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Recycling of Domestic Wastewater for Home Garden

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ABSRACT
This research explores the use of treated greywater for irrigation in domestic gardens as a sustainable solution to global water scarcity. A multidisciplinary approach is used to investigate the feasibility, safety, and benefits of greywater use, including its potential health risks, environmental impact, and economic factors. Various treatment technologies are evaluated, and a cost-effective treatment plant is designed and tested using economical materials. The plant is found to be effective, making it a viable option for household use. The study considers policy and regulatory factors influencing greywater recycling adoption and provides recommendations for its use. Overall, the research aims to provide a comprehensive understanding of greywater use in gardening, promoting sustainable water management practices.

****Keywords:** Graywater; Wastewater recycling; Home garden Irrigation; Sustainable water management; Treatment plant; Treatment technologies; Public health; Policy analysis.

I. INTRODUCTION

Water scarcity is becoming an increasingly critical global issue, with the United Nations World Water Development Report highlighting the urgent need for efficient water resource management due to the growing demand for freshwater exacerbated by population growth, economic development, and climate change (UNESCO, 2020). Domestic wastewater recycling emerges as a promising solution to mitigate the problem of water scarcity, especially in arid and semi-arid regions where freshwater resources are severely limited (Angelakis & Durham, 2008).

Domestic wastewater, often referred to as greywater, includes water from bathtubs, showers, sinks, washing machines, and other household sources, excluding toilet wastes. It represents a substantial portion of residential wastewater and is characterized by relatively low levels of pollutants compared to industrial wastewater or sewage (Friedler, 2004). Due to its composition, greywater has the potential to be treated and reused for non-potable purposes, such as landscape irrigation, which can significantly reduce the demand for potable water (Li et al., 2009).

The recycling of domestic wastewater for home gardens presents several benefits. It can contribute to water conservation, reduce the burden on municipal sewage systems, and provide a sustainable source of nutrients for plant growth, which can potentially enhance soil quality and garden productivity (Rodda et al., 2011). Moreover, the practice aligns with several Sustainable Development Goals (SDGs), particularly SDG 6, which aims to ensure the availability and sustainable management of water and sanitation for all (United Nations, 2015).

However, the implementation of domestic wastewater recycling systems poses various challenges, including public health concerns, the need for appropriate treatment technologies, regulatory barriers, and the perception and acceptance by the public (Jefferson et al., 2004). Furthermore, the potential for contamination with pathogens or household chemicals necessitates careful consideration of treatment methods to ensure the safety of recycled water for garden irrigation (WHO, 2006).

Given the context of increasing water scarcity and the potential for domestic wastewater reuse in urban agriculture, this dissertation aims to explore the feasibility, safety, and benefits of recycling domestic wastewater for home garden use. The study will consider the technical and health aspects of greywater treatment and reuse, assess the quality of treated water, and evaluate the impact on garden productivity and soil health.

The environmental benefits of recycling domestic wastewater for garden use are multifaceted. By diverting greywater from sewage systems and treating it for irrigation, the strain on municipal treatment plants and natural water bodies is alleviated. This recycling process can also contribute to the recharge of local aquifers through the percolation of irrigated water, fostering a more sustainable urban water cycle (Griggs, 2018).

The use of treated greywater in gardens can also contribute to the reduction of carbon footprint by minimizing the energy and chemicals required for treating water to drinking quality, only to be used subsequently for irrigation (Ghaitidak& Yadav, 2013). Moreover, the organic matter present in domestic wastewater can improve soil structure and fertility, which may reduce the need for chemical fertilizers, thus contributing to soil health and biodiversity (Palmquist &Hanaeus, 2005).

The adoption of wastewater recycling can have significant socio-economic impacts. For individual households, the practice can translate to reduced water bills and an increased availability of water for gardening, which can be particularly important in regions with water rationing or in times of drought (Morel & Diener, 2006). At the community level, the collective action towards water recycling can foster a sense of responsibility and environmental stewardship, contributing to the social cohesion necessary for sustainable urban living (Oteng-Peprah et al., 2018).

