Annals of Agricultural Sciences 64 (2019) 237–243

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Annals of Agricultural Sciences

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Application of the epuvalisation technology for the tertiary treatment of secondary treated effluents using geranium plants

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ARTICLE INFO

Keywords:
Epuvalisation
Wastewater
Nutrients
Percentage removal
Secondary treatment
Geranium plants

ABSTRACT

The effluent of secondary treatment process at Al-Quds University wastewater treatment plant was tertiary treated using an Epuvalisation technique in which geranium plants (*Pelargonium hortorum*) was employed as a treatment vehicle. The Epuvalisation system was installed in a greenhouse in which germanium was planted hydroponically in a closed-loop mode using secondary treated wastewater (TWW) and fresh water (FW) as a control. The water quality analysis results before and after the growing season of TWW showed a reduction of 23% and 41%, for BOD and COD, respectively. The electrical conductivity (EC) and total dissolved solids (TDS) for TWW demonstrated a reduction of 52% and 53%, respectively. Similar trend was observed for FW in which the reduction in EC and TDS were 48% and 49%, respectively. Furthermore, the percent reduction of the concentration of suspended solids, phosphate ions (PO_4^{-3}), chloride ion (Cl^-), total nitrogen (TN), and potassium ion (K^+) in TWW were found to be 95%, 89%, 60% 98% and 59%, respectively. Plant growth parameters (plant height, fresh and dry weight, number of branches and flowers number) of geranium revealed no significant difference between irrigation with TWW and FW. The chemical plant analysis of roots, leaves, stems and flowers revealed no significant difference between hydroponic plantation in TWW and in FW. From these results it is safe to conclude that the Epuvalisation technique is a promising technique for advanced wastewater treatment using ornamental plants such as geranium due to its simplicity, low cost and easy use.

1. Introduction

The scarcity of freshwater in most countries is an increasingly acute problem, particularly as their populations continue to grow rapidly and place higher demands on water resources. The agriculture sector is the largest consumer of water supplies. Agriculture consumes about 87% of the total water consumption in the Middle East and North Africa region (MENA) (Abu-Madi et al., 2003). In the Palestinian territories, the total estimated water used for agriculture is not exceeding 150 million cubic meters annually. This amount represents 45% of the total water consumption, which is reflected directly on the limited prospects for the development of irrigated agriculture that can have an important economic, social and political role in rebuilding the Palestinian economy (Alsharif et al., 2008).

Wastewater has to be reclassified as a renewable water resource rather than as a waste (Abu-Madi and Al-Sa'ed, 2009). Reclaimed wastewater has been recognized as a valuable non-conventional resource (Abu-Madi et al., 2003). Reclaimed wastewater is a treatment of different types of wastewater for reuse application. The climate change affect in the reuse application. Climate change affect directly or indirectly on the wastewater reclamation and its reuse to conserve freshwater resources. The direct climatic factors include temperature, precipitation, sea level rise and severe conditions, whereas the indirect factors related to management and operation activities as water use control, greenhouse gases and adaptation measures (Vo et al., 2014).

Epuvalisation is a French word that means a biological treatment technique that comes from the contraction of two French words: épuration (purification) and valorisation (valorisation); it uses plants,

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https://doi.org/10.1016/j.aoas.2019.12.007
Received 1 September 2019; Received in revised form 30 November 2019; Accepted 18 December 2019
Available online 28 December 2019

not only to purify water but also for the growth and production of these plants. The plants roots act as a physical filter which holds the suspended matters. Epuvalisation has been applied with ample success in many Mediterranean countries and in Belgium as a tertiary purification process of secondary treated effluent utilizing different plants (Qurie et al., 2019; Qurie et al., 2013). The technique was applied for treated wastewater (Papadopoulos et al., 2007). In addition, it was used for Sr/Cs in wastewater treatment (Tang et al., 2012).

This technique consists of hydroponic plantation in channels. The wastewater flows into the channels and keeping a direct contact with the plants' roots (Hyden, 2006). The roots are utilized as bio-filters and adsorbents for the removal of nitrogen, phosphorus and other macronutrients. In addition, toxic elements and salts can be removed from wastewater (WW) by an accumulation into the plant tissues. The system mechanism consists of gravitational effluent flowing through open channels to keep the water well aerated. The channels host the plant roots not only for water absorption purposes but for trickling and biological filter functions as well (Qurie et al., 2013).

The roots play a dominant role in taking up the nutrients, thus decreasing the total dissolved solids, which includes nitrogen and phosphorus. This technique can be operated in closed or open loop modes. The open loop system is less efficient in the removal of nutrients and salinity due to minimal contact time, while the closed loop system is more efficient because of a relatively longer retention time (Qurie et al., 2019).

