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Effect of Greywater Irrigation on Soil Available-Phosphorus

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Abstract

This paper deals with the effect of using greywater for irrigation on the properties of desert soils and the growth of *Lilium, oats and sunflower* under controlled greenhouse conditions. The studied greywater treatments were 0, 25, 50, 75 &100% v/v. pH and electrical conductivity values of greywater used in this study were 8.68 and 2.05 dS/m, respectively. Results showed that irrigation with greywater has an effect on both soil soluble phosphorous and exchangeable phosphorous after plant harvest. Thus, a significant amount of phosphorous can be add to soil through the reuse of greywater. Detergents in washing wastewater contain many contaminants, which in turn affect pH values and electrical conductivity. Whereas, irrigation treatments at a rate of 100% of greywater showed an increase in pH and electrical conductivity values compared to the control and other treatments. Results also showed a clear effect on plants productivity (Biomass), as observed by a decrease in wet and dry weight of plants shoots and root in the treatment 25%, and the best productivity for them during treatment was with 50% and returned to decrease to 100% of greywater. This indicates that irrigation with high concentrations of greywater may reduce the productivity of some plants, including the studied species.

Keywords: *Greywater, Phosphorous, Soil, Domestic plants, Recycle, Libya.*

1. Introduction

Water is a limited source and confirming sustainable water supply, especially in arid and semi-arid regions is critical. During a drought, greywater may be a valuable source of water for domestic plants and lawn. The lengthy e drought of recent years has required a greater focus on developing guidelines for water conservation and recycling. To deal with water scarcity, both industrialized and developing countries are increasingly turning to home greywater for irrigation, greywater recycling is becoming a more important practice of water management, helping to preserve high-quality fresh water and also lowering pollution and overall supply costs. Greywater is untreated wastewater collected from showers, kitchens, sinks, and laundries. Greywater use on land is likely to have environmental consequences, which may be positive and/or negative. Current new technologies and changing attitudes toward wastewater reuse suggest that GW reuse has potential in the developing countries (Al-Hamaiedeh and Bino, 2010) (Flafel *et. al*., 2020). Due to the absence of human excretions (e.g. urine and faecal matter and toilet paper), greywater is less contaminated than municipal wastewater. Greywater is commonly considered to be large volume with low pollution levels (Matos *et. al*., 2012). The majority composition of greywater are cations (such as, Ca, Mg, K), anions (such as, nitrate, sulphate anions, carbonate, and chloride) as well as organic micro pollutants (OMPs) resulting from the detergents (Mohamed *et. al*., 2018). The dumping of greywater into soil drainage is a frequent practice. However, these practices have become unacceptable due to the distribution of pollutants such as chemical agents, OMPs, and pathogens into the natural water and soil and then the transmission into the human via food chain. Besides, greywater's high salinity, which comes from detergents, it accounts for 50–80 percent of total water use in home settings, making it the most major source of water savings. However, other applications such as irrigation of green areas in parks, school yards, cemeteries, golf areas, car wash, and fire protection are practiced (Lu and Leung , 2003). One of the most widely utilized strategies is the use of greywater for irrigation. This is especially important in arid zones, where water is scarce and the reuse of greywater for irrigation could save up to 50% on potable water use. Pinto *et. al*., (2010) reported savings in the range of 30–50% when greywater is reused for toilet flushing and garden irrigation. The microbial activity in the rhizosphere may be influenced by the reuse of greywater for growing plants. However, the long-term sustainability of reusing greywater has been questioned, as polluting the environment is a possibility if greywater is handled incorrectly. Phosphorus has been highlighted as a possible risk for various forms of irrigation and can accelerate freshwater eutrophication (Turner *et. al*., 2013). Sodium tripolyphosphate or potassium phosphates are a major source of phosphorus in greywater. Generally, two processes explain the chemical availability of phosphorus; desorption of phosphorus from sorption sites on iron and aluminium oxyhydroxides, associated with clay mineral surfaces and organic matter; and dissolution of phosphorus compounds present as soil minerals and or fertiliser (Turner *et. al*., 2013). This can cause high phosphorus levels being irrigated onto the soil. Unfortunately, they often do not address relevant issues on environmental impacts and sustainability. It is clear that there is a lack of knowledge about greywater's effects and sustainability. Guidelines for greywater application must be updated to address phosphorus impacts along with education programs to encourage residents to maintain the environmental sustainability. In this study greywater used for irrigation of some deferent plants. The greywater irrigation was studied to evaluate the question of greywater irrigation sustainability and to assess the positive effects of reuse greywater on the soil characteristics and the impact on the phosphors availability in soil.