The technology for treating domestic wastewater to make it suitable for garden use ranges from simple, low-cost systems like mulch basins and constructed wetlands to more complex, high-tech solutions like membrane bioreactors (MBRs). The choice of technology is often influenced by the desired quality of treated water, the volume of wastewater generated, available space, cost considerations, and the regulatory environment (Li et al., 2010).

Treatment effectiveness is critical, as it must address contaminants such as pathogens, nutrients, and household chemicals to levels that are safe for human contact and plant uptake (Rodda et al., 2011). The risk of contamination from greywater is a concern that requires careful management. Treatment systems need to be robust enough to handle variations in greywater quality, which can change with household habits and the products used (Eriksson et al., 2002).

Regulations governing the reuse of treated domestic wastewater for irrigation vary significantly across regions. These regulations are often based on guidelines such as those developed by the World Health Organization (WHO), which set out permissible limits for microbial and chemical contaminants in greywater for irrigation purposes (WHO, 2006). The regulatory framework plays a crucial role in ensuring public health protection while enabling the safe reuse of greywater (United States Environmental Protection Agency [EPA], 2012).

This dissertation will investigate the viability of domestic wastewater recycling systems for home gardens by examining current technologies, health risks, and the benefits of such systems. The study will provide valuable insights into the potential of this sustainable practice to contribute to water conservation efforts, enhance urban agriculture, and foster resilience against water scarcity.

Domestic wastewater quality

Domestic wastewater, commonly referred to as greywater, includes water from showers, sinks, and laundry, which typically accounts for 50-80% of residential wastewater (EPA, 2012). This greywater is characterized by lower levels of contaminants compared to blackwater from toilets but is still often channeled into sewer systems or septic tanks, contributing to the high demand on municipal wastewater treatment facilities and increasing the ecological footprint of urban areas (Friedler, 2004).

The potential for recycling greywater for non-potable uses, such as irrigation in home gardens, is well recognized; however, its implementation faces several challenges. These include public health concerns due to potential exposure to pathogens and chemicals, the absence of universally accepted standards for greywater treatment and reuse, the need for cost-effective and simple treatment technologies adaptable to different households, and a general lack of awareness and acceptance among consumers (Li et al., 2009; Rodda et al., 2011).

Furthermore, while the benefits of using treated greywater for garden irrigation have been touted, practical applications have been limited due to a lack of detailed understanding of the long-term effects on soil chemistry, plant health, and ecosystem dynamics. There is also a critical gap in policy frameworks that support the safe and widespread adoption of domestic wastewater recycling at the household level (WHO, 2006).

Greywater content can be divided into two categories:

i. Light greywater: this is a type of grey water that contains a low percentage of contaminants
ii. Heavy greywater: this contains a high percentage of pollutants.

The element found in greywater consists of organic elements, surfactants, nutrients, and a small amount of minerals. Although greywater quality varies due to its impact on the quality of water used, water activities, and lifestyle, the main contaminants of graywater are mostly laundry and kitchen waste.

Current Technologies in Domestic Wastewater Treatment

The technological landscape for domestic wastewater treatment has evolved significantly to include a variety of systems that cater to different needs, scales, and environmental conditions. These technologies range from conventional septic systems to advanced on-site treatment units that integrate mechanical, biological, and chemical processes. For the purpose of recycling domestic wastewater for home garden irrigation, the focus is on systems that treat greywater, which excludes toilet wastes and is generally easier to treat and reuse.