The system can also produce two valuables, water and plant valorization. Water valorization which is the complementary treatment can make the water suitable for non-restrictive irrigation and plants valorization in which the system will produce. Valuable plants (ornamentals); seed; animal feeding under given and strict conditions regarding toxic compounds such as heavy metals or any other compounds that could enter the food chain (Rababah and Al-Shuha, 2009). In our lab, we have investigated the Rosemary plant using the same technique and same water type. The results emerged from this study demonstrated a good adaptation with increasing rate of all plant growth parameters (Qurie et al., 2019). The technique was applicable using brine water for Basillicum irrigation which highly adapted in brine water and biomass production (Qurie et al., 2013).

The aim of this experiment was to investigate the ability of geranium plants *(Pelargonium hortorum*) to purify a secondary treated wastewater using Epuvalisation technique in greenhouse environment. The main objectives of this study were to plant geranium plants *(Pelargonium hortorum*) in epuvalisation system using secondary treated wastewater and fresh water and to determine the plant growth parameters and plant tissue analysis during and at the end of the seasons. The physical, chemical and biological analysis for influents and effluents of both secondary treated wastewater and fresh water as blank are determined during the study period. Comparison of the plan parameters between the two irrigation systems is used as a tool to determine the efficiency of the use of secondary treated wastewater in epuvalisation system.

2. Material and methods

2.1. Epuvalisation design and expriements

The experiment was conducted at Al-Quds university campus- five kilometers from Jerusalem. The Epuvalisation system was installed near Al-Quds University wastewater treatment plant (AUWWTP) to host geranium plants. The effluent of a secondary treated wastewater of AUWWTP was applied in this experiment in addition to FW as a control (Qurie et al., 2013; Qurie et al., 2019).

The Epuvalisation system at Al-Quds University is represented in Fig. 1 which is composed of two equivalent sections; one is used for irrigation with secondary treatment wastewater as hydroponic system and the other for fresh water as a control. Each system consists of two 0.5 m^3 storage tanks (one for influent and the other for effluent) and four cropping channels. For each system, the influent tank is placed one meter higher than the Epuvalisation tracks to allow water to flow by gravity through four channels. Each channel (made of galvanized metal) is 3 m long, 0.45 m wide and 0.14 m depth where the height of the water in the channels is 0.11 m. The four channels were placed consecutively with 0.1 m height difference between each channel. The slope of each channel is about 1%–1.5%. The effluent storage tank is located under the channel placed in the bottom. The effluent was continuously pumped to the influent tank in close cycle. To enhance the dissolution of oxygen, the channels were continuously aerated by air pump using thin aeration plastic pipes.

2.2. Plant selection

Ornamental plants were selected for hydroponic treatment using secondary treated wastewater. The selection depends on the adaptation and survival of the plant in water media, rooting must be composed of fine rootlets “hairy roots” with no tap roots to increase the absorption area of nutrients and the ability for regeneration to ensure plant replacement. In this experiment, geranium was selected as an epuvalization plant, since it satisfies the above requirements. The Geranium (Pelargonium) plant is a perennial herb that belongs to the Geraniaceae family which was selected for experimentation because of it contains high levels of essential oil that is widely used in the perfumery, cosmetic, and aromatherapy industries (Rajeswara Rao et al., 1996).

Geranium young plants were planted in open channels of secondary treated wastewater and fresh water as a control which were supplied with additional nutrients (nitrogen, potassium, phosphorus, magnesium, and iron). Nutrients were periodically added to the influent tanks of both secondary treated wastewater and freshwater using 5.0, 4.0, 1.0, 0.8, 0.7, 0.5 mM of total nitrogen, total potassium, calcium, phosphorus, magnesium, and iron, respectively, using the following chemicals: K_2SO_4, KCl, KNO_3, $Ca(NO_3)_2{\cdot}4H_2O$, NH_4NO_3, KH_2PO_4, $MgSO_4{\cdot}7H_2O$, Fe−Na EDTA. Micronutrients were added in adequate amounts (μM): 2.97 $MnCl_2{\cdot}4H_2O$, 1.24 $ZnCl_2$, 0.66 $CuCl_2{\cdot}2H_2O$, 24.75 H_3BO_3, 0.083 $(NH_4)6\ Mo_7O_{24}{\cdot}4H_2O$, and 0.0413 $NiCl_2$(Ng et al., 2008; Khalid, 2009) every 10 days.