2. Materials and Methods

Greywater was collected from home laundries in suitable bottle according to the Australian Standard: AS/NZS 5667.1 (Standards Australia, 1998a, 1998b) then sent to laboratory for analysis. Soil samples were obtained from a local farm in Brack, Libya. Air dried and sieved through 2 mm sieve to remove any pebbles or non-soil material and mixed thoroughly to obtain uniform soil material. Soil key properties were determined in the laboratory to characterise the soil used, and the properties at planting and after harvest were determined. The soil moisture was brought close to the field capacity of soil. Three plant species (*Lilium, Avena sativa & Helianthus annuus*) were selected according to their tolerance to the pollutants in soil.

Green house experiment was performed under controlled environmental condition at Environ. Sci. dept. Sebha Univ., Libya. Five irrigation dilution mixtures were used (i.e., 100% potable water (control), 25% greywater, 50% greywater, 75% and 100% greywater). The effect of irrigation by greywater was examined using plant and soil. Factorial experiments with three factors, 45 pots were arranged in a Complete Randomized Design (CRD). The pots were filled with sandy-loam desert soil obtained at a depth of 0-15 cm. Plant species (*Lilium, Avena sativa* and *Helianthus annuus*) with three replicates were grown for 30 days. The change in root and shoot length was observed and recorded.

Greywater chemical parameters measured were; pH, electrical conductivity: EC, suspended solids: SS, Total phosphorus: TP using procedure described by (Clesceri *et. al*., 2000). Soil pH was measured using pH meter in solutions ratio of 1:1 (Aishah and Elssaidi., 2019). Soil texture was determined by pipette method (Kettler *et. al*., 2001). EC was measured using conductivity meter (Richards,1954), Total dissolved solids (TDS) were calculated as (TDS=EC25×0.064), The Ca and Mg were extracted using ammonium acetate pH 7.0. Calcium and magnesium ions were determined by titrimetric method using E.B.T and Murexid reagents (Franson *et. al*., 1995). Phosphorus was determined according to the procedure of Chang and Jackson (1958) and Aishah and Elssaidi, 2019).

Biomass, plant height and leaf numbers were measured in each replication during the study period. Plants were harvested at the end of experiment prior to analysis, washed with deionized water to remove soil particles. The fresh samples were weighed and oven dried for 48 hours at 70 ºC until constant weight (Wu *et. al*., 2009). Roots and shoots were oven dried at 70 □C to determine dry weights. Relative Growth rates (RGR) was used to compare between different plant species and reported in terms of grams per day (g DW day^{-1}) based on total dry biomass using the following equation (Hadad *et. al*., 2006):

$$\mathbf{RGR} = \frac{\ln W2 - \ln W1}{T}$$

Where: *W1 and W2 are the initial & final dry weights (g), respectively and T is time (day).*

3. Results and Discussion

Greywater characterization

Greywater quality is mainly determined by its source. The pH, EC, SS, and TP are critical characteristics to consider for greywater sustainability and reuse. Result showed that the pH of greywater tested was 8.7 (Table 1). As a highly alkaline pH in the range of 8–10 was reported by Pinto *et. al*., (2010). Greywater originating from laundries has demonstrated varying levels of alkaline pH values in the range 8–10 (Eriksson *et. al*. 2002), 9.3–10 (Christova-Boal *et. al*. 1996), 8.1 (Surendran & Wheatley 1998), and 9.3–9.5 (Dixon *et. al*. 1999). For electrical conductivity provides an indication of salt content extent. EC depends on the type of detergent and life style of resident's. Salinity is an important factor in deciding whether water is suitable for irrigation or not. The tested greywater EC was 2.05 dS m^{-1} and TDS 0.1312 $mg.l^{-1}$. This is within the FAO's recommended limits (FAO, 1985) (> 3.0 $dS.m^{-1}$ and TDS > 2000 $mg.l^{-1}$). Water and wastewater salinity is characteristically measured using total dissolved salt and electrical conductivity. Overall, there appears to be no exact pattern of EC levels for different greywater streams (i.e., kitchens, bathrooms, washing machines); nevertheless, shower water has a low EC level, whereas laundry, dishwashers and bathroom, have high EC levels. Greywater calcium and magnesium concentrations were found 32 and 14.4 $mg.l^{-1}$, respectively. These ranges are within FAO (1985) standards. Studied greywater also contain 1.5 $mg.l^{-1}$ of phosphorus. The elevated P levels observed could be due to the combined effects of selected households using high-P detergents, these values were within the limits suggested for wastewater (Zavadil, 2009).

