SUSTAINABLE AND INTEGRATED TECHNIQUES FOR MANAGING GREYWATER IN THE STATE OF KUWAIT

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ABSTRACT

Due to its rapidly expanding population and limited water supply, Kuwait is having serious problems managing its water resources. Groundwater, desalinated water, and treated wastewater are Kuwait's main sources. In an effort to alleviate the water shortage, a workable process for cleaning greywater for indoor and outdoor reuse is being investigated. Finding environmentally friendly treatment methods that support the principles of sustainable development is the aim of the study. On top of one of the buildings was a pilot plant designed to treat light greywater from a housing complex that was still under construction. The collection tank-self-cleaning filter, pressure sand filtration, carbon adsorption, and ultraviolet and/or chlorine disinfection are the primary technical elements of the proposed treatment plant. Over the course of a year, the project intends to assess the pilot plant's effects on the quality of treated greywater. The results showed that the raw greywater had a comparatively low amount of organic matter (BOD = 106 mg/l, COD = 174 mg/l, and TSS = 53.5 mg/l). The primary results show that only 23.4% of the non-ionic surfactants were eliminated following treatment, compared to 92% of BOD and COD and 93% of TSS. While cationic and non-ionic surfactants were mostly eliminated, anionic surfactants were reduced to a degree of greater than 90%. Finally the greywater has been successfully treated to be reused in different domains.

Keywords: Wastewater Management; Greywater Management; Sustainable Development; Smart Cities in Kuwait.

INTRODUCTION

Water scarcity is one of the largest hazards to human life and the environment in many parts of the world. This situation has made the search for alternative water sources urgent. In addition to helping meet water demands, treated greywater can promote sustainability and water resource management. The State of Kuwait has long faced freshwater scarcity due to its climate. Approximately 121 mm, or 156.2 thousand cubic meters, of precipitation fell on average each year in 2014. There hasn't been much precipitation. It increased, rising from 26.13 mm in November 2015 to 18.39 mm in December 2017 (Environment Public Authority-Kuwait, 2019). Furthermore, the population growth-induced decrease in the per capita share of freshwater necessitates the implementation of a water management strategy that includes greywater treatment and reuse.

Greywater management frequently gets less attention than other environmental sanitation systems, like solid waste and toilet water management, despite its benefits. In certain places, untreated greywater is dumped into sewage or rainwater drainage systems. Despite having the lowest percentage of contaminants, untreated greywater can nevertheless have an impact on human health as well as the condition of soil and groundwater since it contains chemicals, salts, fats, oils, and solid particles (Environment Public Authority-Kuwait, 2019).

By following international standards for the treatment process, we can significantly decrease the chances of groundwater pollution. This underscores the crucial importance and value of treating and reusing greywater. However, it's essential to acknowledge the potential negative effects of utilizing untreated greywater, which are frequently disregarded. In addition, it is essential to avoid harming human health.

Reusing greywater can help towns and governments save a lot of water. Studies have shown that by treating and recycling greywater at its source, the amount of wastewater released into the sewage system can be reduced, saving 25–43% of potable water (Penn et al., 2012; Mourad et al., 2011; Revitt et al., 2010). Furthermore, integrating the environmental pillar of sustainable development aligns with the 2030 Sustainable Development Goals and Goal 6: Water and sanitation for all.

The study intends to address Kuwait's water deficit and suggests a method for reusing greywater indoors and outdoors for activities such as toilet flushing, irrigation, and car washing. It also aims to find and investigate feasible greywater treatment solutions before implementing them in a housing unit in Kuwait to reduce negative environmental impacts and enhance water management. The applied approach develops a low-cost treatment methodology that is affordable for both homeowners and the government.

In terms of language, "greywater" describes its murky condition and the difference between fresh, clean water (also known as "white water") and sewage water (also known as "black water"), which is untreated wastewater from sinks used for laundry, bathing, and toilets. Wastewater from toilets, urinals, and industrial processes is not considered greywater. Kitchen sink effluent is also often rejected due to its high food and oil content (Eriksson E. K., 2002). As a result, greywater is defined as wastewater with no black water discharge and a high amount of wastewater with many potential uses (Filali, H., et al. 2022).

The advantages and disadvantages of treating greywater are the subject of numerous studies. The importance of conserving water has increased due to climate change. Meanwhile, it was found that at least 60% of wastewater from homes is secondary, and greywater, another name for municipal wastewater, has traditionally been discarded despite being easily recyclable (Bouchra H., et al, 2018, Al-Husseini T., et al. 2021). The significance of recycling and using greywater is thus made evident. Treated greywater can be used for irrigation, toilet flushing, and many other uses after major impurities are removed (Do Couto, et al., 2013). Recycled greywater can also benefit agriculture by reducing wastewater discharge into ecosystems and the pressure on water supplies (Maimon, A.; Gross, A., 2018). Furthermore, nitrogen and phosphorus can be reused for improving the growth of the plant.