2.3. Experimental process

Adaptation stage with fresh water and fertilizers was the first stage of the experiment. Aeration stage was conjugated with the process for 6 h continuously everyday by using a timer. Plants were planted at 0.25 m distance from each other to permit roots to develop in a sufficient volume for geranium plants. Irrigation with secondary treated wastewater including fertilizers was the second stage where FW was used as a control. Closed loop was used for each cycle with period time extended to 10 days.

2.4. Water quality analysis

The water quality was frequently tested for different samples of influent and effluent at the initial and final stage of the cycle to evaluate the treatment process for fresh water and secondary treated waste water. Standard water and wastewater examination methods were used for water quality analysis (Eaton et al., 2005).

2.5. Plants tissue analysis

At the end of the experiment, the plants were harvested and separated into roots, leaves and stems and then dried in the air. The dried samples were used for chemical plant tissue analysis. The chemical analysis included total nitrogen, total phosphorus, sodium, chloride and potassium. A standard method for soil and plant analysis was used for chemical plant analysis (Gericke and Kurmies, 1952; Seale, 1984; Ryan

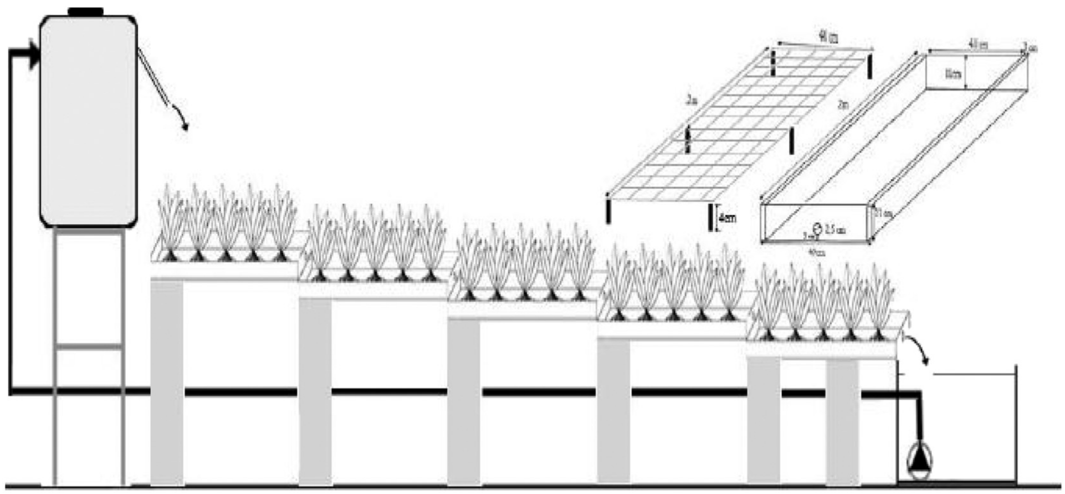

Fig. 1. Graphical design for Epuvalisation system and its channels.

Table 1
Chemical, physical and biological parameters for secondary treated wastewater from Al-Quds wastewater treatment plant and fresh water (FW) without fertilizers.

Parameter	FW	TWW
pH	7.3 ± 0	7.4 ± 0.3
EC (μS/cm)	563 ± 15	1177 ± 6
TDS ($mg{\cdot}L^{-1}$)	277 ± 6	587 ± 6
SS ($mg{\cdot}L^{-1}$)	0 ± 0	79 ± 0
Turbidity ($mg{\cdot}L^{-1}$)	0 ± 0	125 ± 2
COD ($mg{\cdot}L^{-1}$)	39 ± 5	182 ± 2
BOD ($mg{\cdot}L^{-1}$)	16 ± 2	107 ± 5
Mg^{2+} ($mg{\cdot}L^{-1}$)	18 ± 0	13 ± 1
Ca^{2+} ($mg{\cdot}L^{-1}$)	36 ± 0	68 ± 2
K^{+} ($mg{\cdot}L^{-1}$)	2.5 ± 0	25 ± 0.5
Na^{+} ($mg{\cdot}L^{-1}$)	60 ± 0	154 ± 0
TN as NH^{4+} and NO^{3-} ($mg{\cdot}L^{-1}$)	0 ± 0	24 ± 0
$PO_4{}^{3-}$ ($mg{\cdot}L^{-1}$)	0 ± 0	11 ± 0
Cl^{-} ($mg{\cdot}L^{-1}$)	80 ± 0	186 ± 0

et al., 1996).

