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Al-Quds University

Improvement of Large Scale Wastewater Treatment Plant Using Epuvalisation Technique And Micelle Clay Complex Column

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Improvement of Large Scale Wastewater Treatment Plant Using Epuvalisation Technique And Micelle Clay Complex Column

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Improvement of Large Scale Wastewater Treatment Plant Using Epuvalisation Technique And Micelle Clay Complex Column

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Dedication

To my family specially my parents for their understanding, support, patience and love.

To my friends for cheer me up when things does not work.

To the dreamers who believe one day their dreams will come true,

To people who think our life's path is happy & easy or sad & hard all the time, because life like rollercoaster sometimes up and sometimes down.

Sabreen Zidan Raseem Daghra

Declaration

I certify that the thesis is submitted for the degree of master is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not be submitted for a higher degree to any other university or institution.

Signed:

Sabreen Zidan Raseem Daghra

Date: 20/12/2017

Acknowledgment

After an intensive period of 4years, today is the day: writing this note of thanks is the finishing touch on my thesis. It has been a period of intense learning for me, not only in the scientific arena, but also on a personal level. Writing this thesis has had a big impact on me. Though only my name appears on the cover of this thesis, a great many people have contributed to its production. I owe my gratitude to all those people who have made this dissertation possible and because of whom my graduate experience has been one that I will cherish forever. I would like to reflect on the people who have supported and helped me so much throughout this period. My deepest gratitude is to my supervisor Dr. Mohannad Qurie. I have been amazingly fortunate to have an advisor who has given me the freedom to explore by myself and at the same time the guidance to recover myself when my steps faltered. Don taught me how to question thoughts and express ideas. His patience and support helped me overcome many crisis situations and finish this thesis. I am also indebted to the staff members of chemical & biological research center for their wonderful collaboration. You supported me greatly and you were always willing to help me. I would particularly like to single out my gratitude to Al-Quds University and to all my teachers in the environmental studies department for the excellent education I had.

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Abstract:

Many countries are moving towards building large-scale membrane based on wastewater treatment plants to use treated wastewater for none restricted irrigation. The effluent of secondary treatment process at Al-Quds University wastewater treatment plant was treated using an Epuvalisation system and Micelle-clay complex column. The Epuvalisation technique is a hydroponic treatment, technique that used for secondary wastewater purification. The Rosemary (*Rosmarinus officinalis*) and Geranium plants *(Pelargonium hortorum*) were selected for Epuvalisation system. Both fresh water and secondary treated wastewater were applied on the system in a greenhouse and in a closed-loop for many days.

The results of water quality analysis of both TWW and FW using the Rosemary plants showed a remarkable decrease of biological oxygen demand and chemical oxygen demand with a reduction of 24% and 13%, respectively for TWW; whereas the effluent of FW showed 29%, and 16%, reduction for the same parameters. The results of water quality analysis of both TWW and FW using Geranium plants showed a decrease in the biological oxygen demand and the chemical oxygen demand with a reduction of 23% and 41%, respectively for TWW; whereas the effluent of FW showed 23%, and 67%, reduction for the same parameters. The removal percentage of electrical conductivity in FW decreased to 48%, and 52% in TWW, almost the same in TDS 49% and 53% respectively. The removal percentage in TWW of suspended solids was 95%, PO_4^{-3} was 89%, Cl^- was 60%, TN was 98% and K^+ was 59%.

Plant growth parameters (plant height, fresh and dry weight, number of branches and flowers number) of Rosemary and Geranium showed no significant difference between irrigation with both media. The results of plant analysis of roots, leaves, stems and

flowers showed that there is no effect for irrigation with the secondary wastewater in plant tissues.

The results have shown that the Epuvalisation system is a promising technique for wastewater treatment using the Rosemary and the Geranium plants.

Membrane Technology manufacturing and ensamling construction have been drastically improved during the past few years. However, membrane fouling is still the main disadvantage of this technology. In an earlier publication, polishing of secondary treated wastewater by bench top filter filled with micelle-clay complex, demonstrated that the water quality obtained from this filter is similar to that obtained from Ultra filtration using spiral wound membranes with reduced cost. The micelle-clay complex is composed of Octadecyltrimethyaammonuim bromide (ODTMA) and montmorillonite clay. The aim of this work is to investigate the efficiency of micelle-clay complex filters in polishing secondary treated wastewater by using small scale wastewater treatment plant.

A column filled with a mixture of micelle-clay complex and sand was installed inside small scale wastewater treatment plant at Al-Quds University. The sand was pre-washed with fresh water and air dried. A mixture of sand and micelle-clay complex in ratio 3:1 (w/w) was prepared. The flow rate and operation time were adjusted to 200 liter per hour and 4 hours per day. Samples from influents and effluents were taken continuously as a function of volume at 20 L, 50 L, 100 L, 200 L, 400 L and 800 L. These cycles were repeated for several days. The samples were analyzed for chemical, physical and biological quality using standard methods of water and wastewater examination.

The results showed that the efficient removal of COD during the time of operation days. The removal efficiency varied between 53 to 95%. Turbidity results showed efficient removal by micelle-clay complex due to adsorption of collides, micro-emulsion, macro molecules and suspended particles by both micelle clay complex and sand. The characteristics of UF-SW and MCXC was almost the same which means UF-SW could be replaced by using MCXC.

The results showed that the benefit of inserting micelle clay complex column as pre-treatment stage before advanced membrane technology system in large wastewater treatment plant.

Table of Contents:

Declaration i

Acknowledgment ii

Abstract: iii

Chapter One: Introduction: 1

Effect of Untreated Wastewater on the Environment 4

Wastewater 4

Reuse for Agricultural Irrigation 6

Water and Wastewater in The State of Palestine 6

Wastewater Treatment Technology: 8

Epuvalisation 8

Adsorbent Materials 10

Micelle Clay Complex Column 10

Literature Review: 11

Problem Statement: 14

Objectives 14

Aim: 14

Goals: 15

Thesis Outline 15

Experimental Flow chart: 16

Chapter Two: **Materials and Methods**: 17

2.1 Study Area 17

2.2 AUWWTP Components and Treatment Stages 17

2.2.1 Secondary Treatment 17

2.2.2 Tertiary Treatment 18

2.3.1Epuvalisation Experiments: 20

Chemicals and Reagents 27

2.5 Instruments: 28

2.6 Sampling and Standard Preparation..28
Chapter Three: **Results and Discussions**: 29
3.1 Epuvalisation Experiment 29
3.1.1 Rosemary..29
3.1.2 Geranium Result: 41
3.2 MCXC Experiment 53
3.2.1Water Quality of UF-HF Effluent 53
3.2.2 Performance of Micelle-Clay Complex Column (MCXC) 55
3.2.3 Flow Rate of Influent of UF-SW Membrane: 57
3.2.4 Water Quality: 57
Chapter Four: **Conclusion and Recommendations**: 60
4.1 Conclusion 60
4.2 Recommendation 61
References.. 62
الملخص.. 71