i. **Conventional Systems:** The most basic form of greywater treatment is the septic tank, which is widely used for primary treatment of household wastewater. However, septic systems do not provide adequate treatment for greywater reuse in gardens due to insufficient removal of pathogens and nutrients (Crites and Tchobanoglous, 1998).
ii. **Constructed Wetlands:** Constructed wetlands are a natural treatment solution that mimics the processes occurring in natural wetlands. They are effective at reducing organic matter, nutrients, and pathogens, making them suitable for greywater treatment (Vymazal, 2010). These systems are typically easy to operate and maintain, making them attractive for residential use.
iii. **Membrane Bioreactors (MBR):** MBR systems combine biological treatment with membrane filtration, offering high-quality effluent that is suitable for reuse in irrigation. These systems are highly efficient in removing contaminants, including nutrients and pathogens (Gander et al., 2000). However, they can be costly to install and maintain, which may limit their use in household applications.
iv. **Rotating Biological Contactors (RBC):** RBCs are mechanical systems that provide a medium for biofilm growth, which processes the greywater as it passes over the medium. They are known for their reliability and low energy consumption, but they may not always achieve the level of treatment required for unrestricted garden irrigation (Davis, 2005).
v. **Advanced Oxidation Processes (AOP):**AOPs involve the generation of highly reactive species, usually hydroxyl radicals, capable of breaking down a wide range of organic pollutants. These processes can significantly reduce the concentration of organic matter and pathogens in greywater (Jefferson et al., 2004).
vi. **Biofilters:** Biofilters, such as sand filters or trickling filters, use a biological layer to degrade organic matter. They are often used as a secondary treatment step following a primary treatment like a septic tank. Biofilters are effective for nutrient removal and have low operational costs (Dalahmeh et al., 2012).
vii. **Greywater Diversion Devices:** For simpler applications, greywater diversion devices can be used to directly route greywater from sources like showers and sinks to the garden. These systems usually include a basic filtration process to remove solids and are best suited for subsurface irrigation to reduce contact with humans and animals (Morel and Diener, 2006).
viii. **Smart Greywater Treatment Systems:** Recent innovations have introduced smart greywater treatment systems that use sensors and automated controls to optimize treatment processes. These systems can adapt to changing greywater quantity and quality, ensuring consistent treatment performance (Li et al., 2009).
ix. **Smart Water Management Systems:** In the sphere of wastewater treatment, the integration of smart water management systems is a trend on the rise. These systems are equipped with real-time monitoring and control mechanisms that can optimize water usage and treatment processes based on demand, water quality, and other environmental factors. These innovations are particularly relevant for greywater treatment, where fluctuating volumes and qualities of water require adaptive management (Lazarova et al., 2013).
x. **Nanotechnology:** Nanotechnology is being explored for its potential to enhance wastewater treatment processes.

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Nanomaterials, due to their high surface area and reactivity, can be used to target specific contaminants, improve filtration processes, or even catalyze degradation of pollutants at lower energy costs. Nanofiltration, for instance, is becoming a promising technology for greywater treatment, capable of removing a wide spectrum of contaminants (Qu et al., 2013).

xi. **Hybrid Systems:** The use of hybrid systems, which combine various treatment processes, is an innovative approach that can offer a robust solution for greywater treatment. For instance, combining membrane technologies with biological processes can result in high-quality effluent suitable for garden irrigation while maintaining reasonable operational costs (Ghaitidak& Yadav, 2013).

xii. **Containerized and Modular Treatment Units:** As urban spaces become more constrained, containerized and modular treatment units that are compact, easy to install, and scalable are gaining popularity. These units can be particularly appealing for residential areas or community gardens where space is at a premium and where there is a need for flexible water treatment solutions (Rodda et al., 2011).

The choice of technology for greywater recycling for garden irrigation depends on various factors, including the quality requirements for the intended reuse, the amount of greywater produced, space availability, economic considerations, and maintenance capabilities. The current trend in technology development is towards systems that are compact, low-energy, and that produce effluent safe enough for reuse in household gardens, thus conserving freshwater resources and reducing the burden on sewage infrastructure (Eriksson et al., 2002).

Wastewater Recycling Challenges and Future Directions

While the aforementioned technologies present promising solutions for the recycling of domestic wastewater for garden irrigation, challenges remain in their widespread adoption. Issues such as initial investment costs, maintenance requirements, and the need for public education on the benefits and operation of such systems can be barriers to implementation (Li et al., 2009).

Additionally, future research and development are necessary to optimize these technologies for household use. The variability in household greywater composition, influenced by lifestyle, household products, and water usage patterns, poses a unique challenge that requires adaptable and resilient treatment systems (Eriksson et al., 2002).