Given the limited supply of water resources, especially in arid and semi-arid regions, treated greywater can be viewed as a significant alternative approach to lessen the strain of water resource withdrawal, which is one of the primary problems that the context of sustainable development and water management is addressing (Filali, H., et al, 2022). According to the study's findings, recycling treated greywater is a cost-effective and sustainable way to manage water resources and may even help preserve natural water supplies.

Regarding the negative aspects, a study shows that several factors, such as lifestyle, the types of fixtures used, and the climate, affect the quality of greywater generated (Oteng-Peprah M., et al, 2018). Several of the treatment systems under study are unable to offer full treatment because each system has a unique capacity to eliminate a specific set of targeted contaminants. Due to perceived contamination or a lack of trust in the system's level of treatment, users' perceptions of greywater treatment and reuse were only favorable for non-potable uses. In other research (e.g., Zhou et al., 2020; Filali et al., 2022), this could have an effect on the environment and public health, particularly in nations where greywater recycling methods do not aim for full treatment but rather to remove specific pollutants.

Among other things, the climate affects the rates and features of greywater generation (Oteng-Peprah et al., 2018). This implies that the production and composition of greywater are influenced by weather factors. Furthermore, given that arid and semi-arid regions are particularly crucial for the recycling and reuse of greywater, this suggests that weather patterns such as high temperatures and little precipitation may make greywater reuse strategies even more crucial (Khajvand et al., 2022; Nghiem et al., 2006).

Organic materials, fertilizers, bacteria, heavy metals, and surfactants are just a few of the many types of pollutants that can be found in greywater. Depending on the source and domestic habits, these pollutants' composition and concentration can differ greatly (Oteng-Peprah et al., 2018; Perumpully et al., 2023). For instance, greywater usually has a high organic content and notable BOD and COD levels. However, poor biodegradability is indicated by a BOD:COD ratio that is frequently low (<0.5) (Bakare et al., 2016). According to Dwumfour-Asare et al. (2017), greywater also contains heavy metals including Fe, Pb, Zn, and Cd, bacteria like Salmonella spp., E. coli, and total coliforms, and high quantities of nutrients, especially nitrogen and phosphorus.

Numerous approaches and strategies have been developed to examine the effectiveness of various greywater treatment technologies. According to Bouchra H. et al. (2018)[*], the

[*] For example: Low load greywater treatment systems (Slow sand, Rapid sand, Roughing, Slanted soil, Silica, Biosand, Constructed wetlands, Gravel, Anthracite, Lava rocks, Fabric, Ceramic, and Clay), High load greywater treatment systems (Algae, Activated carbon, Biochar, MBBR, MIEX, UASB, and SBR).

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most effective treatment technologies for improved water quality appear to be those that are complimentary to conventional filtration systems, such as reactors and UV disinfection. It is evident that there are great deal of variations and evolutions in different systems, and that each type of technology performs differently due to the variation of raw greywater (Bouchra H., et al, 2018).

Additionally, a study offers a hybrid treatment solution for residential greywater. In addition to the natural flocculation process, the system included a secondary treatment (a bioreactor system) with microalgae for greywater treatment and a first stage (a natural filtration unit) (Wurochekke A., et al. 2016). The hybrid system (filter unit, phytoremediation, and flocculation processes) is extremely capable of producing high quality treated greywater, according to the study, which also noted that this system is an operational solution for the remediation of residential greywater.

Previous case studies have focused on greywater recycling for residential areas in India. Since two-thirds of home wastewater in India is categorized as greywater, a study focuses on recycling and reusing residential greywater from an apartment complex near Vadvalli, Coimbatore (Nandhagopal, Rajeshkumar, 2022). After treatment, the researchers say, greywater can be utilized for gardening, construction, flushing, and other uses. They also highlight how fragile traditional treatment methods are and how they require careful monitoring and process control. As a result, natural wastewater treatment techniques—especially those that use aquatic plants—are gaining traction as substitutes.

Shelarl et al. (2019) conducted an additional investigation focuses on identifying the most suitable and economical method for treating greywater in India's rural regions. It presents a review of existing low-cost technologies for treatment of greywater. As the Municipal Council Nasik (India) was using a high-cost method and not that much effective. The study uses method of stabilization tank which is considered one of the low-cost treatment technologies, and more effective compared to other treatment methods.

Due to its untreated discharge into streets and other public areas, concentrated greywater poses a threat to the environment and human health in urban poor areas of sub-Saharan Africa. In order to address the issue, Amare (2016) investigated on-site treatment solutions that are socially, economically, and environmentally acceptable. The concentrated greywater generated by urban poor people could be treated in a lab using the vermifilter model used in this work. Using a batch supply system, the experimental design investigates the vermifiltration system's operational requirements in hot climes. The 200 mm diameter PVC pipe filters were filled with sand, gravel, and fine sawdust. The vermifilters were inoculated so that they could be compared to a control unit. The effectiveness of the system was assessed using the removal efficiencies of coliforms, nutrients (NH4+, NO3-, NO2-, and PO43-), and pollutants as determined by a variety of physic-chemical parameters (tCOD, dCOD, BOD5, TSS, DO, VS, pH, and temperature). On average, all trials eliminated more than 90% of BOD5 and TSS, 80% to 90% of COD, 60% to 70% of NH4+, 40% to 50% of NO3-, 50% to 60% of NO2-, and PO43-, and 1-4 log units of coliforms.