Phosphorus is a crucial nutrient for plants, although even slightly high concentrations can cause eutrophication, greywater normally contains low level of nutrients (N & P) compared to domestic wastewater (Nguyen *et. al*., 2020). In general, these results concluded that greywater studied chemical composition is in the standards limits and this greywater has the potential to be utilized in irrigation.

Table 1. The characterization of the greywater used

Properties	Unit	Values
pH		8.7
EC	mS/cm	2.1
TDS	mg/L	0.1312
P	µg/L	1.5
Ca	µg/L	32.0
Mg	µg/L	14.4

Soil physicochemical characterization:

Gebauer *et. al.* (2021) stated that soil texture is a fundamental physical property of soils. Which classified in this study as *Loamy Sand* soil according to the United States Department of Agriculture (USDA) soil texture classification (Soil Survey Staff, 2014). As stated by Wen *et. al.* (2019) soil texture is an important soils physical property. (Table 2) shows some of the physical and chemical characteristics of the soil. The soil studied had a slightly alkaline pH (7.6), which is very common in arid and semi-arid regions. In addition, the results revealed a low OM level (2.0%), which is common in arid desert regions. Reduced organic matter input is responsible for a large portion of the loss in soil organic carbon, increased decomposability of crop residues, and tillage effects that decrease (Alaswad *et. al.*, 2019). Generally, tested soil has low EC value (0.933 $mS.cm^{-1}$) and TDS (0.597 $mg.L^{-1}$).

Table 2. The characterization of the soil used

Properties	Unit	Values
Soil texture		***Loamy Sand Soil***
Sand	*%*	*40.5*
Silt	*%*	*46.8*
Clay	*%*	*12.8*
pH	-	7.6
FC	%	26
EC	mS/cm	0.933
Ca	µg/kg	32
Mg	µg/kg	19.2
Soluble P	µg/kg	14.5
Exchangeable-P	µg/kg	1.2
OM	%	2.00
TDS	mg/L	0.597

Greywater effect on soil characterisation

Selected plant species were grown for one month in loamy sand soil pots. Then harvested and oven dried before used for analysis. The results revealed that even greywater may have higher pH (8.7), the applied water resulted in soil pH increases. Soil chemical parameters were changed due to greywater irrigation (Table 3), that might be able to affect the soil quality owing to the presence of salts. Generally, greywater treatments increased the pH and EC in tested soil, especially, that irrigated with 100% level, which showed higher value than others (tap water). These findings were in agreements with Sivongxay, (2005) who found evidence on salts accumulation and surfactants in arid soils that irrigated by greywater and causing changes in properties of soil. Furthermore, soil pH and several salts accumulation can affect greywater sustainability and irrigation reuse. Al-Hamaiedeh and Bino (2010) study indicated that soil salinity has increased over time, and some freshwater leaching is necessary to maintain soil suitability for plant growth. However, for soil planted with *Lilium*, the high content of basic cations such as Na^{+}, Ca^{2+}, and Mg^{2+} caused pH increase after greywater application. Greywater with high pH acts as a dispersing agent, which causes soil particles split and lead to higher soil cation exchange capacity: CEC, (Anwar 2011). Irrigation by greywater resulted to higher values in soil EC. The maximum recorded EC was with 100% treatment (2.46 $dS.m^{-1}$), followed by 75% level (2.32 $dS.m^{-1}$). The rise in EC is mostly due to the initial level of greywater TDS that would accumulate in soil with continued application, which lead to accumulation of low soluble salts in soil. This means that detergents is associated with the increase of soil EC. Similarly, Rodda *et. al*. (2011) observed that irrigation by greywater resulted in increased over time in soil and eventually an increase in Na concentrations and other metals in plants grown using greywater. Particular source of concern is long-term sustainability issue such as increasing soil salinity. High soil salinity values cause soil structure deteriorations, decrease of soil permeability and reduction of crop yields owing to toxic and osmotic effects. However, salts added continuously through irrigation may become concentrated in the soil as water may absorbed by plants or evaporated from the soil. Salt accumulation in rhizosphere may impact some plants growth if it exceeds their tolerance limits. To manage this issue, fresh water in excess of plant water usage at specific times could be needed to leach rhizosphere accumulated salts. Also, the concentrations of Ca and Mg were affected by greywater treatments. The higher rate of greywater application the higher concentrations of Ca and Mg (296.0 & 48.0 $\mu g.Kg^{-1}$, respectively). Evidence is given that greywater plays a significant influence in increasing P into different Soluble-P and Exchangeable-P forms in the teared soil. Generally, soluble-P contents were higher than exchangeable-P. This in line with Aishah and Elssaidi, (2019).