List of Tables

Table	Title	Page
Table 1	Chemical, physical and biological parameters of secondary treated wastewater.	30
Table 2	Physical and chemical quality of hydroponic recycled water after 10 days.	31
Table 3	Physical & chemical characteristics of hydroponic recycled water.	35
Table 4	Chemical, physical and biological parameters of secondary treated wastewater.	42
Table 5	Physical and chemical quality of hydroponic recycled water after 10 days.	43
Table 6	Physical and chemical quality of hydroponic recycled water after 10 days.	47
Table 7	Physical, chemical and biological quality of the UF-HF permeates.	54
Table 8	Microbiology analysis comparison between UF-HF & MCX.	55
Table 9	Variation of physical, chemical and biological characteristics of influent of effluent of micelle clay complex column.	56
Table 10	Comparison between flow rate of effluents of MCX Column and UF-HF without using MCX.	57
Table 11	Water Quality of influent and effluent of UF-SW.	58

List of Figures

Figure	Title	Page
Figure 1	The position of Epuvalisation technique and MCXC at (AUWWTP).	20
Figure 2	Graphical design for Epuvalisation system & it's channel.	22
Figure 3	Al-Quds University wastewater treatment plant after integrating MCXC.	25
Figure 4	Variation of EC with time (days) for Rosemary Plants.	33
Figure 5	Variation of TDS with time (days) Rosemary Plants.	34
Figure 6	Variation of Rosemary height (cm) during season of Epuvalisation experiment.	37
Figure 7	Rosemary plant weight in fresh & dry condition.	37
Figure 8	Variation of average Rosemary branching number of plants.	38
Figure 9	Variation of average Rosemary flowering number of plants.	38
Figure 10	The total nutrients content of Rosemary roots after 6 weeks.	40
Figure 11	The total nutrients content of Rosemary stems after 6 weeks.	40
Figure 12	The total nutrients content of Rosemary leaves after 6 weeks.	41
Figure 13	Variation of EC with time (days) for Geranium plants.	45
Figure 14	Variation of TDS with time (days) for Geranium plant.	46
Figure 15	Variation of Geranium height (cm).	48
Figure 16	Variation of Geranium branch number.	48
Figure 17	Variation of Geranium flower number.	49
Figure 18	Different plant weight in fresh & dry condition in (g).	49
Figure 19	The total nutrients content of Geranium roots after 10 weeks.	51
Figure 20	The total nutrients content of Geranium stems after 10 weeks.	51
Figure 21	The total nutrients content of Geranium Flowers after 10 weeks.	52
Figure 22	The total nutrients content of Geranium Leaves after 10 weeks.	52

List of Abbreviations

MENA	Middle East North Africa
TSS	Total Suspended Solids
SS	Suspended Solids
COD	Chemical Oxygen Demand
BOD	Biological Oxygen Demand
WWTP	Wastewater Treatment Plant
MCM/y	Million Cubic Meter per year
MCM	Million Cubic Meter
ODTMA	Octadecyltrimethylammonium
MCXC	Micelle Clay Complex Column
MCX	Micelle Clay Complex
UF	Ultra Filtration
HF	Hollow Fiber
SW	Spiral Wound
RO	Reverse Osmosis
AUWWTP	Al-Quds University Wastewater Treatment Plant
m^3	Cubic Meter
m	Meter
ppm	Part per Million
m^3/h	Cubic Meter per Hour
KD	Kilo Dalton
Psi	Pounds per Square Inch
MWCO	Molecule Weight Cut Off
N.F.T.	Nutrient Film Technique
P.N.F.	Permanent Nutrition Flow
TWW	Treated Wastewater
FW	Fresh Water

L	Liter
Ca^{2+}	Calcium ion
Mg^{2+}	Magnesium ion
K^{+}	Potassium ion
Na^{+}	Sodium ion
Cl^{-}	Chloride ion
PO_4^{3-}	Phosphorous ion
NO^{3-}	Nitrate ion
NH_4^{+}	Ammonium ion
TN	Total nitrogen
TP	Total phosphorous
TK	Total potassium
EC	Electrical Conductivity
TDS	Total Dissolved Solid
TUR	Turbidity
$mg.L^{-1}$	Milligram per liter
FC	Fecal Coliform
TC	Total Coliform
TPC	Total Plate Count
$mg.g^{-1}$	Milligram per gram
l/h	Liter per Hour
Min	Minute

Chapter One:

Introduction:

Water is vital and of great important to every living thing; in some organisms, up to 90% of their body weight comes from water. Up to 60% of the human body is water, each day humans must replace 2.4 liters of water, some through drinking and the rest taken by the body from the foods eaten,(USGS, 2013).

Human rights and water resources are among the most compelling issues to have captured the attention of the world community in recent years. As a result, these topics have been placed at the top of the global development agenda, occupying a prominent place at conferences and forums and generating debate that has been both extensive and complex. One reason for this crisis is hydrological variability in most parts of the world,(Freestone and Salman, 2004). Another major contributing factor is the overwhelming increase in population, urbanization, and the resulting environmental degradation. The world population has more than tripled during the last century, while water uses for human purposes have multiplied sixfold. With the continued upsurge in population growth, and with the finite amount of water, this situation is sure to worsen,(Freestone and Salman, 2004).

The fact that the world faces a water crisis is obvious. It is reported that more than 2 billion people are affected by water shortages in over 40 countries, 1.1 billion people do not have sufficient drinking water, and 2.4 billion people have no provision for sanitation. Current predictions forecast that by 2050 at least one in four people is likely to live in a country affected by chronic or recurring shortages of fresh water,(Freestone and Salman, 2004).

Recent estimates suggest that climate change will account for about 20 percent of the increase in global water scarcity. An important virtual source of irrigation water is wastewater, The use of treated wastewaters in urban areas is expected to grow in the future, for irrigating trees, parks and golf courses. Water rights are a contentious issue and require more attention, (UN Agencies, 2003).

Renewable natural resources, such as land, forests and water, are universally important to poverty reduction and development, and are facing increasing pressure in many parts of the world. Global economic and environmental problems, along with increasing social disparities, serve as risk multipliers in the context of increasing resource competition. At present, the majority of extant literature concern, (World Bank, 2009). The Middle East and North Africa (MENA) region is considered the driest region of the world with only 1% of the world's freshwater resources, (Qadir et al., 2010).

The scarcity of freshwater in most countries of the MENA region is an increasingly acute problem, particularly as their populations continue to grow rapidly and place higher demands on water resources. Fourteen of 20 MENA nations are in water deficit (less than 500 m^3 of renewable water supply per capita per year), (Jagnnathan et al., 2009). Due to demographic growth, countries that are relatively well endowed with water resources, such as Egypt, Lebanon, Morocco, and Syria, may join the water-deficient nations by 2050. (Jagnnathan et al., 2009) Many arid countries already are witnessing prolonged droughts and irregular rainfall. In the MENA region, Morocco and countries in West Asia (Jordan, Palestine, and Syria) have been particularly affected,(Jagnnathan et al., 2009).