More broadly, the research on greywater management systems highlights how these systems can help support future more sustainable development as a way to manage water resources. It has also made sense to view these systems as essential to tackling the global water crisis because they can reduce pollution and water consumption. The increasing popularity of greywater management systems raises the possibility that further study in this field is required. In order to promote the broad implementation of these systems and to look into the long-term impacts of greywater management systems on the environment and public health, it also urges the creation of laws and regulations.

However, addressing both quality and social elements is essential to the effective implementation of greywater reuse systems. Enhancing users' understanding of these systems can lower the likelihood that the new technology would be rejected by society (Domènech & Saurí, 2010). It is essential for broad and long-term adoption to develop 'greywater reuse literacy' in the community through easily available, user-friendly information packages (Pinto & Maheshwari, 2010). To incorporate alternative and

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decentralized water delivery systems into urban life, public officials and implementers must foster social learning processes and foster trust among citizens (Domènech & Saurí, 2010).

MATERIALS AND METHODS

Greywater treatment and reuse technologies encompass physical, biological, and chemical systems. The majority of these methods employ disinfection as a post-treatment and a solid-liquid separation process as a pre-treatment (Fig. 1). Pre-treatments including septic tanks, screens, and oil and grease separators are frequently used to lower the quantity of particles, even if the disinfection step is used to meet the microbiological standards. This prevents a blockage in the subsequent treatment.

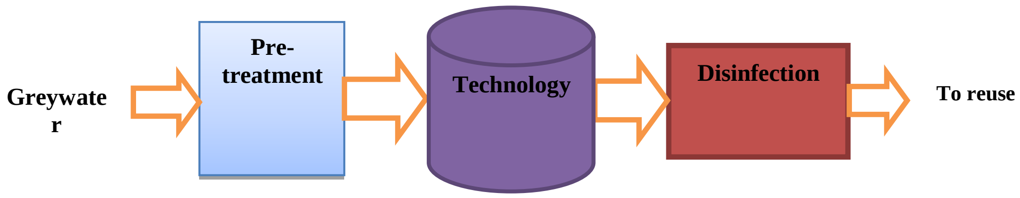

Figure 1. Solid-liquid Separation General Steps

A chlorine injection system, a primary tank for collecting raw water, a pump for feeding the filters, a filtration unit, a chemical injection system, an ultraviolet sterilization unit, a final tank for collecting treated water, a pump for feeding the water outlets, measuring devices, UF membranes to operate in parallel, and an operating and control unit are some of the technical components that typically make up a greywater treatment unit.

When creating plans and specifications for new facilities or making changes to the current network, greywater treatment units must commit to establishing two water recycling networks. A network of sewage and agricultural bins must be established, as well as a dedicated tank to collect treated water. Greywater, which is collected in a ground tank for treatment before being recycled in trash and agricultural bins, is drained via the first network. The drainage of black water is the second network. When treating greywater, there are additional factors to take into account: the plant is technologically suitable for reusing the water's quality; the station's design capacity is proportionate to the actual demand for its use; the station's return to the required efficiency; the station's suitability for the location and number of users; and, lastly, the station's low cost and ease of operation and maintenance.

At a pilot plant situated on the building's roof, light greywater streams from a housing complex that was still under construction were segregated and merged into a single stream that was pumped for treatment. Sand filters, carbon filters, a UV disinfection column, and a chlorination unit made up the majority of the chosen pilot treatment procedures. Flow meters were placed in the water pipes serving the kitchens and toilets in order to measure the amount of greywater. In addition to the flow meters, data loggers were set up to wirelessly record and transmit the readings. The samples were taken from bath tub assemblies and basins in a ground tank (greywater storage tank) equipped with valves to regulate the greywater flow (Fig. 2).

This plant is intended for package-type greywater treatment plants with an average daily flow of 1.5–3 CMD. It is crucial to remember that the plant's capacity is restricted by either the maximum hydraulic flow or the daily organic load, which are as follows: 1.5 CMD is the plant schedule.

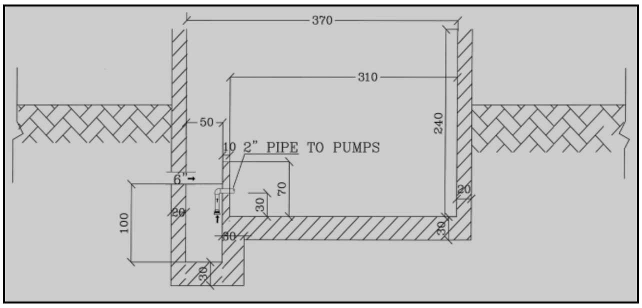

Figure 2. Design Grey Water Storage Tank.