Soil planted with *Avena sativa* plants, revealed sequential increase in soil pH owing to the adding of greywater. The solubility and availability of certain nutrients in treated soils would be affected by an increase in soil pH. The inclusion of Na in greywater as primary content in laundry detergents can potentially rise the level of pH in irrigated soil. These findings are consistent with the findings reported by Waisel (2012), who claimed that Na increased through the dissociation of adsorbed Na which raising the pH of the soil solution. In general, these findings revealed that greywater irrigation has direct effects on EC, Ca, and Mg, where, the concentrations increased because of the use of greywater during the growing season. Therefore, addition of greywater to the soil could provide essential nutrients for plant species growth. Some authors agree with the above viewpoints, stating that wastewater irrigation improved soil characteristics (Yassin *et. al*., 2017).

Phosphorus is one of the key elements necessary for the growth of plants. Greywater irrigation can increase phosphorus concentrations. The values of soluble-P and exchangeable-P were increased following greywater application. The higher rate of greywater application (100%), the higher concentrations of Soluble-P and Exchangeable-P, (14.30 & 3.00 µg.Kg^{-1} respectively) (Table 3).

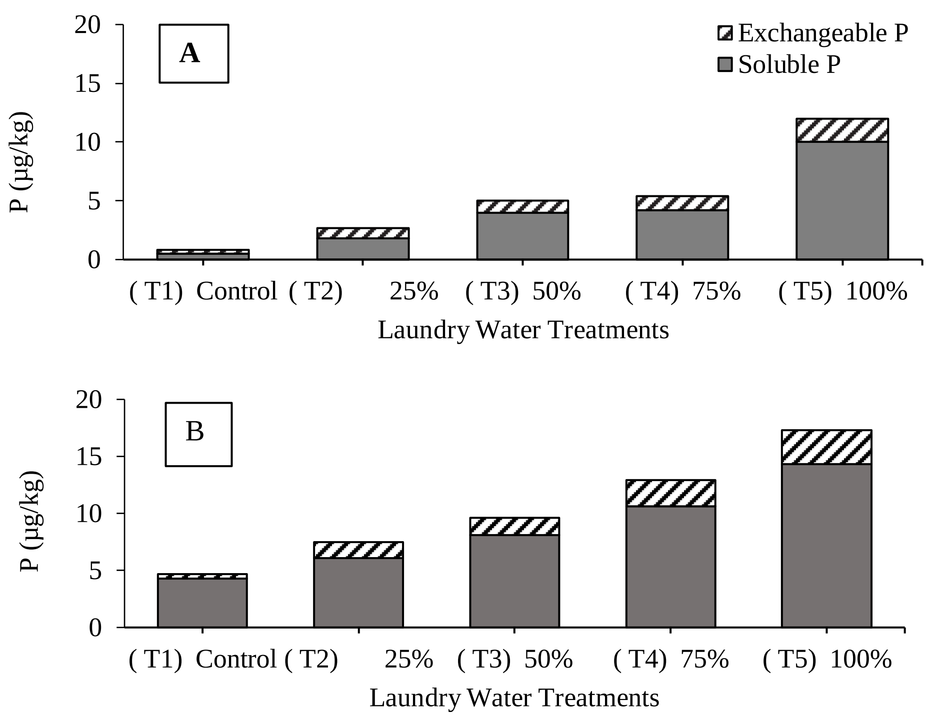
However, the application of greywater in soil cultivated with *Helianthus annuus* is likely to result in soil pH increase. Soils irrigated with 100% treatments had a higher value (8.3) than other treatments. Excessive applications of highly alkaline water (> 8.5) may, however cause a pH alteration in the soil in the short term (Myers *et. al*. 1999). The highly alkaline laundry detergents helps to dissolve organic dirt; such as grease, oils and food scraps. Use of greywater with total dissolve salts (TDS) to soils over extended periods of time might also cause salinity problems. Salts found in all laundry detergents, usually sodium salts such as sodium nitrate, sodium sulphate, sodium phosphate and sodium silicate, are making them highly saline. Greywater irrigation resulted in increased Ca and Mg, soluble-P and exchangeable-P soil that was treated with higher rate of greywater application (100%) (Table 3).

Table (3): Effect of greywater treatments on chemical characterization of the treated soil.