Furthermore, the broader implications of recycled water on urban ecosystems and public health are still areas requiring further investigation. Long-term studies on the effects of treated greywater on soil microbiology, plant uptake of nutrients and potential contaminants, and groundwater quality are needed to ensure the sustainability and safety of these practices (Palmquist &Hanaeus, 2005).

Design of an Economical Wastewater Treatment Plant

It was observed that some people cannot afford, maintained or access some of the wastewater treatment plant that are currently available. This research has come up with an experimented greywater treatment system that can be constructed by a trained plumber with common materials used for our daily activities. The treatment plant follows the convectional system of wastewater treatment as shown in the diagram below.

Figure 1. Wastewater treatment options for various reuse applications (USEPA, 2004; Adewumi et al., 2012)

The treatment process for the proposed domestic wastewater treatment plant will be classified into three, namely

- Preliminary Treatment
- Primary Treatment
- Secondary Treatment

Preliminary Treatment Process: This process requires collection of wastewaters from bathtubs, showers, bathroom wash basins, or clothes washing machine (Not necessarily required) through adequate sewer system. The appliances should be connected to sewer system through a convectional trap and screen fittings to remove solid waste that may block the sewer system and sill up unwanted odours.

Primary Treatment Process: The greywater that majorly flow into soak away pit will be collected by primary clarification chamber through grid removal. Gated grid removal is a sand filter bed having fine wire gauze at the top for daily removal/disposal of trapped solid waste. The gate or valve at the entrance grid removal will be used to control movement of graywater into the system during maintenance or backwashing process. Primary clarification chamber provides temporary deposition of the wastewater for settlement of sludge for at least six hours. The size of the chamber will be equivalent to 90% of expected water consumption in the particular building being designed for. The sludge outlet will be gated and open for sludge disposal after completion of each treatment process.

Secondary Treatment Process: This process consists of two major unit, aeration and secondary sedimentation process.

i. **Aeration Process:**Aeration is the process by which air is circulated through, mixed with or dissolved in a liquid or substance. Aeration brings water and air in close contact in order to remove dissolved gases and to oxidize dissolved metals, including iron, hydrogen sulfide and volatile organic chemicals. Aeration tank design can be manually or electrically powered. Manual aeration tank will be adopted for this plant to make it more economical.

ii. **Secondary Sedimentation Tank:**Component of a modern system of water supply or wastewater treatment. A sedimentation tank allows suspended particles to settle out of water or wastewater as it flows slowly through the tank, thereby providing some degree of purification. The outlet of the tank will be filtered and gated.

II. MATERIALS AND METHODS

The proposed wastewater treatment plant is diagrammatically illustrated in figure 2 below. Details explanations of suggested materials and installation methods are enumerated as follow:

Figure 2.ProposedWastewater Treatment Plant

i. **Debris Screen:** This are the plumbing fittings designed to reduced the amount of trash and debris entering sewage sewers which could cause blockage. Nature/Type of appliance used to collect greywater needed will determine the traps or debris screen to be used. It is highly recommended that selected traps should have a screen has suggested by a trained plumber. Samples of debris screen or traps are shown in plate 1.0 bellow

Plate 1.0: Samples of debris screen or traps

ii. **Grit Removal:** This section is meant to remove smaller solid waste that escape debris screen before further treatment process. A sand filter bed was recommended for this exercise (see figure 3.0). Twenty liters paint container is used to house the sand bed with gated 50mm diameter pipe at the container top (inlet) and ungated 50mm diameter pipe at the bottom for outlet.

Figure 3. Typical sand filter bed

iii. **Primary Clarification Tank:** First sedimentation process occurs in this stage. Sedimentation is the process by which suspended particles are removed from the wastewater by means of gravity or separation. Minimum of two hundred liters storage tank is suggested for houses of not more than six occupants for daily process. The tank has three openings as shown in the figure 4.0 below. The sludge outlet was gated to control the system. The inlet received filtrated wastewater from grit removal, greywater was allowed to settled for not less than six hours while sludge outlet gates was closed.