As rapid urbanization continues, water scarcity will create pressure to shift water from agricultural to domestic and industrial uses. According to the latest collection of simulation results reviewed by the Intergovernmental Panel on Climate Change, consensus is strong that precipitation will decrease substantially in MENA countries, (Jagnnathan et al., 2009).

Water scarcity is a major threat for food security and political stability in the region,(Abu-Madi and Al-Sa'ed, 2009).The increasing competition for good-quality water has cut into agriculture’s water share,(Qadir et al., 2010).

Agriculture consumes about 87% of the total water consumption in the Middle East and North Africa region MENA while water is a scarce commodity,(Abu-Madi et al., 2003). In The State of Palestine the total estimated water used for agriculture does not exceed 150 million cubic meters annually in the West Bank (60 million cubic meters) and 90 million cubic meters in the Gaza Strip. 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, (MoA, 2016).

Water resources can be classified to conventional and non-conventional water resources. Conventional water resources depend on rainfall amount and it forms groundwater, springs and flash floods, such as surface water and groundwater. However, non-conventional water resources rely on human intelligence to obtain water from different sources than natural resources. Such as desalinated water and treated wastewater. The desalination and wastewater treatment plants helped to reduce the stress on conventional water resources which might improve the quantity and quality of groundwater. Treated wastewater is one of the non-conventional water resources and it is considered supportive source for fresh water that used for irrigation activities, (Murad, 2010).

Among all the aquatic systems, the free water systems are considered the most appropriate to obtain reclaimed wastewater for irrigation. Epuvalisation is a system well in use in temperate countries as a tertiary treatment, producing an effluent available for unrestricted agricultural reuse, producing greenhouse or decoration flowers, seaside windbreak plants, etc. According to the gravity flow of the liquid be purified and abundant aeration, the microbial flora acts like a bacterial bed. It mineralizes matter in solution and the plants, by their root system,(Xanthoulis et al., 2003, Qurie, et al., 2013).

Effect of Untreated Wastewater on the Environment

Untreated wastewater usually contains numerous disease-causing microorganisms that dwell in the human intestinal tract. Wastewater also contains nutrients, which can stimulate excessive growth of aquatic plants and algae (eutrophication), and it may contain toxic compounds. These contaminants have to be removed or reduced to a safe and environmentally sound level for environmental protection purposes in order that the water course can retain its utility (for fishing, bathing, etc.) downstream,(Abu-Madi and Al-Sa'ed, 2009).

There is almost no contaminant that cannot be removed from water. The question becomes that of cost. As alternative water resources become increasingly less available, the need for innovative and cost-effective treatment technologies will rise steadily,(Najm and Trussell, 1999).

Wastewater

About 43% of wastewater generated in the MENA region is treated; a relatively high percentage compared to other developing-countries dominated regions. This is because of the perceived importance of wastewater as a water resource and several oil-rich countries with the resources to treat wastewater. The MENA region has an opportunity for beneficial reuse of wastewater but few countries in the region have been able to implement substantial wastewater treatment and reuse programs. However, some countries such as Tunisia, Jordan, and Palestine have policies in place that address wastewater treatment through a range of instruments. Policymakers in these countries consider use of treated wastewater to be an essential aspect of strategic water and wastewater planning and management. With flexible policy frameworks addressing rapid demographic changes and increasing water scarcity in the MENA region, water reuse has great potential if integrated with resource planning, environmental management and financing arrangements,(Qadir et al., 2010).

Wastewater has to be reclassified as a renewable water resource rather than waste,(Abu-Madi and Al-Sa'ed, 2009). Reclaimed wastewater has been recognized as a valuable non-conventional resource,(Abu-Madi et al., 2003).The development of nonconventional resources such as desalinated water and reclaimed wastewater is increasingly relevant to face climate change effects,(Jagnnathan et al., 2009).

This helps in augmenting water availability, and at the same time in preventing environmental pollution. Wastewater reclamation and reuse is well recognized for its ability to mitigate water shortage which is a major threat to sustainable development and political stability in the MENA region. Substantial efforts have been made to make better utilization of wastewater as a non-conventional water resource, (Abu-Madi and Al-Sa'ed, 2009).

The agriculture sector is the largest consumer for water supplies and the utilization of treated wastewater “called also recycled water or reclaimedwater” would provide multi benefits to include an affordable solution for water shortage and an economic pollution control measure,(Elbana et, al., 2014).

Reuse for Agricultural Irrigation

Wastewater is a material that can increase productivity and must be treated for provide food security when it is used as an alternative water source,(Mizyed, 2013).Reuse of treated wastewater in irrigated agriculture provides additional water supplies and, on the other hand, it would reduce environmental pollution caused by untreated/poorly treated wastewater,(Abu-Madi et al., 2008).

Since the beginning of the 1980s many countries have been using untreated or partially treated wastewater for agricultural irrigation. Treated wastewater is used for agricultural irrigation directly and indirectly. In direct reuse, the treated effluent is taken from the wastewater treatment plants (WWTPs) to the irrigation site. In indirect reuse, the treated effluent is discharged into surface water or groundwater aquifers. The effluents, thus, are deliberately blended with freshwater available in the wadis, dams, rivers, and aquifers and used, on purpose or not, by downstream farmers, (Abu-Madi and Al-Sa'ed, 2009).

In Mexico they produced 1500 MCM/y of sewage, 100 % of this wastewater production is reused, approximately 80 % is used for irrigation. In Santiago, Chili they produced 190 MCM/y of sewage, 100 % of this wastewater production was reused, approximately70 % is used for irrigation, (Abu-Madi and Al-Sa'ed, 2009).

Water and Wastewater in The State of Palestine

The State of Palestine is facing a rapid population growth with limited water resources. The continuous demand for water forces Palestinians to look for alternative water recourses. In fact, water shortage is a major constraint for economic and social development and sustainability of the agricultural sector in arid and semi-arid areas such as the Palestinian Territories. Such water scarcity will become more critical as domestic and industrial sectors place higher and higher demand on water; Palestine will experience serious water deficit which will be about 271 MCM in 2020, (Abu-Madi et al., 2008).

Due to natural factor and restriction, on Palestinian water access in posed by the Israeli side, current water resources in Palestine provides a per capita average of one-half of the World Health Organization’s daily requirements. Palestinian's average about 70 liters/day of fresh water although 66% of the population averages less than 50 liters/day,(Davidson, 2006).

There are 157 MCM of all water which is for domestic/municipal and agriculture use, including springs available for Palestinians on the West Bank,(PWA, 2013).

In the State of Palestine agriculture is the dominant economic sector and it plays a central role in ensuring Palestinian food security. Despite the small size of the West Bank the area enjoys a diversity of climatic regions, which makes it possible to grow almost anything, all year round, (Haddad et al., 2008).