2.6. Plant growth parameters

During the progress of the experiment, the plant growth parameters (plant height, fresh weight, dry weight, branches number and flowers number) were measured for all plant samples. At the end of the season,

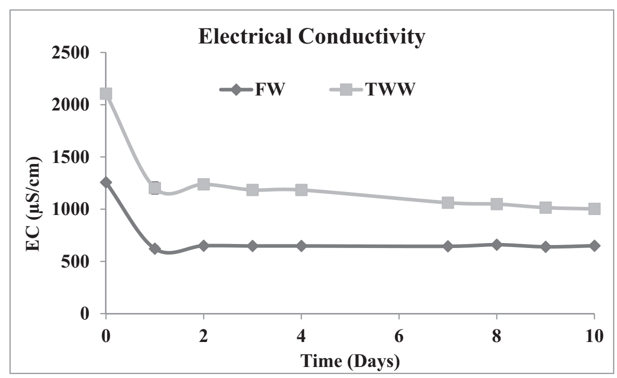

Fig. 2. Variation of EC with time (days) using TWW as compared to FW. Both treatments contained the same quantity of macro and micronutrients.

plants were collected for fresh biomass measurements. Then, they dried and weighted for dry biomass measurements.

3. Results and discussion

The biological treatment effluent (secondary treated wastewater) from wastewater treatment plant at Al-Quds University was used for the hydroponic plantation of geranium plants together with plantation in FW as a control. Water quality parameters, plant growth parameters

Table 2
Physical and chemical quality of hydroponic recycled water after 10 days of Epuvalisation treatment using FW and TWW. (Mean values ± standard deviations).

Parameter	FW		Removal (%)	TWW		Removal (%)
	Influent	Effluent		Influent	Effluent	
pH	7.4 ± 1	8.4 ± 0		7.3 ± 1	6.0 ± 0	
EC ($\mu S{\cdot}cm^{-1}$)	1257 ± 12	650 ± 0	48	2106 ± 12	1003 ± 6	52
TDS ($mg{\cdot}L^{-1}$)	627 ± 6	320 ± 0	49	1053 ± 6	500 ± 0	53
SS ($mg.L^{-1}$)	2.4 ± 3	2 ± 0	17	81 ± 36	4 ± 0	95
TUR (NTU)	7 ± 10	5.5 ± 4	21	117 ± 57	7 ± 0	94
COD ($mg{\cdot}L^{-1}$)	188 ± 16	63 ± 21	67	282 ± 4	167 ± 4	41
BOD ($mg{\cdot}L^{-1}$)	43 ± 10	33 ± 1	23	71 ± 21	55 ± 3	23
Mg^{2+} ($mg{\cdot}L^{-1}$)	13.5 ± 1	3 ± 0	78	19 ± 5	14 ± 3	26
Ca^{2+} ($mg{\cdot}L^{-1}$)	124 ± 1	72 ± 13	42	151 ± 0	99 ± 0	34
K^{+} ($mg{\cdot}L^{-1}$)	38 ± 43	10 ± 0	74	43 ± 26	14 ± 2	59
Na^{+} ($mg{\cdot}L^{-1}$)	70 ± 4	28 ± 2	60	138 ± 3	129 ± 12	7
$PO_4{}^{3-}$ ($mg{\cdot}L^{-1}$)	39 ± 0	0 ± 0	100	61 ± 2	7 ± 1	89
$Cl^{-}mg{\cdot}L^{-1}$	62 ± 26	39 ± 6	37	89 ± 88	36 ± 26	60
TN as NH^{4+} and NO^{3-} ($mg{\cdot}L^{-1}$)	4.4 ± 0	0 ± 0	100	24 ± 0	0.4 ± 0	98

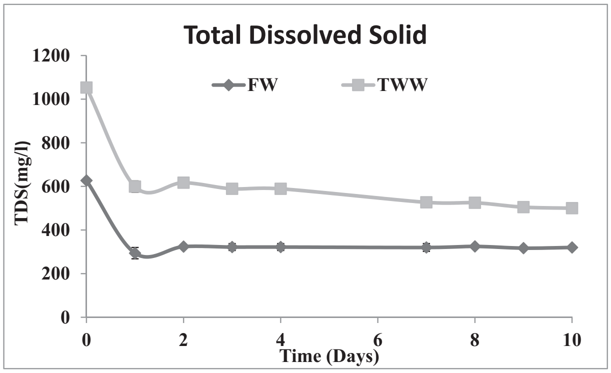

Fig. 3. Variation of TDS with time (days) using TWW as compared to FW. Both treatments contained the same quantity of macro and micronutrients.