Cultivar	Properties	Unit	Greywater Treatments				
			Control	25%	50%	75%	100%
Lilium	pH		7.90	8.23	8.25	7.26	8.27
	EC	dS/ m	1.47	1.59	1.98	2.32	2.46
	Ca	µg/kg	80.00	208.00	256.00	272.00	296.00
	Mg	µg/kg	19.20	33.60	38.40	44.10	48.00
	Soluble-P	µg/kg	05.0	1.80	4.00	4.20	10.00
	Exchangeable-P	µg/kg	0.30	0.90	1.00	1.20	2.00
Avena sativa	pH		7.91	8.04	8.09	8.09	8.10
	EC	dS/ m	1.05	1.11	1.27	1.32	1.65
	Ca	µg/kg	64.00	248.00	620.00	640.00	640.00
	Mg	µg/kg	43.40	43.20	33.60	28.80	24.00
	Soluble-P	µg/kg	4.30	6.10	8.10	10.60	14.30
	Exchangeable-P	µg/kg	0.40	1.40	1.50	2.30	3.00
Helianthus annuus	pH		7.73	8.06	8.19	8.24	8.28
	EC	dS/ m	1.44	1.92	2.11	2.47	2.97
	Ca	µg/kg	120.00	208.00	218.00	220.00	241.00
	Mg	µg/kg	19.20	28.80	33.60	52.80	52.80
	Soluble-P	µg/kg	1.10	2.10	2.70	3.40	3.60
	Exchangeable-P	µg/kg	0.60	0.80	0.90	1.30	2.10

Phosphorus availability in treated soil

The P availability in most ecosystems is influenced by soil properties such as parent material mineralogy, rates of leaching and texture of soil. P availability in desert soils is often considered to be low (Aishah and Elssaidi, 2019). In dry environments, greywater reuse is critical for long-term water management, promoting the preservation of the limited freshwater resources, and reducing environmental pollution and overall input cost (Al-Mefleh *et. al*., 2021). To get a comprehensive view of the differences in the availably of phosphorus among the greywater treatments, the mean concentrations of soluble-P and exchangeable-P in the treated soils were compared. Figure (1) showed noteworthy differences between the soils cultivated with *Lilium*, *Avena sativa* and *Helianthus annuus* due to the proportion of plant P uptake. Generally, the amount of soil soluble-P and exchangeable-P increased linearly with increasing greywater amount (Fig. 1). These findings proved the major role of greywater plays in increasing the availability of soluble-P and exchangeable-P in teared soil. The higher rate of greywater application (100%) contributed to higher soluble-P and exchangeable-P concentrations. In general, soluble-P contents in tested soil were higher than exchangeable-P. This in line with Aishah and Elssaidi, (2019). In most ecosystems, the availability of P is controlled by soil properties and considered to be low (Aishah and Elssaidi, 2019).



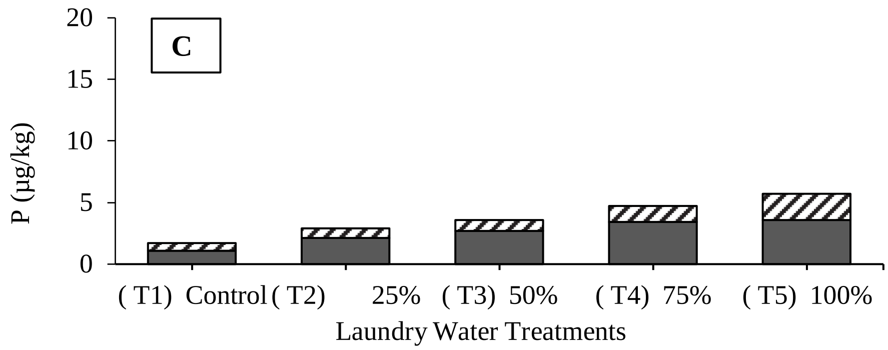


Figure (1): Availably of Phosphorus in treated soil cultivated with, A: *Lilium,* B: *Avena sativa.*, and C: *Helianthus annuus.*

Effects of greywater on cultivated plants:

Biomass is the most commonly used as an index for plants growth on soil irrigated by greywater. Table (4) presented the impacts of different irrigation treatments on the wet as well as dry weight values, as well as the biomass of shoots and roots of the examined plants. On the other hand, there was a trend of slight reduction in wet and dry weight of roots and shoots when irrigating *Lilium* plants with 25% greywater compared to control. The highest roots and shoots values were with 50% treatment then slightly decrease under 100% greywater treatment. Detergents also contain phosphorus and nitrogen nutrients that necessary for plant growth, so greywater may reduce fertiliser application.