In The Historical Palestine95% of all produced sewage is collected in central sewage systems,(Davidson, 2006).The percentage of the population that is connected to sewer networks in The State of Palestine is 94% overall: 23% in Gaza and 71% in the West Bank,(PCBS, 2010).

There are scattered wastewater reuse pilot projects for agriculture with a total reuse capacity of not more than 1.0 MCM/y in Gaza Strip. There are efforts to transfer Al Bireh plant effluent to Al-Auja area to be used for palm trees and other crops,(PWA, 2013).

Wastewater Treatment Technology:

The wastewater treatment process included physical, chemical and biological process. These processes can be divided into four stages: preliminary, primary, secondary and tertiary treatment process,(Metcalf & Eddy, 2012). The preliminary, primary and secondary are called conventional wastewater treatment, they included a physical process such as sieve (for screening the large object and rags) and biological process such as activated sludge (to break down and removal of organic material). Fourth stage of treatment is a tertiary process and called advanced treatment of conventional effluent. Where use a physical and chemical process (such as ozone, membrane filtration and adsorption),(US.EPA, 2004).

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, not only to purify but also for the growth of these plants, the roots of these plants act as a physical filter which hold the suspended matters. It has been applied with success in many Mediterranean countries and in Belgium.(Xanthoulis, 2000) Also could be employed as a further purification process of effluent water in tertiary sectors of treatment plants,(Qurie et al., 2013).

This technique consists in plants put in "channels" without soil (bare roots). The wastewater flows in the channels through the plants' root systems,(Asia Link, 2008).Which utilizes the roots of plants as bio-filters to remove nitrogen, phosphorus and other macronutrients. In addition, toxic elements and salts can be accumulated into the plant tissues from wastewater. 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 a closed or open loop system. 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,(Xanthoulis, 2000).

In the past they used Nutrient Film Technique (N.F.T.), shallow film,(Asia Link, 2008).Which is a modification of the hydroponic plant growth system in which plants are grown directly on an impermeable surface to which a thin film of wastewater is continuously applied. Root production on the impermeable surface is high and the large surface area traps and accumulates matter. Plant top-growth provides nutrient uptake, shade for protection against algal growth and water removal in the form of transpiration, while the large mass of self-generating root systems and accumulated material serve as living filters,(FAO, 1992).

Nowadays they use Permanent Nutrition Flow (P.N.F.), continuous and adjustable amount of water. This method is preferable for several reasons: 1) If the conveyance systems break down ensures the plants don't suffer from lack of water; and

2) for heavily polluted waters, the P.N.F. promotes greater and prolonged contact with the plant roots on which an abundant microbial flora has developed,(Asia Link, 2008).

Besides its purification ability, the system can also produce two valuables: 1) Water valorisation which is the complementary treatment can make the water suitable for non-restrictive use such as irrigation. 2) Plants valorisation in which system will produce valuable plants (ornamentals, biomass …);seed; animal feeding and human feeding under given and strict conditions regarding toxic compounds such as heavy metals or any other compound that could enter the food chain,(Asia Link, 2008).

Adsorbent Materials

Adsorption is considered to be one of the most promising techniques for wastewater treatment over the last decades. The economic crisis of the 2000s led researchers to turn their interest in adsorbent materials with lower cost, such as green adsorption which meansthe low-cost materials originated from: 1) Agricultural sources and by-products (fruits, vegetables, foods);2)Agricultural residues and Wastes.3) Low-cost sources from which most complex adsorbents will be produced (such as activated carbons). These "green adsorbents" are expected to be inferior to the super-adsorbents complex materials as modified chitosans, activated carbons, structurally-complex inorganic composite materials etc., but their cost-potential makes them competitive,(Kyzas et al., 2014).

Through continuous research, adsorption studies using two low cost adsorbents, activated carbon and positively octadecyltrimethylammonium complex (ODTMA-complex) (micelle-clay complex) revealed that both adsorbents are efficient in removing the pharmaceutical together with their biodegradation products, pesticide, toxic heavy metal Cr (VI) and Non-steroidal anti-inflammatory drugs,(Khamis et al., 2011, Karaman et al., 2012, Qurie et al., 2013, Awwad et al., 2015, Khalaf, et. al., 2015).

Micelle Clay Complex Column

The complex was prepared from the organic cationoctadecyltrimethylammonium (ODTMA) and the negatively charged clay-mineral, montmorillonite. This complex has a very large surface area, which includes large hydrophobic domains and is positively charged, about half of the cation exchange capacity of the clay. Micelle-clay composites have already been proven useful in the removal of about 20 neutral and anionic pollutants. The filtration process was adopted to monitor the efficiency of the complex towards removing total suspended solids (TSS), turbidity, chemical oxygen demand (COD), biological oxygen demand (BOD), total bacteria count, total coliform and fecal coliform,(Khamis et al., 2012).

Literature Review:

Xanthoulis et al. (2003) the aim of this study is to find long term solutions to the general problem of wastewater reuse in Mediterranean countries. The efficiency of the regional plants species were tested; flowers produced under irrigation were compared for their quality between irrigated one with water produced by Epuvalisation and four other sources of water, with and without fertilizers. This technique has the particularity to remove nitrates and phosphates from the wastewater and reduce the indicators of physical-chemical and biological contamination. The treated effluents meet the standards set for discharging wastewater into surface waters and the quality standards for irrigation waters.

Xanthoulis et al. (2006) and Asia Link (2008) investigated the Epuvalisation technique projects that used in different countries; they mentioned the most efficient species for this technique, and the reduction of physio-chemical pollution as heavy metals and also the reduction of microbial contamination with secondary and tertiary wastewater in closed and open circuit in Belgium and Portugal

Haddad et al. (2009) they studied the performance and feasibility of using hydroponics as decentralized wastewater treatment plants in the rural areas of the West Bank. In this study rosemary was used in barrels hydroponic system.

Bozdogan and Sogut (2013) they determined the effect of use urban wastewater treated pilot-scale subsurface flow constructed wetland in Karaisalı-Adana on rosemary (Rosmarinusofficinalis cv. Abraxas) and lavander (Lavandulaofficinalis cv. Bella Purple) that are used densely at green area in Mediterranean Region.Irrigation with treated wastewater didn't cause negative effect on plant growth for two species.

Qurie, et al. (2013) they investigated the potential of using an Epuvalisation system to treat brine generated from an inland RO unit. The system utilizes Basilicum (Ocimum basilicum L.) as salt tolerant plant. Water quality parameters as well as plant growth factors were monitored analysis of the effluent brine showed a remarkable decrease of electrical conductivity (EC), PO_4^{3-}, chemical oxygen demand (COD) and K^+ with a reduction of 60%, 74%, 70%, and 60%, respectively, as compared to the influent. The effluent of the control treatment showed 50%, 63%, 46%, and 90% reduction for the same parameters as compared to the influent. Plant growth parameters (plant height, fresh and dry weight) showed no significant difference between fresh water and brine treatments. The objective of reaching zero liquid discharge was achieved.