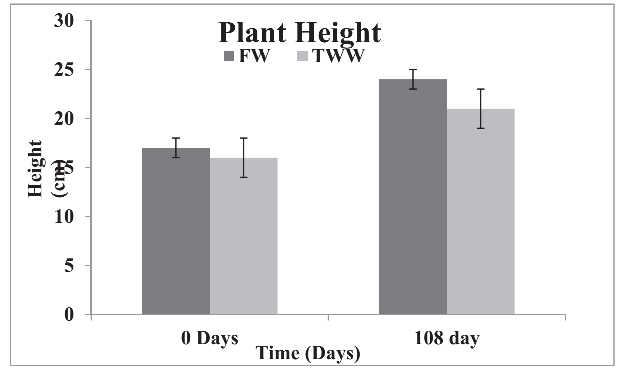

Fig. 4. Variation of geranium height (cm) during season of the Epuvalisation experiment which irrigated with both types of water, TWW and FW.

and chemical plant tissue analysis were monitored and are discussed below.

3.1. Water quality

The chemical, physical and biological characteristics of the secondary treated wastewater (TWW) and fresh water (FW) as sources for the epuvalization system without fertilizers are presented in Table 1.

Fertilizers were added to both TWW and FW as described in the experimental section. Chemical and biological analysis of the water quality for both systems in the beginning of irrigation experiment was conducted right after fertigation and at the end of 10 days of the growing season (Table 2). Inspection of Table 2 reveals that the percentage removal of BOD is 23% for both plantation in TWW and FW, whereas, the percentage removal of EC is 48% and 52% for plantation in FW and TWW, respectively. The percentage removal in TDS is 49% and 53%, for plantation in TWW and FW, respectively. Furthermore, the percentage removal of SS, PO_4^{-3}, Cl^-, TN and K^+ in plantation in TWW are 95%, 89%, 60%, 98% and 59%, respectively. These results could be explained on the bases of the uptake and decomposition of fertilizers and organic compound by the plant roots. It should be noted that fertilizers are needed to be optimized for a particular plant. It was reported in the literature, that the addition of 120 ppm N produced fewer flowers than the addition of 60 ppm in flower cultivation N, showing that in the addition of fertilizer above 60 ppm N had a negative effect on flower production (Qurie et al., 2013).

The decrease in the concentration of phosphate ions in TWW was larger than that in FW. This result indicates that the initial concentration of phosphate ions in FW was below the needed values for the growing season, whereas its initial concentration in TWW was in excess of 7 ppm. This translate to a percentage removal of 100% and 89% in FW and TWW, respectively, which are much higher than those reported in the literature (37%) for the planation of different vegetables, flower, tress and hirb (Haddad and Mizyed, 2011).

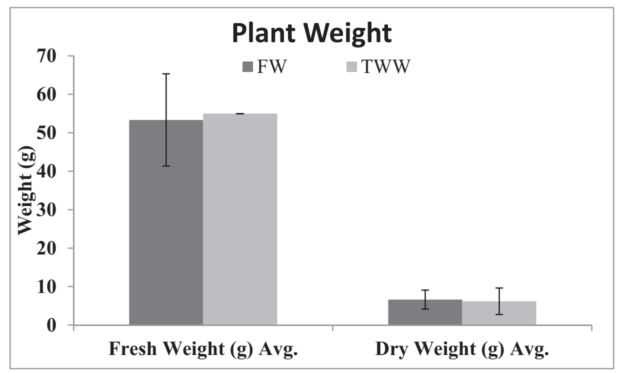

Fig. 5. Variation of geranium plant weight in fresh and dry condition in grams (g) after the end of plantation period using TWW and FW.

Table 3
Physical and chemical quality of hydroponic recycled water after 10 days of Epuvalisation treatment using TWW as compared to FW during the same period. Mean values ± standard deviations (SD).