Present study results presented the effect of greywater irrigation on the *Avena sativa* plants growth. A slight increase in wet and dry biomass of root and shoot by irrigating *Avena sativa* with different greywater treatments was observed, and the reported trend (with 25, 50, 75 & 100%) was compared to control. This agree well with the reported findings by Al-Hamaiedeh and Bino (2010), where an increase in inorganic nutrients in crops that had irrigated by greywater also observed. Greywater therefore, has significantly reduces fertiliser's application specially, on gardens and lawns. Irrigation is also preferred for nutrient application since nutrients are applied more gradually and nutrients are less washed away during wet weather. Generally, this study proved an increase in plants productivity due to greywater nutrients. Greywater irrigation has been adopted around the world and has been suggested as a possible long-term answer to increase water demands.

The maximum productivity of *Helianthus annuus* was obtained with control. The findings (Table 4) demonstrated that greywater treatments decreases the biomass of *Helianthus annulus*. However, the detergents in greywater may be tolerated by most ornamental plants. So, the most important consideration is not to over irrigate.

Table 4. Effect of various greywater treatments on the productivity of tested plants.

Plant species/parts		Control Wet weight	Control Dry weight	25% Wet weight	25% Dry weight	50% Wet weight	50% Dry weight	75% Wet weight	75% Dry weight	100% Wet weight	100% Dry weight
Lilium	Shoots	2.00	0.16	0.20	0.17	4.09	0.19	3.08	0.05	2.25	0.28
	Roots	58.04	42.9	55.6	5.25	51.17	38.6	31.37	21.79	24.09	15.42
Avena sativa	Shoots	0.55	0.25	0.94	0.31	0.93	0.34	1.01	0.27	0.52	0.27
	Roots	0.44	0.34	0.75	0.54	0.74	0.56	0.64	0.39	0.71	0.46
Helianthus annuus	Shoots	10.06	1.78	5.69	0.88	5.19	1.21	2.52	0.68	0.85	0.25
	Roots	3.62	1.45	2.40	0.80	1.68	0.62	1.01	0.30	0.38	0.14

The increased biomass per unit time is termed as relative growth rate (RGR). So, RGR used to compare among plant species that differ in size. In agreement with previous research, the tested plants do appear to have different RGR (Houghton *et. al*., 2013 and Aishah *et. al*., 2019). The results of our study indicated a variance for the growth rate of the plant species. These differences in the RGR were thought to reflect the variation in physiology of plant species (Aishah *et. al*., 2019). RGR obtained can be compared among plant species that differed widely in size (Table 5). RGR of the plants was in the order of *Lilium* 0.080 g(DW).day^{-1} > *Helianthus annuus* 0.031 g(DW).day^{-1} > *Avena sativa* 0.020 g(DW).day^{-1}.

Table 5. Effect of greywater treatments on growth rate (RGR g(DW).day^{-1})

Plant species	Treatments Control	25%	50%	75%	100%
Lilium	0.040	0.040	0.080	0.070	0.061
Avena sativa	0.020	0.004	0.002	0.010	0.020
Helianthus annuus	0.031	0.012	0.02	0.010	0.020

Plant height for *Lilium, Avena sativa* and *Helianthus annuus* shows differences between greywater treatments levels (Table 6). There is considerable variability in the phytotoxic effects of greywater on various plant species. As a result, identifying greywater tolerant and intolerant plants is critical for greywater recycle. There is a scarcity of information on this topic in the literature. The length of *Lilium, Avena sativa* and *Helianthus annuus* tend to be affected by the use of greywater. However, there was a trend of reduction in lengths of *Lilium, Avena sativa* and *Helianthus annuus* by irrigating tested plants with 100% greywater compared to other treatments. The highest length for *Helianthus annuus* and *Avena sativa* were recorder with potable water 33.30 and 17.00 cm, respectively. While the highest length for *Lilium* was obtained using 25% level. The current study's findings indicate that greywater has an effect on plant species growth for the treatments investigated. These findings are in line with the results of the several researches that indorsed some negative effects of greywater on plant species growth (Bubenheim *et. al*., 1997; Wiel-Shafran *et. al*., 2006). As greywater is typically alkaline in nature, acid preferable plants are unlikely to be amenable to greywater usage. On the other hand, most ornamental plants may tolerate detergents in greywater such as phosphate fertilizer, but it's crucial not to over-irrigate.