Many researcher study the efficiency of micelle-clay, Qurie et al. (2013) said the adsorption is considered to be one of the most promising techniques for wastewater treatment over the last decades. Micelle-clay composites have already been proven useful in the removal of about 20 neutral and anionic pollutants. Khamis et al. (2012)

Brooket al. (2013) demonstrated the removal of anionic detergents from synthetic water, well water, and gray water (GW), and the removal of pathogenic microorganisms from GW. The removal of anionic detergents, total suspended solids, and bacteria using micelle/montmorillonite complexes mixed with excess sand.

Polubesova, and Nir, (2005) removed the anionic pollutants (imazaquin, sulfentrazone, sulfosulfuron) and neutral pollutants (alachlor, acetochlor, chlorotoluron, bromacil) from water by micelles preadsorbed on montmorillonite using micelles of octadecyltrimethylammonium and benzyldimethylhexadecylammonium (BDMHDA).

Khamis, et al.,(2012)investigated the purification capability of tertiary treated wastewater with loose UF-membranes using Filters filled with a micelle-clay complex mixed with sand. The complex was prepared from the organic cationoctadecyltrimethylammonium (ODTMA) and the negatively charged clay-mineral, montmorillonite. The turbidity, total suspended solids (TSS), fecal coliforms (FC), and total coliforms (TC) were reduced to zero. The values of COD and BOD were reduced several-fold. Qurie et al., (2013) studied the effectiveness of ODTMA-MMT micelle clay complex for the removal of Cr (VI) anions from water. The micelle-clay complex was capable of removing Cr(VI) from aqueous solutions without any prior acidification of the sample, the removal effectiveness reached nearly 100% when using optimal conditions for both batch and continuous flow techniques.

Khalaf, et. al., (2015) studied the efficiency of advanced technology for the removal of selected pharmaceuticals, ibuprofen, mefenamic acid and the adsorption of both pharmaceuticals using ODTMA-clay-micelles complex at the wastewater treatment plant at Al-Quds University. MCXC integration in wastewater treatment plant will improve the removal efficiency of these drugs from wastewater.

Problem Statement:

Al-Quds University Wastewater Treatment Plant (AUWWTP) is suffering from over loading of wastewater so as a solution Epuvalisation technique & micelle clay complex was suggested.

For our experimental purposes, a part of activated sludge treated wastewater was carried to the Epuvalisation system to reduce the load of (AUWWTP), to treat the secondary treated wastewater and plants production.

Before the installation of ultra filtration with hollow fiber membrane, the spiral wound membranes had suffered severely from fouling which rendered this process to be expensive and not feasible. This fouling was mostly eliminated and thus the operation of the system improved significantly with the introduction of the HF unit.

In this experiment we investigated whether introducing a clay-micelle complex filter within this system would further improve the overall process and would reduce the operational as well as the equipment cost drastically for this advanced system while preserving water quality.

Objectives

Aim:

To improved Al-Quds University Waste Water Treatment Plant efficiency by first, using treated secondary effluent from activated sludge by Epuvalisation technique using ornamental plants, and second by installing micelle clay complex column included efficient adsorbent (ODTMA bromide- Montmorillonite complex) after UF hollow fiber unit.

Goals:

1. Investigate the efficiency of Epuvalisation technique using ornamental plant using Secondary Treated Waste Water.

   1.1 Plant selections.

   1.2 Water quality analysis for influent & effluent (Physical, Chemical & Biological test like EC, pH, TDS, COD, BOD, microbiology TC, FC).

   1.3 Measure the plant growth parameter.

   1.4 Measure the plant tissue analysis including N, P, K, Na, and Cl.

2. Investigate the efficiency of micelle clay complex column in advanced Waste Water Treatment Plant by:

   2.1 Adjust the influent flow rate of UF-SW stage.

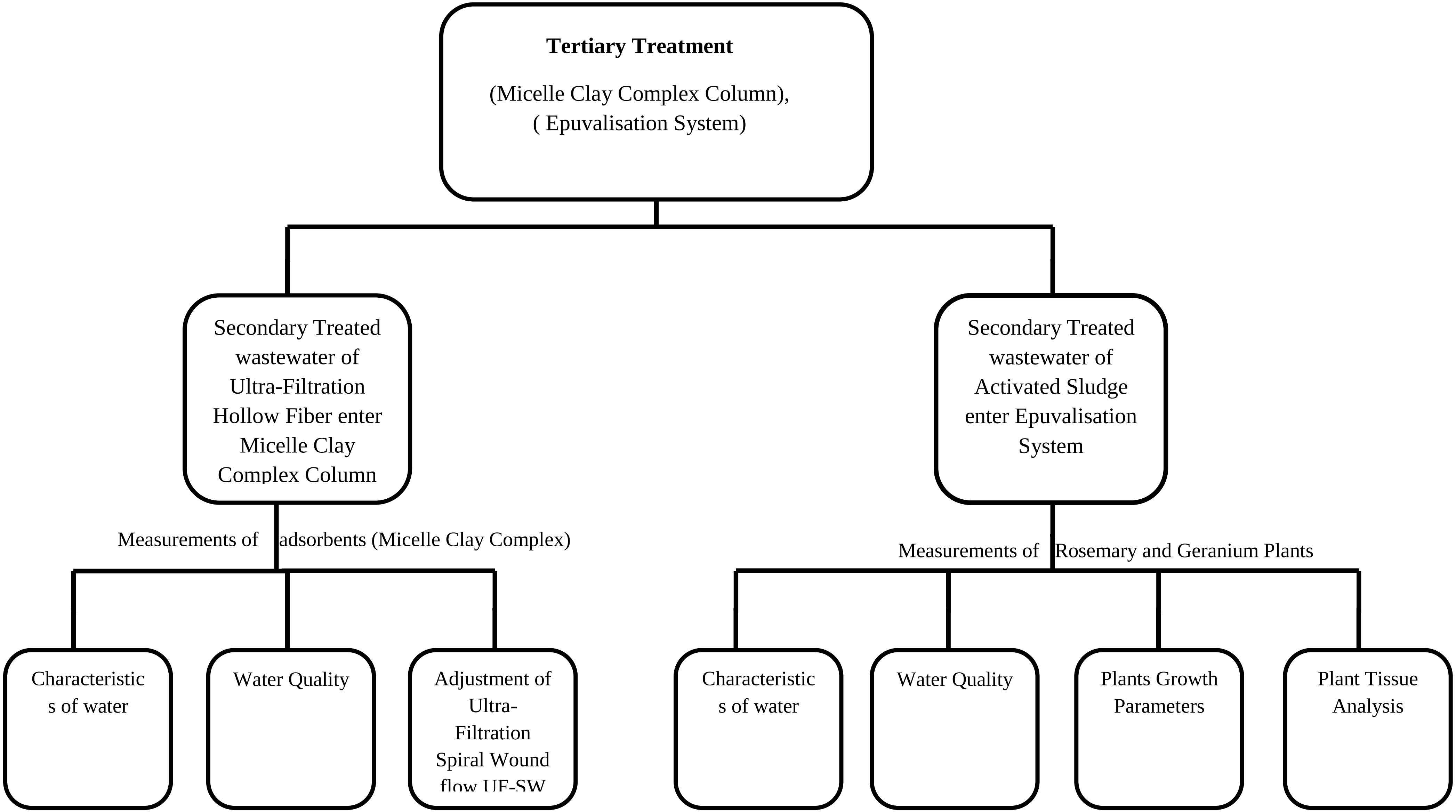
   2.2 Water quality analysis of influent and effluent of micelle clay complex column included (Physical, Chemical & Biological tests as EC, pH, TDS, COD, BOD, microbiology TC, FC).