Parameter	FW		Removal (%)	TWW		Removal (%)
	Influent	Effluent		Influent	Effluent	
pH	7.5 ± 1	8.4 ± 0		6.9 ± 0	6.4 ± 0	
EC μS·cm^{-1}	1027 ± 6	625 ± 7	39	1560 ± 0	970 ± 0	38
TDS mg·L^{-1}	510 ± 0	310 ± 0	39	780 ± 0	480 ± 0	39
SS mg·L^{-1}	13 ± 1	0 ± 0	100	78 ± 2	0 ± 0	100
TUR NTU	13 ± 12	6.5 ± 1	50	114 ± 3	4 ± 3	97
COD mg·L^{-1}	108 ± 0	64 ± 0	41	131 ± 13	54 ± 7	59
BOD mg·L^{-1}	43 ± 6	31 ± 0	28	67 ± 11	27 ±	60
Mg^{+2} mg·L^{-1}	29 ± 4	26 ± 1	10	24 ± 2	19 ± 0	23
Ca^{+2} mg·L^{-1}	95 ± 59	79 ± 25	17	126 ± 57	98 ± 2	22
K^+ mg·L^{-1}	138 ± 87	78 ± 32	23	167 ± 88	100 ± 0	40
Na^+mg·L^{-1}	87 ± 9	68 ± 9	22	170 ± 11	162 ± 5	5
PO_4^{3-} mg·L^{-1}	35 ± 0	0.2 ± 0	99	47 ± 0	10 ± 0	79
Cl^- mg·L^{-1}	93 ± 19	80 ± 13	14	191 ± 19	155 ± 6	19
TN as NH^{4+} and NO^{3-} mg·L^{-1}	2.1 ± 0	0.1 ± 0.0		7 ± 2	0.2 ± 0	97
FC (cuf/ml)	0	0		10,500	0	100
TC (cfu/ml)	0	0		13,500	0	100

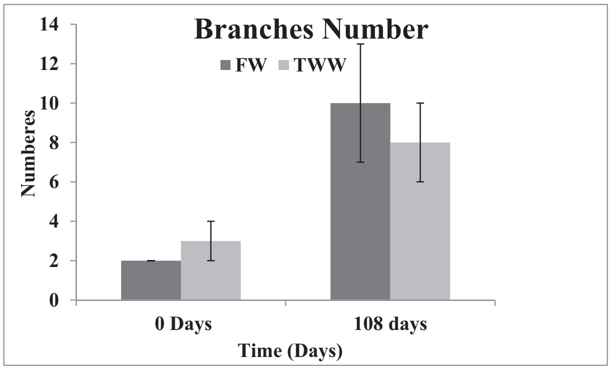

Fig. 6. Variation of geranium branch number during the epuvalisation experiment using TWW and FW.

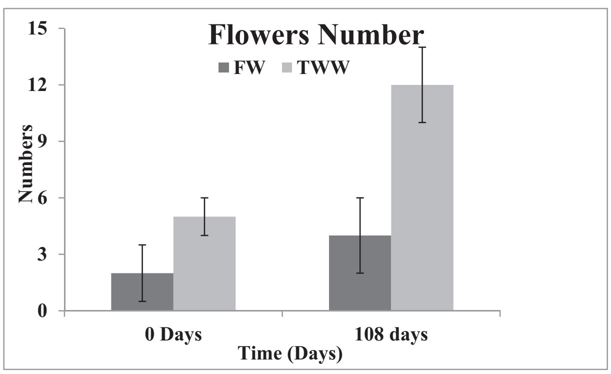

Fig. 7. Variation of geranium flower number during the epuvalisation experiment using TWW and FW.

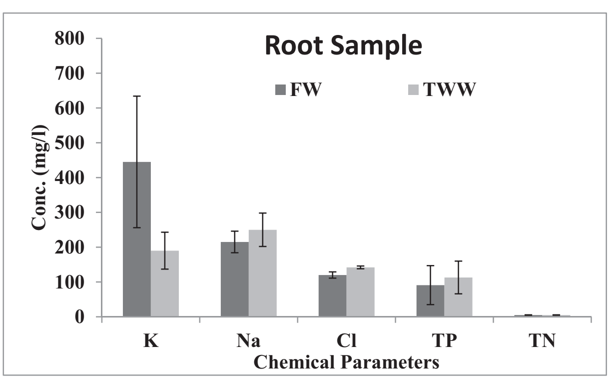

Fig. 8. Variation of nutrients content of geranium roots after 10 weeks of epuvalisation experiment using TWW as compared to FW. (Mean values ± standard deviations (SD) of three replicates).

3.2. Continuous monitoring of EC and TDS during the first closed cycle

Figs. 2 and 3 summarize the variation of EC and TDS with time during the first cycle of 10 days for both plantations in FW and TWW, respectively. On the first day from the beginning of the hydroponic cycle, two doses of the same quantity of fertilizers were added to both tanks containing TWW and FW. A gradual decreasing of EC and TDS values are observed during the monitoring period. In the first irrigation cycle of plants the EC didn't decrease in high ratio due to the plant adaption stage and biomass of young plants. This reduction of advanced cycles can be attributed to the plant uptake of various nutrients. For TWW, the EC started at 2106 μs·cm^{-1} and reduced to 1003 μs·cm^{-1} at the end of the cycle with a percentage removal of 52%. On the other hand, for FW, the EC started with 1257 μs·cm^{-1} and reduced to 640 μs·cm^{-1} at the end of the monitoring cycle with a percentage removal of 48%. Similar trend was observed for TDS, where in TWW it started with 1053 mg·L^{-1} and reduced to 500 mg·L^{-1} with a percentage removal of 53%, whereas in FW, it started at 627 mg·L^{-1} and reduced to 320 mg·L^{-1} with a percentage removal of 49%. These results point out the there is no effect on the uptake of the nutrients by the plant in TWW as compared to FW.

