatment and reuse technologies states the different properties of greywater. This great difference in greywater characteristics is mainly due to water use in various household activities to meet human needs. Implementing a greywater treatment system at the household level targets a specific option for reuse and thus increases households' number to implement treatment options for greywater recycling. The development of technologies available to treat or remove specific pollutants that do not provide complete greywater treatment requires the following:

1. Ensure a reliable water supply and sustainable management for future generations.
2. Preserving the dwindling groundwater resources in the country, and practices must be applied. There is a real and serious problem that deserves political and humanitarian attention, which is groundwater depletion. The current study reviews and suggests using greywater in various potential areas, thus regulating the demand for freshwater. A greywater system may be very robust on school/college campuses, especially those with residential facilities.
3. It can be concluded from this study that greywater recycling is the most effective non-potable source for increasing water demand. A sustainable greywater recycling process's main benefits are demand control, rainwater, and rainwater storage as alternative water supply options. Using these workarounds for this purpose is not always accurate. On the other hand, the demand for drinking water decreased during the year and the quantities of wastewater that had to be treated were decreased also.
4. Reducing transportation costs, pressure on major recycling networks, proper maintenance and public awareness enhancement will make the decentralized system more efficient and convenient. Therefore, a new method for treating and reusing wastewater has been proposed, proposing different greywater treatment and black water treatment. Greywater can be treated, and black water can be treated as the main method through onsite treatment processes. At the household or group level, decentralized systems can be introduced so that the recycling system needs stability and ease of operation.
5. Although the proposed systems have some flaws, proper management and the introduction of sustainable, low-cost, high-quality technology, wetland installations are the best way to treat greywater with high efficiency and add programs and strict user control practices effectively.
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