Source: Originally developed by the company that built the treatment plant

Separating greywater streams from blackwater streams was the first difficulty encountered because every structure in Kuwait has a single plumping system for collecting wastewater. In order to achieve this, the study was carried out in a newly constructed building where the light greywater plumbing system—which includes pipes that transport greywater from showers, bathtubs, and hand-washing basins—can be divided and merged into a single greywater stream. This house complex's whole plumbing system was isolated

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during the early phases of development. The plumbing system in the restrooms was changed so that treated greywater would be supplied to all of the toilet flush tanks. Further, all separated greywater streams were combined underground of the building. The main purpose of the separation from the source using two parallel pipelines is to choose between directing to the sewage pipes or reusing them after self-treatment or directing them to the central treatment plants (see Figure 3 and 4).

Figure 3. Modified Plumbing System Inside the Bathroom

Figure 4. Underground Pipes System Separating Black Water from Greywater

The following steps can be used to demonstrate the greywater treatment process: The collection tank, pump to feed filters, self-cleaning filter, pressure sand filtration, carbon adsorption, and ultraviolet and/or chlorine disinfection are just a few of the numerous technical parts that make up the treatment plant, as seen in Figure (5). Various measurement instruments, a pump to supply water outlets, a backwash filter, and a collection tank for the final cleaned water.

In practice, as shown in figure (6), there are two self-cleaning filters, two sand filters, and two carbon filters. The reason for the presence of two treatment lines is to make sure that during the time of the maintenance, the system remains operational. **Greywater Storage Tank**: The combined stream of greywater, which does not include water from the kitchen or cloth washing machine, is collected into the underground greywater storage tank and then pumped to the treatment plant at the roof of the building. A blower system is added to the reaction process and expels odor.

Self-Cleaning Filter: Pumped from the storage tank, greywater goes through the self-cleaning filter in order that all floating materials will be removed which may otherwise choke the pipeline and pumps. It removes obstacles and heavy impurities up to 80 or 100 microns before entering the system. Also, there is a timer that works to get rid of the impurities trapped in the filter, which are pumped into the sewage system along with the blackwater. **Sand Filter**: the main purpose is to remove the impurities as small as 20 microns to purify water.

Carbon Filter: It works to get rid of the taste and smell that probably excite. **UV Disinfection**: Treated Greywater will be going through UV disinfection unite before reaching the treated Greywater roof Tank. Ultraviolet radiation is extensively used to eradicate microorganisms like bacteria. **Treated Water Tank**: Store the treated greywater to be pumped to another tank (Roof Tank). **Chlorine Dosing System**: To sterilize the resulting water. The quantity is determined according to the amount of water in the treated water tank. **Treated Greywater Roof Tank**: Stores the treated greywater to be reused, for example in the toilet flushing system or outdoor use. **Back Wash**: There is pump to pump water into the filters for the back-wash process.

Flow meters are installed in all pipelines that transport potable water in order to track water consumption. Data loggers that wirelessly record and transmit the flow-meter values were placed next to the flow-meters for remote water usage monitoring; one logger was placed for every four flow-meters.

A 12-month sampling and analysis task was established in order to evaluate various aspects, such as seasonal influences, that may impact the quality of greywater and the treatment process. One liter of greywater was collected before and after treatment, and samples were taken weekly to observe the treatment process's gradual effects. Standard methods for analyzing water and wastewater were used to evaluate the samples' physical, chemical, and biological properties (Figure 7) (American Public Health Association-APHA, 2017).