   2.3 Compare between MCXC effluent and UF-SW effluent.

Thesis Outline

Thesis consists of four chapters. Chapter one includes general introduction and literature review. Chapter two covers the study area, also research methodology, Al-Quds university wastewater treatment plant, and the description of two treatment systems epuvalization and micelle clay complex. Chapter three present, the results and discussion, results of Epuvalisation system using Rosemary and Geranium plants, water quality measurements (physical, chemical and biological analysis), and plant tissue analysis and plant growth. The second part of this chapter describes installation of Micelle Clay Complex Column System in AUWWTP, results of water quality of both influent and effluent in addition to flow rate control and comparison with UF-SW. The conclusions of our study, recommendations and references are listed in chapter four.

Experimental Flow chart:



Chapter Two:

Materials and Methods:

2.1 Study Area

Al-Quds University Wastewater Treatment Plant (AUWWTP) at Al-Quds University (Palestine), locates at Al-Quds University in Abu Dies village (West Bank), to the southern east of Al-Quds University Campus, (AUWWTP) is a pilot wastewater treatment plant that consist of four treatment stages: Preliminary, primary, secondary and tertiary.

(AUWWTP) collects a mixture of black (from toilets), gray (from showers and sinks), and storm (rain) water, as well as waste water (from certain laboratories), which hosts approximately 13,000 students and staff members in the day time.

2.2 AUWWTP Components and Treatment Stages

The treatment plant consists of a primary treatment (two stage primary settling basin), secondary treatment (activated sludge which treats up to 50 m^3/day of wastewater with 16-20 hours retention time followed by coagulation and chlorination). Then the secondary effluent is introduced to a sand filter, chlorinator and Alum as coagulating agent before entering the ultra-filtration membrane, which consists of two units (ultra-filtration hollow fiber (HF), spiral wound (SW)). After ultra-filtration process, the effluent is filtered by activated carbon column followed by advanced treatment (reverse osmosis (RO) system).

2.2.1 Secondary Treatment

During aeration in activated sludge process, the microorganisms metabolize the organic matter giving rise to a reduction of wastewater BOD. Wastewater is then treated with aluminum sulfate as coagulating agent to promote the removal of suspended solids. The treated wastewater is collected for reuse in a special pond and the destruction of microbes is achieved by chlorination in the form of Trichlor discs.

2.2.2 Tertiary Treatment

2.2.2.1 Ultra-Filtration Treatment

The secondary effluent is introduced to a sand filter before entering the ultra-filtration (UF) membrane. The ultra-filtration system used consists of two components: a hollow fiber UF unit having a capacity 36 m^3/day and a spiral wound UF unit with a capacity of 12 m^3/day according to the manufacturer's specifications.

2.2.2.1.1 Ultra-Filtration Hollow Fiber

The hollow fiber unit is equipped with two pressure vessels that house the hollow fiber membranes having 100 kDa cut-off (AST technologies, Model No. 8000 WOUT_IN_8080, Israel) as pre polishing stage for the UF spiral wound.

2.2.2.1.2 Ultra-Filtration Spiral Wound

The spiral wound UF membranes consist of three layers: a polyester support web, a micro porous polysulfone interlayer and ultra-thin barrier coating on the surface. The UF membrane type is NIROSOFTRM10-8, 8040 spiral wound. The molecular weight cut-off (MWCO) of the membrane is 20 kD which is equivalent to 0.01 micron separation rate. The UF compartment consists of a couple of 2 × 4 inch pressure vessels having a pressure resistance up to 150 psi. Each vessel holds two separate membranes. The spiral wound stage produces good water quality with less than 20 ppm BOD and less than 30 ppm TSS and free from bacteria, which makes the water suitable for non restricted irrigation.

2.2.2.2 Activated Carbon and Reverse Osmosis (AC and RO)

After ultra-filtration process, the effluent is filtered by activated carbon adsorbent column followed by RO. Then a blend of UF effluent and effluents of RO with salt content similar to that of fresh water are used for irrigation, thus sustaining the soil from deterioration due to salt build up.

RO membranes are manufactured from thin polyamide film having a working pH ranging 1-11(model BW30-4040 by DOW Filmtec, USA). The RO compartment consists of 1 × 4 inch pressure vessel of composite material with a pressure resistance up to400 psi. The vessel holds two 4 inches RO membranes. An anti-scaling commercial product (NCS-106-FG, mainly containing phosphonic acid disodium salt) is continuously dosed to the RO feed at a concentration of 4 ppm in order to prevent the deposition of divalent ions. The RO system is designed to remove major ions and heavy metals with a permeate capacity of 0.5 m^3/h (12 m^3/day).

2.3 Methods:

To achieve our aims Epuvalisation system was applied to treat the effluent of secondary treated waste water of (AUWWTP), and micelle clay complex column was installed to (AUWWTP) after Ultra-Filtration Hollow Fiber to treat the effluent of Ultra-Filtration Hollow Fiber before entering Ultra-Filtration Spiral Wound. Figure 1 shows the position of Epuvalisation technique and micelle clay complex column at (AUWWTP), the numbers in Figure 1 shows the variation sectors of waste water flow and how it's usually work.