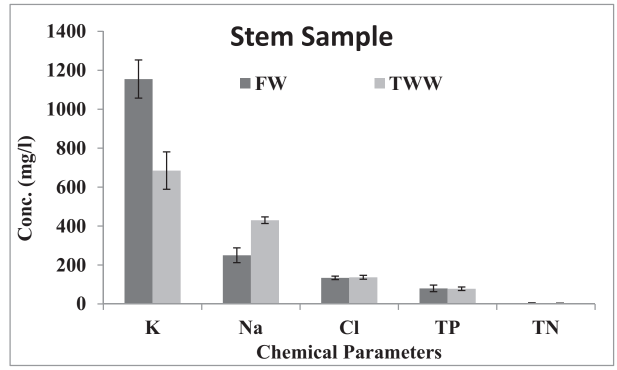

Fig. 9. Variation of nutrients content of geranium stems after 10 weeks of epuvalisation experiment using TWW as compared to FW. Mean values ± standard deviations (SD) of three replicates.

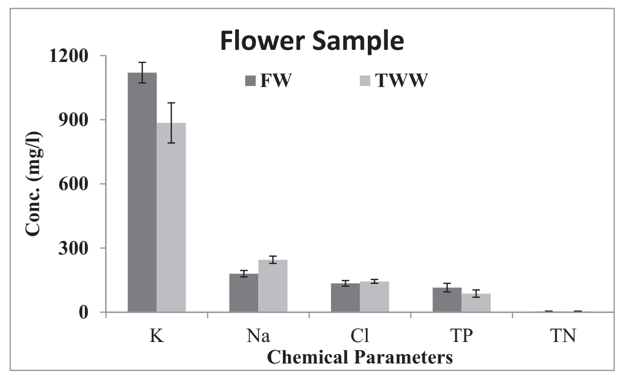

Fig. 10. Variation of nutrients content of geranium flowers after 10 weeks of epuvalisation experiment using TWW as compared to FW. (Mean values ± standard deviations (SD) of three replicates).

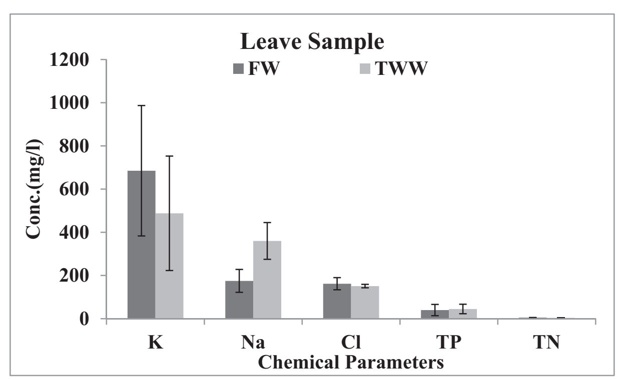

Fig. 11. Variation of nutrients content of geranium leaves after 10 weeks of epuvalisation experiment using TWW as compared to FW. Mean values ± standard deviations (SD) of three replicates.

The quality of water for TWW and FW used for the irrigation after the first cycle is shown in Table 3. The results show a decrease in EC; the determined values were 39% and 38% for FW and TWW respectively, which shows no significant difference between the uptake in FW and TWW.

The removal efficiency for TDS was equal between FW and TWW (39%), for COD and BOD the removal percentages were 41% and 28% for FW and 59% and 60% for TWW, respectively,

The removal percentage in TWW of suspended solids was 100% equal to that of FW, the influent was 13 mg·L^{-1} and 78 for FW and TWW, respectively and the effluent was 0 for both types of water. The PO_4^{-3} percentage removal value was 99% in FW and 79% in TWW, and the TN and K^+ values were 97% and40%, respectively.

The water quality analysis for the same experiment using Rosemary plant irrigated with secondary treated effluent STE and fresh water indicates that rosemary plants can be used as a polisher of STE with a removal efficiency of 24%, 26% and 13% for BOD, TDS and COD, respectively (Qurie et al., 2019).