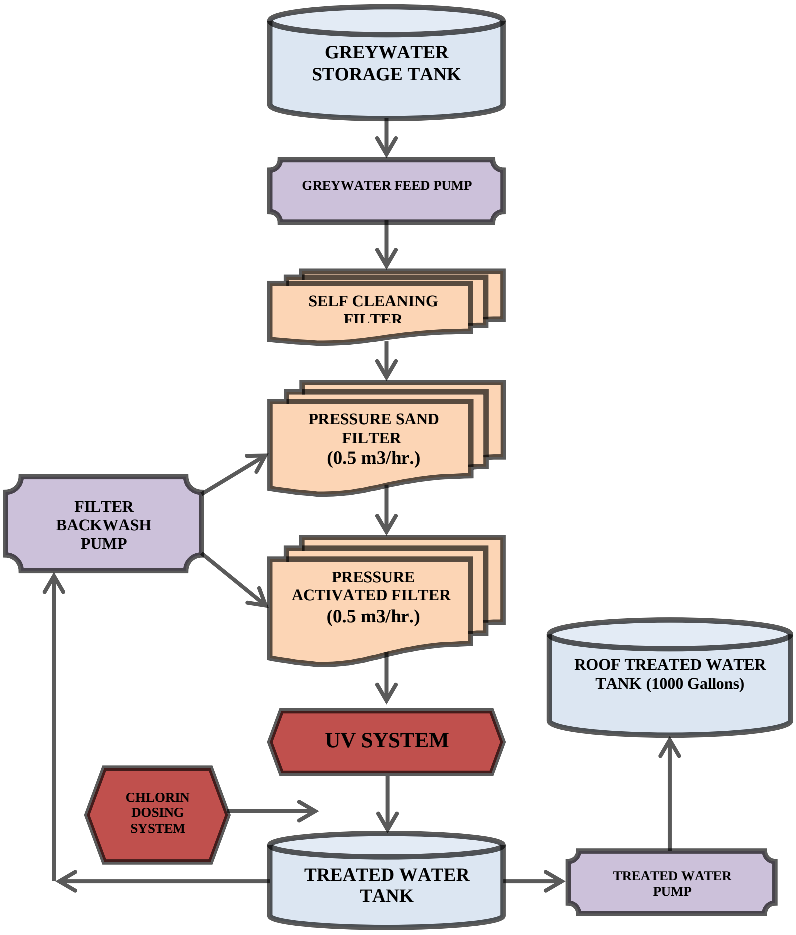

Figure 5. Greywater Treatment System Flow Chart.

This greywater treatment method consists of multiple phases. Following the collection of greywater in the subterranean storage tank, a blower system is built as a physical treatment to remove odor. Apart from being physically treated to remove any floating debris, greywater also goes through a self-cleaning filter that removes heavy contaminants and obstacles as small as 80 or 100 microns. The impurities that are trapped in the filter and pumped into the sewage system are eliminated by the device using a timer. As part of the physical treatment, the sand filter's main job is to cleanse water by getting rid of impurities as small as 20 microns. A carbon filter is also used to remove the taste and odor that are prone to irritate. UV disinfection is a popular chemical treatment technique for eliminating bacteria and other microorganisms. Finally, a chlorine dosing system is used to disinfect the resulting water.