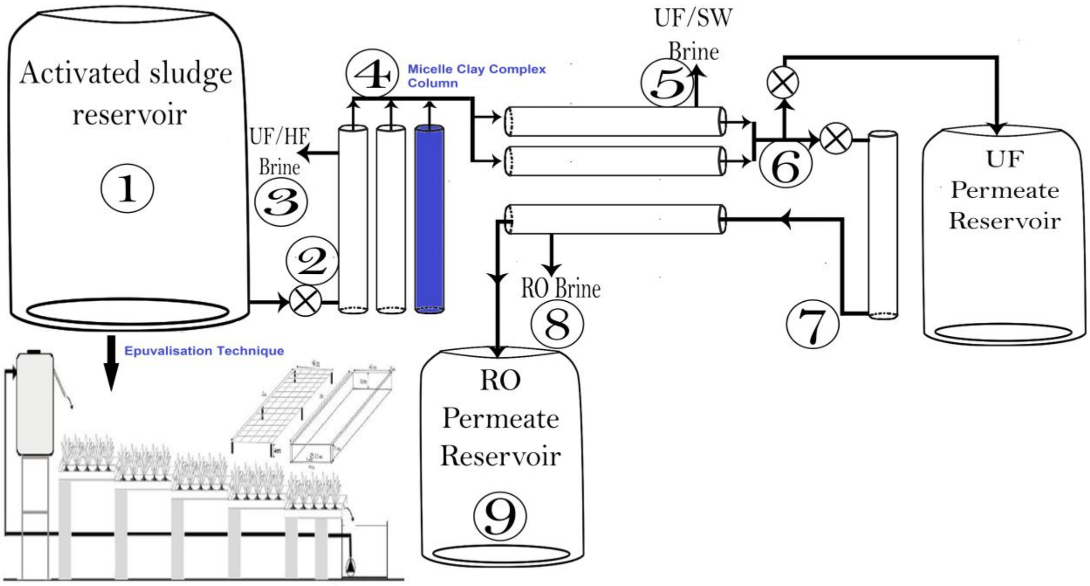


Figure 1: The position of Epuvalisation technique and micelle clay complex column at (AUWWTP).

2.3.1Epuvalisation Experiments:

The aim of this experiment is to investigate the ability of Rosemary plants (*Rosmarinus officinalis)* and Geranium plants *(Pelargonium hortorum*) to purify the secondary treated wastewater using Epuvalisation technique.

The experiment was conducted at Al-Quds university campus-Jerusalem. The system was installed to host Rosemary plants, the adaptation started on December 23rd, 2014 in greenhouse near the wastewater treatment plant, 50 Rosemary plants were planted in Epuvalisation system, the adaptation stage ended on January 20th, 2015, secondary treated wastewater was used in 4 channels and fresh water was used as control in another 4 channels, in both channel system using freshwater including the macro and micro nutrients with same fertilizers quantity, after adaptation fertilizers was added and cycle lasted for 10 days, after several cycles the experiment was ended.

For Geranium plants plantation was on December 2, 2015.The adaptation stage was ended on December 13th, 136 Geranium plants were distributed equally between treated wastewater and fresh water channels, and as Rosemary experiment the same process was followed for cycles.

2.3.1.1 Experimental Design

The Epuvalisation system at Al-Quds University is represented in figure 2 which is composed of two equivalent sections; one is used for irrigation with secondary treatment wastewater as hydroponic system while the other used fresh water as control. Each system consists of two 0.5 m^3 storage tanks (one for influent and the other for effluent) and 4 cropping channels. For each system, the influent tank is placed one meter higher than the Epuvalisation tracks to let water flow by gravity through four channels. Each channel (made of galvanized metal) is 3meter long, 0.45 m wide and 0.14m depth where the height of the water in the channels is 0.11m. The 4 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.

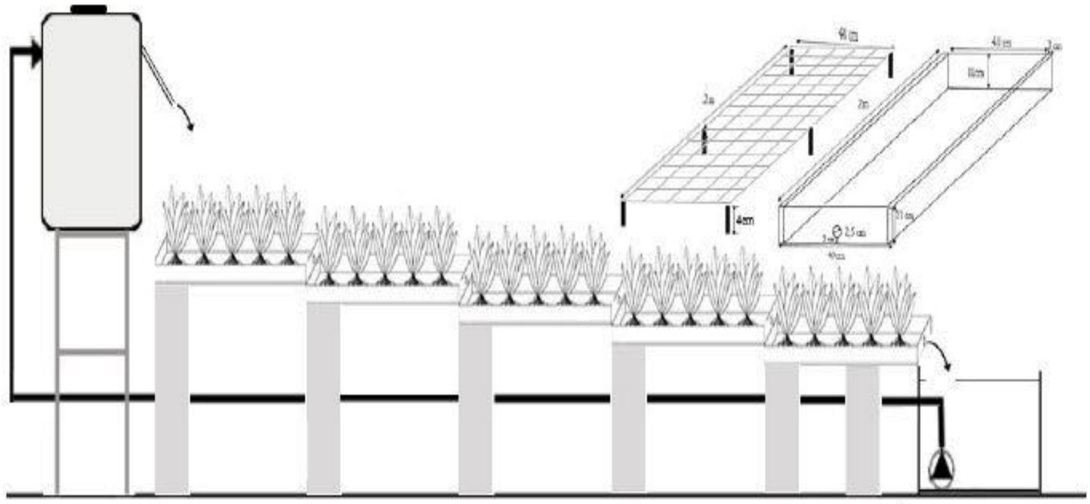


Figure 2: Graphical design for Epuvalisation system & it's channel.

2.3.1.2Plant Selection

Ornamental plants were selected for hydroponic treatment using secondary treated wastewater. The selection depends on the adaptations and survive of the plants 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 to regenerate to ensure plant replacement,(Xanthouli et al., 2003; 2006).

According to these conditions Rosemary and Geranium young plants were selected.

and planted in open channels of secondary treated wastewater and fresh water as control supplied with additional nutrients (nitrogen, total potassium, phosphorus, magnesium, and iron). Nutrients added in influent tanks of both secondary treated wastewater and fresh water every 10 days respectively.

2.3.1.3 Experimental Process

Adaptation stage with fresh water and fertilizers was the first stage of our experiment. Aeration stage was conjugated with the process for 6 hours continuously everyday by using timer. Plants were planted at (0.25 m, 0.15 m) distance from each other to permit roots to develop in a sufficient volume for Rosemary and Geranium respectively. Irrigation with secondary treated wastewater with fertilizers was the second stage where FW was used as control. Closed loop was used as a monitor for each cycle with period time extended to 10 days.

2.3.1.4 Water Quality Analysis:

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.

2.3.1.5 Plants Tissue Analysis:

Samples from dried separated Rosemary and Geranium plants (roots, leaves, stems and flowers) were used for chemical plant tissue analysis. The chemical analysis included total nitrogen, total phosphorus, sodium, chloride and potassium. Standard method for soil and plant analysis was used for chemical plant analysis. (Gericke and Kurmies, 1952; Seale, 1984; Ryan et al., 1996)

1.3.1.6 Plant Growth Parameters:

In the beginning of the experiment, plant growth parameters were measured for all plant samples. Plants were labeled and plant growth heights were measured during the season, at the beginning and at the end of the cycle. At the end of the season, plants were collected and the fresh biomass was weighted and recorded, then dried and weighted the dry biomass and recorded.

2.3.2 MCXC Experiment:

The secondary treated effluent was pumped to the hollow fiber ultra filtration unit, then to micelle clay complex column. The MCXC permeate was collected in a tank and used to feed the UF spiral wound. We focus here on presenting a relatively novel means for removal of micro pollutants and microorganisms from water using a micelle-clay sorbent. The goal of this experiment is to study the efficiency of MCXC as novel absorbents for removal microbial and organic matter causing decreasing the clogging of UF-SW membrane.