Table (6): Average the heights of plants (cm) under greywater treatments

Plant species	Treatments				
	Control	25%	50%	75%	100%
Lilium	9.50	18.60	12.40	10.50	9.30
Avena sativa	33.30	13.90	12.30	7.30	6.90
Helianthus annuus	17.00	16.50	13.00	10.90	9.80

Conclusion

The purpose of this research is to evaluate the quality of greywater in order to identify its potential for reuse. Greywater samples were collected and analysed from laundries to determine their water quality parameters. Our recent study concluded that the laundry greywater contains noteworthy concentrations of suspended solids, inorganic constituents and total –P. The recycle and reutilizing of greywater has been experienced in numerous countries due to the obvious benefits in terms of fresh water reserves and management. The main concern is the accumulation of salts in the soil, which can lead to salinity problems. Irrigating plants with laundry greywater resulted in increased soil pH and EC. Furthermore, sandy soils irrigated with raw laundry greywater increased availability of phosphorus into soluble-P and exchangeable-P. We found that laundry greywater can be used for irrigation which is very important in arid as well as semi-arid areas when freshwater is limited.

References

List of References

Aishah, R. M., & Elssaidi, M. A. (2019). Fractionation of organic and inorganic phosphorus in sandy soils irrigated by treated wastewater cultivated by hordeum vulgre & vicia faba. Journal of Pure & Applied Sciences, 18(4).

Aishah, R., Shamshuddin, J., Fauziah, C., Arifin, A., & Panhwar, Q. (2019). Using plant species for phytoremediation of highly weathered soils contaminated with zinc and copper with application of sewage sludge. BioResources, 14(4), 8701-8727.

Alaswad, F., Aishah, R.M., Mohmat-Yousff, F., Jusoh, I., Kusin, F., Ashaari, Z., &. Mostafa, R. (2019).Soil organic matter dynamics in particle size fractions as revealed by the 13C/12C isotopic ratio in tropical soil. Libyan Journal of Ecological & Environmental Sciences and Technolog., 1 (2),16-21

Al-Hamaiedeh H., & Bino M., (2010). Effect of treated grey water reuse in irrigation on soil and plants. Desalination, 256(1-3), 115-119.

Al-Mefleh, N. K., Othman, Y. A., Tadros, M. J., Al-Assaf, A., & Talozi, S. (2021). An assessment of treated greywater reuse in irrigation on growth and protein content of Prosopis and Albizia. Horticulturae, 7(3), 38.

Anwar A. H. (2011) Efect of laundry greywater irrigation. J Enviro Res Devel 5(4).

Bubenheim D., Wignarajah K., Berry W., & Wydeven T. (1997). Phytotoxic effects of greywater due to surfactants. Journal of the American Society for Horticultural Science, 122:792–6.

Chang, S. C., & Jackson, M. L. (1958). Soil phosphorus fractions in some representative soils. Journal of Soil Science, 9(1), 109-119.

Christova-Boal D., Eden R. E., & Mcfarlane S., (1996). An investigation into greywater reuse for urban residential properties. Desalination. 106:391–397.

Clesceri, L. S., Greenberg, A. E., & Eaton, A. D. (2000). Standard methods for the examination of water and wastewater; American Public Health Association: Washington, DC, 2000.

Dixon A., Butler D., & Fewkes A. (1999). Water saving potential of domestic water reuse systems using greywater and rainwater in combination. Water Sci. Technol. 39:25–32.

Eriksson E., Auffarth K., Henze M., & Ledin A. (2002). Characteristics of grey wastewater. Urban Water J. 4:85–104.

FAO (Food and Agriculture Organization of United Nations). (1985). Water quality for agriculture. FAO, Rome. http:// www.fao.org/DOCReP/003/T0234e/T0234e00.htm.

Flafel, H. M., Kaeebah, A., Fadel, M., & Annejjar, A. T. (2020). Drinking water quality of some commercial water purification systems at sabratha area, Libya. Libyan Journal of Ecological & Environmental Sciences and Technolog., 2(2),9-21.

Franson, M. A., Eaton, A. D., Clesceri, L. S. & Groenberg A. E. (1995). Standard methods for examination of water and wastewater 19th. Amriecan Public Health Association, Washingtion. USA

Gebauer, L., Bouffaud, M. L., Ganther, M., Yim, B., Vetterlein, D., Smalla, K., & Tarkka, M. T. (2021). Soil texture, sampling depth and root hairs shape the structure of ACC deaminase bacterial community composition in maize rhizosphere. Frontiers in microbiology, 12.

Hadad, H. R., Maine, M. A. & Bonetto, C. A. (2006). Macrophyte growth in a pilot-scale constructed wetland for industrial wastewater treatment. Chemosphere. 63(10): 1744-1753.