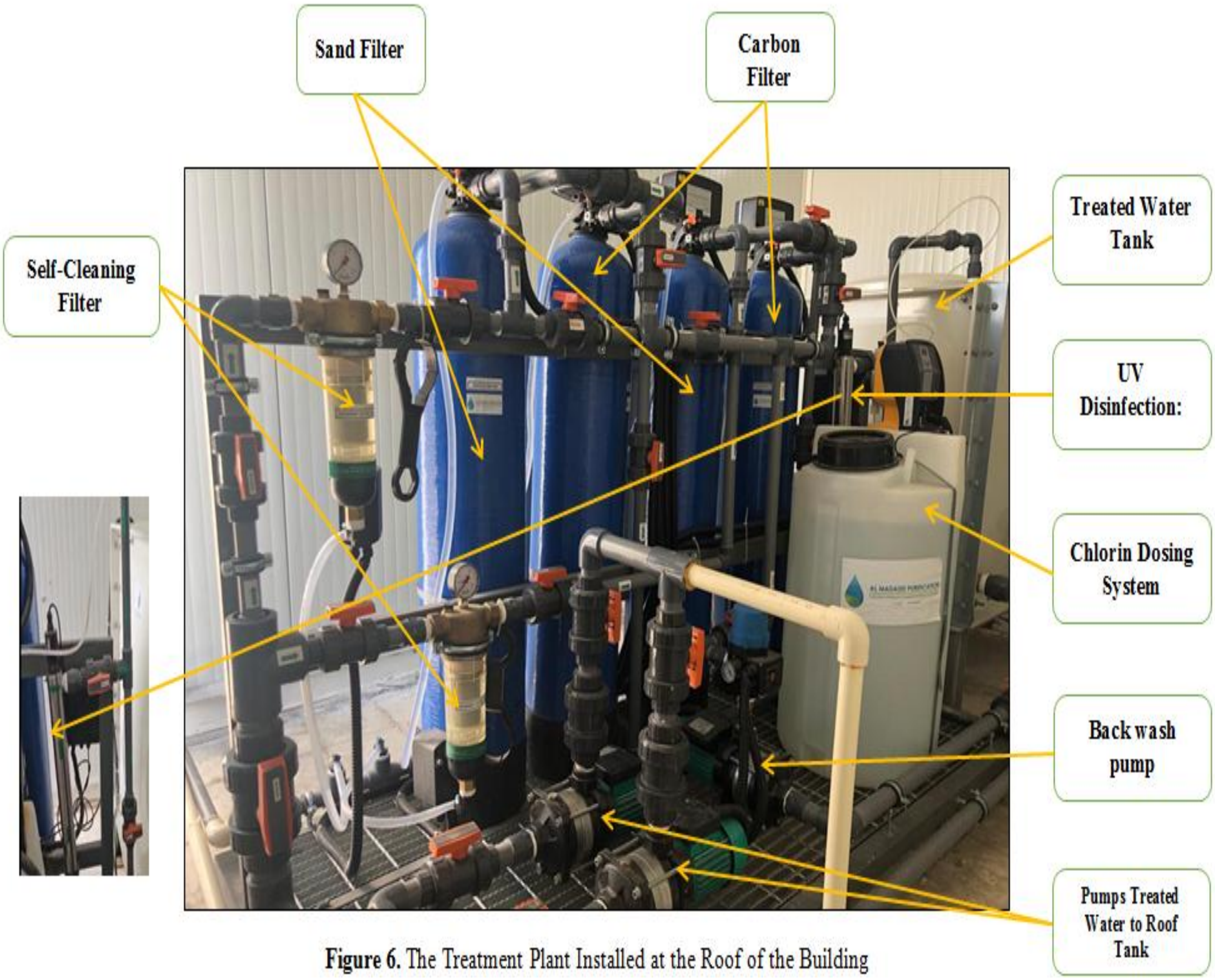

Figure 6. The Treatment Plant Installed at the Roof of the Building

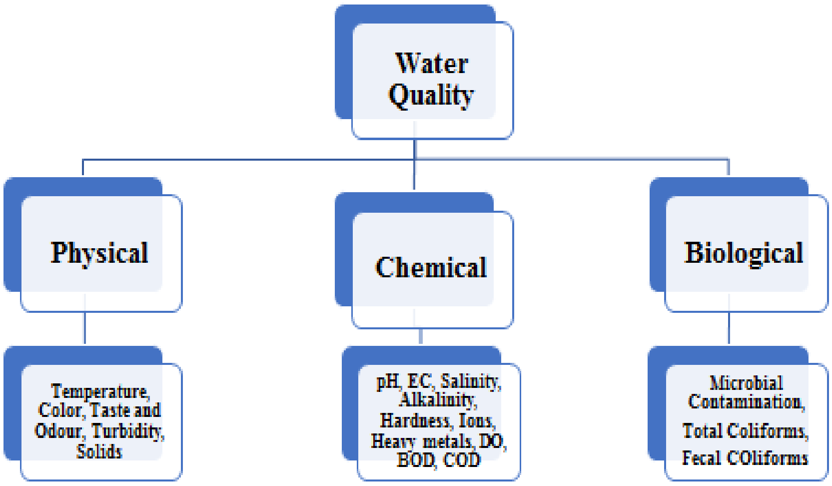

Figure 7. Major Elements of Water Quality

RESULTS

As for the treatment impact on quality of water, Table (1) presents the average quality of greywater before and after treatment during the first four months of the one-year sampling analysis, and Figure (8) present the percentage removal of different nutrients after treatment. The following results are shown:

- Although, the raw greywater was not highly contaminated with organics (BOD = 106 mg/l, COD = 174 mg/l) nor with solids (TSS = 53.5 mg/l), these numbers decreases by 92%, 91.6%, and 93.1% respectively.
- It confirms that light greywater is deficient in nutrients, as concentrations of TN and TP (measured as PO4) were only 4.5 mg/l and 0.5 mg/l, respectively. As there was no external supply of nutrients, no biological treatment unit was included within the pilot project (Fig. 8).
- As shown in the table and the figure, Nitrogen (TN, (mg/l)), and phosphorus (PO4, (mg/l)) were removed by 57.8% and 100% respectively.

- It also displays that the light greywater was also highly loaded with non-ionic surfactants (135.2 mg/l) due to the use of soaps at bathrooms, and was decreases by 23.4% after treatment.
- More than 90% of the anionic surfactants were removed.
- The removals of Non-ionic surfactants and Cationic surfactants were relatively poor.

Table (1): Quality of light greywater before and after treatment

PARAMETER	BEFORE TREATMENT	AFTER TREATMENT	REMOVAL (%)
pH (-)	6.3	6.1	3.2%
EC (µS/cm)	489.6	379.3	22.5%
BOD5 (mg/l)	106.1	8.5	92.0%
COD (mg/l)	174.1	14.7	91.6%
TSS, (mg/)	53.5	3.7	93.1%
TN, (mg/l)	4.5	1.9	57.8%
PO4, (mg/l)	0.5	0.0	100.0%
Anionic surfactants (mg/l)	4.3	0.4	90.7%
Cationic surfactants (mg/l)	0.1	0.1	0.0%
Non-ionic surfactants (mg/l)	135.2	103.5	23.4%