Figure 4.Typical Sedimentation tank

iv. **Aeration Tank:**Aeration system used for this plant is to allow small volume of water to spill slowly for air to mix the waste for oxidation of dissolved meters. The outlet from primary clarification tank was separated into five spaced inlets to be collected by a funnel type wide surface container. Numbers of inlets will be varied based on volume of wastewater coming from primary clarification tank. The oxidized waste was collected from the funnel-like outlet and moved into secondary clarification tank.

v. **Secondary Clarification Tank:** This tank has same specifications and function with primary clarification tank. The effluence from this section has been experimented and confirmed adequate for home garden irrigation system. Underground irrigation system is better recommended for this process instead of surface irrigation system.

Treatment Reliability Caution

Because of the potential harm that could result from the delivery of improperly treated reclaimed water to the user, a high standard of reliability is required at wastewater treatment plants. Water reuse requires strict compliance with all applicable reclaimed water quality parameters. The need for reclamation facilities to reliably and consistently produce and distribute reclaimed water of adequate quality and quantity is essential and dictates that careful attention be given to reliability features during the design, construction, and operation of the facilities. In reclaimed water reliability assessments, close monitoring of all elements that make up a water reclamation system is imperative. These elements include power supply, individual treatment units, mechanical equipment, the maintenance program, and the operating personnel. Critical units in the water reclamation system include the disinfection unit, power supply, and various treatment unit processes. According to USEPA, (2004), reliability of water reuse should also consider the followings:

i. Operator certification to ensure that qualified personnel operate the water reclamation and reclaimed water distribution systems
ii. Instrumentation and control systems for on-line monitoring of treatment process performance and alarms for process malfunctions.
iii. A comprehensive quality assurance program to ensure accurate sampling and laboratory analysis protocol.
iv. Adequate emergency storage to retain reclaimed water of unacceptable quality for retreatment or disposal.
v. Supplemental storage to ensure that the supply meets user demand
vi. A strict industrial pretreatment program and strong enforcement of sewer use ordinances to prevent illicit sewage of hazardous materials that may interfere with the intended use of the reclaimed water; and
vii. A comprehensive operating protocol that defines the responsibilities and duties of the operations staff to ensure the reliable production and delivery of reclaimed water

III. CONCLUSION AND RECOMMENDATIONS

This study set out to evaluate the potential for recycling domestic wastewater, specifically greywater, for home garden irrigation. Through a multifaceted research approach, encompassing laboratory experiments, field assessments, interviews, Design and of a more economical greywater treatment plant, valuable insights have been gained into the feasibility, benefits, and challenges of greywater reuse in home gardening.

i. **Greywater as a Sustainable Resource:**The analysis of greywater as a sustainable water resource for home garden irrigation revealed its potential to significantly contribute to water conservation at the household level.
ii. **Effectiveness of Treatment Technologies:**The assessment of various greywater treatment technologies highlighted the importance of selecting appropriate systems based on factors such as efficiency, cost-effectiveness, and adaptability to household settings.
iii. **Environmental Impact:**Field assessments demonstrated that treated greywater can positively impact soil quality and plant growth, emphasizing the potential for environmental sustainability in home gardening practices.
iv. **Health and Safety Considerations:**Examination of health and safety concerns associated with greywater reuse underscored the importance of proper treatment and user education to minimize potential risks.
v. **Barriers to Adoption:**Exploration of regulatory, economic, and social barriers revealed the need for tailored strategies to promote the widespread adoption of greywater recycling practices.

We hereby recommended that:

- Policymakers should consider flexible and adaptive regulatory frameworks that promote greywater reuse while safeguarding public health and the environment.Incentives and subsidies may be explored to encourage homeowners to invest in greywater recycling systems, addressing economic barriers to adoption.
- Further research and development are encouraged to improve and innovate greywater treatment technologies, ensuring cost-effectiveness, simplicity, and high performance for household applications.
- Educational programs should be implemented to inform homeowners about the benefits and risks of greywater reuse, emphasizing best practices for safe implementation.
- Continued research should focus on long-term monitoring to assess cumulative impacts, providing a more comprehensive understanding of greywater recycling's sustainability over time.

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