Houghton, J., Thompson, K., & Rees, M. (2013). "Does seed mass drive the differences in relative growth rate between growth forms?," The Royal Society's Flagship Biological Research Journal (280), 1762. DOI: 10.1098/rspb.2013.0921

Jackson M. L. (1958). Soil chemical analysis. 30 pp: Prentice Hall, New Jersey.

Kettler, T. A., Doran, J. W. & Gilbert, T. L. (2001). Simplified method for soil particle-size determination to accompany soil-quality analyses. Soil Science Society of America Journal. 65(3):.849-852.

Lu, W., & Leung A. Y. T., :(2003) A preliminary study on potential of developing shower/laundry wastewater reclamation and reuse system, Chemosphere 52 1451–1459.

Matos, C., Sampaio, A., & Bentes, I. (2012). Greywater use in irrigation: characteristics, advantages and concerns. Irrigation-Water Management, Pollution and Alternative Strategies, 159-84.

Mohamed, R. M., Al-Gheethi, A. A., & Noramira, J. (2018). Effect of detergents from laundry greywater on soil properties: a preliminary study. Appl Water Sci 8: 16–24.

Myers, B. J, Bond, W. J., Benyon, R. G., Falkiner, R. A., Polglase, P. J., Smith, C. J., Snow, V. O. & Theiveyanathan, S. (1999), Sustainable effluent irrigated plantations: Australian Guideline, CSIRO Land and Water, Canberra.

Nguyen, X. C., Tran, T. P., Hoang, V. H., Nguyen, T. P., Chang, S. W., Nguyen, D. D., & Bach, Q. V. (2020). Combined biochar vertical flow and free-water surface constructed wetland system for dormitory sewage treatment and reuse. Science of The Total Environment, 713, 136404.

Pinto, U., Maheshwari, B. L., & Grewal, H. S. (2010). Effects of greywater irrigation on plant growth, water use and soil properties. Resources, Conservation and Recycling, 54(7), 429-435.

Richards, L. A. (1954). Diagnosis and improvement of saline and alkali soils. 78 (2) 154. LWW.

Rodda, N., Salukazana, L., Jackson, S. A. F., & Smith, M. T. (2011). Use of domestic greywater for small-scale irrigation of food crops: Effects on plants and soil. Physics and Chemistry of the Earth, Parts A/B/C, 36(14-15), 1051-1062.

Sivongxay A. (2005) Hydraulic properties of Toowoomba soils for laundry water reuse. Thesis BEng Environmental, University of Southern Queensland.

Soil Survey Staff, (2014). Keys to soil taxonomy. United States Department of Agriculture Natural Resources Conservation Service, 12nd ed. pp735–741.

Standards Australia. AS/NZS 5667.1:1998, Water quality — sampling — guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples edn. Homebush NSW: Standards Australia; 1998a.

Standards Australia. AS/NZS 5667.10:1998 Water quality: sampling. Part 10, Guidance on sampling of waste watersStandards Australia ed. ; 1998b [Homebush, NSW].

Surendran, S., & Wheatley, A. D. (1998). Grey-water reclamation for non-potable re-use. Water and Environment Journal, 12(6), 406-413.

Turner, R. D., Will, G. D., Dawes, L. A., Gardner, E. A., & Lyons, D. J. (2013). Phosphorus as a limiting factor on sustainable greywater irrigation. Science of the Total Environment, 456, 287-298.

Waisel Y. (2012). Biology of halophytes. Academic Press INC, London

Wen, K., Li, L., Zhang, R., Yang, L., & Amini, F. (2019). Micro-scale analysis of microbial-induced calcite precipitation in sandy soil through SEM/FIB imaging. Microscopy Today, 27(1), 24-29.

Wiel-Shafran, A., Ronen, Z., Weisbrod, N., Adar, E., & Gross, A. (2006). Potential changes in soil properties following irrigation with surfactant-rich greywater. Ecological Engineering, 26(4), 348-354.

Wu, F., Yang, W., Zhang, J. & Zhou, L. (2009). Cadmium accumulation and growth response of a poplar (Poplus deltoids x Pupulus nigra) in cadmium contaminated purple soil and alluvial soil. Journal Hazard Material.1: 1-6.

Yassin, M., Jamal Safi, J. M., & Mohamed Safi, Y., (2017), Impact of treated wastewater irrigation on soil properties and production of Cucumis melo inodorus in Gaza Strip., Int. J. Soil Sci., 12: 104-112.

Zavadil, J. (2009). The effect of municipal wastewater irrigation on the yield and quality of vegetables and crops. Soil and water research, 4(3), 91-103.