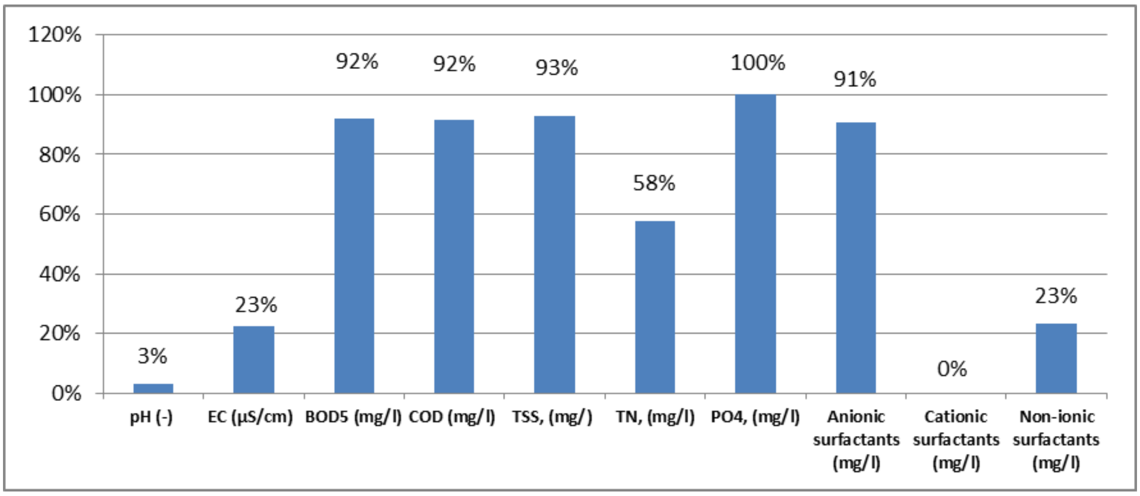

Figure 8. Percentage removals of different nutrients after treatment

It should be mentioned that a number of problems arose during the greywater system installation. In Kuwait, where every building has a single plumbing system for wastewater collection, one of the main obstacles was the requirement to separate the streams of greywater from blackwater. Another issue was the greywater that flooded the subterranean manholes because of the manhole walls or connections. Residents had no concerns regarding the quality of the water used to flush toilets, despite the fact that the greywater had been treated to a level that was nearly drinkable. The location of the greywater sources was another difficulty faced, as it was located close to ground level, therefore, it was difficult to use gravity flow to fill the collection tanks. To solve this issue, it was necessary to install the collection tank below ground level.

DISCUSSION

The current study found that greywater treatment in Kuwait can preserve at least 9% of the water resources that are typically used for toilet flushing, and this share can be extended if greywater is used in a wider range (for outdoor use). Accordingly, this paper provides additional evidence that greywater management is important and can help preserve a valuable water resource and reduce the strain on municipal water treatment systems in light of the growing universal water crisis.

Sustainable and integrated greywater management is a crucial component of urban water strategies for cities in dry countries like Kuwait, where water scarcity is a major problem. Given that greywater makes up around 50% of household wastewater, it presents a significant resource for reuse. Though its usage is still restricted, the State of Kuwait must acknowledge the potential of reusing greywater, mainly for irrigation.

Although a significant portion of Kuwait's treated household wastewater is reused, greywater reuse is less widespread, even though it is simpler to treat than regular domestic wastewater. This implies that the state of Kuwait has a chance to broaden its greywater management strategies. Additionally, incorporating greywater reuse into city infrastructure may enhance sustainability and urban logistical proficiency, lowering freshwater demand and easing the strain on water supplies.

The current study's findings are in line with those of a prior study (Do Couto, E. D. A. et al. 2013), which found that both interior and outdoor uses, like irrigation and car washing, are included in the positive reuse of treated greywater. About 50% of household water, including 9% for toilet flushing, may be treated and reused, per the current study. Only 18% of treated greywater may therefore be utilized indoors; the rest is used outside for watering of gardens, car washing, drainage system drainage, and agricultural irrigation. Two advantages of using treated greywater outside include lowering dependency on conventional water sources and reducing wastewater discharge into the environment. However, masjeds (mosques), hospitals, administrative buildings, car washes, irrigation for gardens and green spaces, and cooling systems for power and fire stations can also use treated water. Therefore, it is clear how much money would be saved by reusing this water in terms of protecting the aquifer, saving electricity, and making the best use of fresh water while also cutting costs. Additionally, after household-level greywater treatment, it reduces the cost of national sanitary water treatment.

Furthermore, when compared to alternative approaches, the suggested treatment strategy employed in this study appears to produce better outcomes. A laboratory-scale subsurface wetland system was established as filtration materials in a recent study (Nandhagopal, Rajeshkumar, 2022) that used sugarcane varietals for phytoremediation purposes. The following is a comparison of the researcher's reported findings with those of the current study: TSS removal efficiencies were 70–91% and 93%, BOD removal efficiencies were 77–89% and 92%, while COD removal efficiencies were 66–81% and 92%. However, the removal efficiencies for total nitrogen (TN) were 58% and 68–84%, respectively. On average, all trials eliminated between 80% and 90% of COD and above 90% of BOD5 and TSS, in contrast to prior research findings (Amare T. A. 2016).

However, concentration-dependent effects, their vulnerability to biodegradation, and differences in surfactant and treatment method efficiency can all be blamed for the low removal rate (23.4%) of non-ionic surfactants. High removal rates for both non-ionic and anionic surfactants in laundry wastewater were shown by a thermophilic aerobic membrane reactor, followed by nanofiltration and activated carbon adsorption. This suggests that combined treatment approaches might be necessary to improve removal (Collivignarelli et al., 2019).