3.3. Plant growth parameters

Plant growth parameters were monitored during and at the end of the growing period (plant height, fresh weight, dry weight, branches number and flowers number). The plants grew very well in hydroponic system. During the season of plantation, the heights of geranium plants measured are summarized in Fig. 4 whereas the fresh weight and dry weight results are summarized in Fig. 5. The plant height was found to increase normally with time. There was no significant difference between the plant height in the case of TWW and FW treatments. No significant change of fresh and dry weight of geranium plants in both types of water. Figs. 6 and 7 summarize the number of plant branches and the average number of flowers for Geranium plants in FW and TWW, respectively, at the beginning and the end of the cycle. The plant growth parameter obtained for the geranium plants are in a good agreement with the Rosemary results obtained using secondary treated wastewater and fresh water irrigation using the same technology; all Plant growth parameters (plant height, fresh weight, and dry weight and average number of branching) were increased in Rosemary plants irrigated with STE and FW (Qurie et al., 2019).

3.4. Chemical composition of plant tissues

Geranium plants were harvested after the end of plantation, then dried, and separated into roots, stems, flowers and leaves. Finally, the samples were digested for chemical analysis of various nutrients content (K^+, Na^+, Cl^-, TP and TN). The results are shown in Figs. 8–11.

Inspection of these figures reveals that potassium had the highest concentration of all chemical contents in roots, stems, flowers and leaves ranging between 445 mg·g^{-1} to 1155 mg·g^{-1} in FW plantations, and 190 mg·g^{-1} to 885 mg·g^{-1} in TWW plantations. Total nitrogen was found at low concentration in roots, stems, flowers and leaves, which ranges between 4 mg·g^{-1} to 5 mg·g^{-1} in FW and TWW plantations. Total phosphorous concentration were found between 40 mg·g^{-1} to 115 mg·g^{-1} in FW plantations with the lowest concentration found in leaves and the highest concentration found in flowers. For TWW plants, the lowest concentration was found in leaves with a value of 45 mg·g^{-1}, whereas the highest valued was found in roots with a value of 113 mg·g^{-1}. Chloride concentration in FW plantations ranged between 120 mg·g^{-1} to 162 mg·g^{-1}, with the lowest concentration found in roots and the highest found in leaves. The highest concentration of Cl^- in TWW plantations was found in leaves (151 mg·g^{-1}) and the lowest concentration was found in stems (137 mg·g^{-1}). The sodium concentrations range was 175 mg·g^{-1} in leaves and 250 mg·g^{-1} in stems. The chemical tissue analysis of Rosemary plant using the same technique revealed that Nitrogen was accumulated in higher amounts compared to the other macronutrients in all parts of the rosemary plants. Low sodium content ranging between 1.63 and 2.82 mg·g^{-1} was found almost equal in plants irrigated with STE or FW. No particular accumulation of chloride was observed in the roots, stems and leaves of the rosemary plants. The geranium chemical tissue analysis showed low Nitrogen concentration for both water irrigations. The K uptake was higher in Rosemary than Geranium according to accumulation of K in the different parts of the plants (Qurie et al., 2019). This indicates that there is a different nutrient uptake in both plants.

The above results point out that the application of Epuvalisation technique fulfilled a multi-objectives of achieving sustainable environment, economic and social benefits that can be implemented in many countries including Palestine. Furthermore, this work demonstrates that the epuvalisation system is simple, flexible, easy to use and manage, low cost, with high tertiary purification efficiency that can be used as a good alternative for small communities.

Geranium plants showed a good efficiency in term of adaptation, purification of treated wastewater with added value of plant production. The observed reduction of organic matter (COD, BOD), suspended and dissolved solids with subsequent decrease in electrical conductivity further reflect this conclusion.

4. Conclusions and recommendation

This study has showed that utilizing the Epuvalisation technology in the plantation of Geranium plants fulfilled the goal of maintaining sustainable environment with low cost technology and social benefits. This research demonstrated that Geranium plants enjoy great efficiency in terms of STE polishing and considerable reduction in TDS, COD and BOD. The biological growth parameters of the Geranium and the chemical analysis of roots, stems and leaves revealed that irrigation with both STE and FW is comparable. Therefore, it can be safe to state that Geranium plants can be planted with great efficiency utilizing the Epuvalisation technology.

This study has proved no negative impact on the operation of the wastewater treatment plant or on the environment. However, the results revealed an improvements of the treated wastewater quality. Therefore, our recommendation is to incorporate the Epuvalisation technology for further purification of the secondary treated water that is generated from the wastewater plant.

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