Water consumption measurements showed that the hand basin, shower, and toilet flushed and washed 32%, 18%, 9%, and 1% of the household water. This includes water from showers and hand basins and amounts to light greywater, or around half of the water consumed. However, the amount of potable water used could only be reduced by 9% if this light greywater were to be utilized again for toilet flushing. Accordingly, if solely treated greywater is utilized for toilet flushing, the 634 billion liters of freshwater used for residential uses in 2020 can be decreased by at least 9%. As the cost of water purification in Kuwait is about USD 1.2 billion per year (Tariq, 2022), this means that at least that 9% of the USD 1.2 billion per year will be preserved.

Additionally, from the perspectives of plant management and society at large, the economic feasibility of centralized systems has been validated. With an emphasis on the necessity of efficient treatment technology and stakeholder participation, the literature generally highlights the potential of greywater management as a part of sustainable urban water management. Additionally, homeowners must pay for the treatment of greywater that comes from their homes. However, by reducing the amount of wastewater that is released into the sewage system, treating greywater at its source for reuse can save the government up to 45% of the cost of wastewater treatment. Additionally, this lessens the strain on the supply of fresh water required for housing.

CONCLUSIONS

Urbanization, climate change, and water shortages have made it imperative for the state of Kuwait to adopt integrated and sustainable greywater management systems, particularly in smart cities, in order to address these issues. By utilizing unique treatment technologies and integrating greywater systems into city planning, Kuwait may enhance water sustainability and resilience. This strategy aligns with the more general goals of city development, which include encouraging environmental sustainability and resource optimization. To fully appreciate the advantages of Kuwait's urban water management system, future strategies should focus on increasing greywater reuse through legislative support, technological innovation, and public involvement.

According to recent studies, decentralized greywater treatment systems can help alleviate the scarcity by meeting non-potable water demand and lowering emissions of pollutants, especially in isolated areas. Among the best methods for decentralized treatment include electrochemical processes, membrane systems, and artificial wetlands. Furthermore, greywater reuse and other sustainable water management techniques can lower costs, improve the environment, and make local water systems more resilient.

In summary, this study answers all of the initial issues by outlining the viability of managing greywater in the State of Kuwait and providing a useful and workable greywater treatment technique that may be applied there. The study has also met all of its general and specific goals because it offers a way to reuse greywater both indoors and outdoors, which will help the State of Kuwait overcome its water problem. It accomplishes its objectives by identifying the newest, contemporary technologies based on eco-friendly treatment techniques and implementing a workable one in a Kuwaiti dwelling unit.

Last but not least, the growing trend in the use of greywater management systems indicates that there may be room for more research in this field. This includes a call for more study and development in this field, the need for laws and regulations to encourage the widespread use of these systems, and an investigation into the long-term effects of greywater management systems on the environment and public health.

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تقنيات مستدامة ومتكاملة لإدارة المياه الرمادية في دولة الكويت

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المستخلص

بسبب التوسع السكاني السريع ومحدودية إمدادات المياه، تواجه الكويت مشاكل خطيرة في إدارة مواردها المائية. تعتبر المياه الجوفية والمياه المحلاة ومياه الصرف الصحي المعالجة المصادر الرئيسية في الكويت. وفي محاولة للتخفيف من حدة نقص المياه، يجري التحقيق في عملية لتنظيف المياه الرمادية لإعادة استخدامها داخليًا وخارجيًا. إيجاد طرق علاجية صديقة للبيئة تدعم مبادئ التنمية المستدامة هو هدف الدراسة. تم إنشاء وحدة تجريبية فوق أحد المباني مصممة لمعالجة المياه الرمادية الخفيفة من مجمع سكني لا يزال قيد الإنشاء. يُعد مرشح التنظيف الذاتي لخزان التجميع، وترشيح الرمل بالضغط، وامتصاص الكربون، والتطهير بالأشعة فوق البنفسجية و/أو الكلور، العناصر الفنية الأساسية لمحطة المعالجة المقترحة. وعلى مدار عام، يهدف المشروع إلى تقييم تأثيرات المحطة التجريبية على جودة المياه الرمادية المعالجة. أظهرت النتائج أن المياه الرمادية الخام تحتوي على كمية منخفضة نسبيًا من المواد العضوية (BOD = 106 ملجم / لتر، COD = 174 ملجم / لتر، و TSS = 53.5 ملجم / لتر). أظهرت النتائج الأولية أنه تم التخلص من 23.4% فقط من المواد الخافضة للتوتر السطحي غير الأيونية بعد العلاج، مقارنة بـ 92% من BOD و COD و 93% من TSS. في حين تم التخلص في الغالب من المواد الخافضة للتوتر السطحي الكاتيونية وغير الأيونية، تم تقليل المواد الخافضة للتوتر السطحي الأنيونية إلى درجة تزيد عن 90%. وأخيراً تمت معالجة المياه الرمادية بنجاح لإعادة استخدامها في مجالات مختلفة.

الكلمات المفتاحية: إدارة مياه الصرف الصحي، إدارة المياه الرمادية، التنمية المستدامة، المدن الذكية في الكويت.