The filtration process was adopted to monitor the efficiency of the complex towards removing total suspended solids (TSS), turbidity, chemical oxygen demand (COD), biological oxygen demand (BOD), total bacteria count, total coliform and fecal coliform.

2.3.2.1 MCXC Preparation:

The complex was prepared from the organic cationoctadecyltrimethylammonium (ODTMA) and the negatively charged clay-mineral, montmorillonite. The complex has a very large surface area, which includes large hydrophobic domains and is positively charged, about half of the cation exchange capacity of the clay. It was shown by X-ray diffraction, electron microscopy and adsorption experiments that the material characteristics of the micelle-clay complex are different from those of an organo-clay complex, which are formed by adsorption of the same organic cation ODTMA (Octadecyltrimethylammonium) as monomers.(Khamis et al., 2012)

2.3.2.2 Experimental:

Micelle-clay complex and sand were purchased in column on August, 17th 2015 until November, 4th.Micelle clay complex prepared by mixing 12mM ODTMA and 1 g montmorillonite with stirring for 72 hours and lypholization. A mixture of (washed and air dried) sand and micelle-clay complex in ratio 3:1 (w/w) was added in column with 1.6 m length and 0.45 m diameter as shown in WWTP diagram.

A schematic diagram for the (AUWWTP) after installing the columns is shown in Figure 3. The columns after the Hollow was filled with the micelle-clay sand mixture.

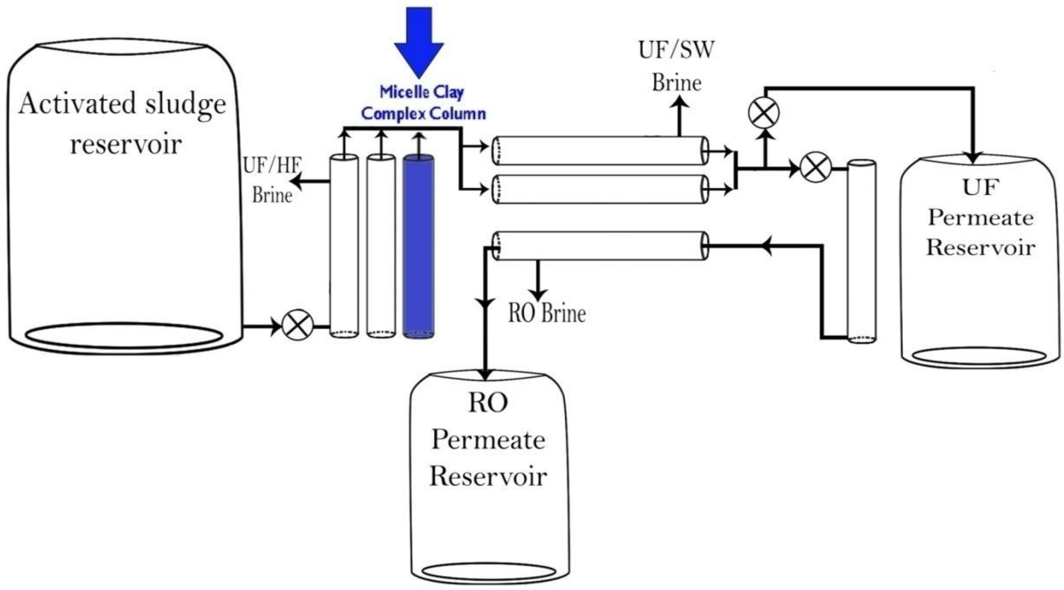


Figure 3: Schematic diagram of the Al-Quds University wastewater treatment plant after integrating the micelle clay complex column (dark color) in sequential of the existing UF-HF unit.

2.3.2.3 Monitoring the Micelle-Cay Filters

The introduction of micelle clay complex column in (AUWWTP) between the UF-HF and UF-SW technologies effluents was proposed to help in decreasing the fouling episodes of subsequent UF-SW membrane stage and hence prolong its lifetime. The removal of organic matter and microbes will prevent membrane fouling as results of bio-accumulation and hence will delay the cake formation on these membranes.

To test objectives monitor the performance of MCXC at the head of UF-HF column product was needed. The flow rate, time of operation and water quality of influent and effluent samples included chemical, physical and biological parameters during the experiment were also measured, As well as the comparison between the UF-SW effluent using UF-HF effluent without micelle clay complex treatment and the effluent of micelle-clay complex column.

2.3.2.4 Method:

The flow rate was adjusted to 200 liter per hour and time of operation was 4 hours per day. Samples from initial influent and effluents were taken as function of volume as following (20, 50, 100, 200, 400 and 800 L), which is equal to these as function of time (6, 15, 30, 60, 120 and 240 min) these cycles were repeated for several days.

2.3.2.5 Water Quality Measurements:

The influent and effluent samples were analyzed for chemical, physical and biological quality. These include pH, EC, TDS, SS, Turbidity (NTU), COD, BOD, Fecal, Total Coliform and Total Plate Count. The standard methods of water and wastewater examination were followed during the analysis.

2.4 Materials:

Chemicals and Reagents

K_2SO_4 (merck), KCl, KNO_3, NH_4NO_3, KH_2PO_4, $MgSO_4 \cdot 7H_2O$, Fe–Na EDTA, $MnCl_2 \cdot 4H_2O$, $ZnCl_2$, $CuCl_2 \cdot 2H_2O$, H_3BO_3, $(NH_4)_6$ $Mo_7O_{24} \cdot 4H_2O$, $NiCl_2$, Glucose, Glumatic acid, Sodium chloride (NaCl), Potassium chloride (KCl), Calcium chloride ($CaCl_{2)}$, Magnesium sulfate ($MgSO_4$), Hydrochloric acid (HCl), Potassium Dichromate ($K_2Cr_2O_7$), Sulfuric Acid 96 % (H_2SO_4), Silver Sulfate (Ag_2SO_4), (SIGMA- ALDRICH, catalogue No. 497266), Sodium phosphate ($Na_3PO_4.12H_2O$), Sodium citrate ($C_6H_5Na_3O_7.2H_2O$), phenol crystals, Sodium nitroprusside ($Na_2FeCN_5NO.2H_2O$), Sodium hydroxide 1N Hypochlorite reagent (Sodium hydroxide 1N, D.I water, 11% sodium hypochlorite), Ammonium chloride (NH_4Cl), Ammoniumvanadate (NH_4VO_3), Nitric acid (HNO_3), Ammoniummolybdate ($(NH_4)_6Mo_7O_{24}.4H_2O$), potassium dihydrogen phosphate (KH_2PO_4), Potassium chromate (K_2CrO_4), Silver nitrate ($AgNO_3$), Sodium chloride solution (0.01N), Sodium chloride (NaCl).

The clay used was Wyoming Na-montmorillonite SWy-2 obtained from Steetley Bentonite & Absorbents (Nottinghamshire, UK). Quartz sand (grain size 0.8-1.5 mm) was purchased from Shoshani& Weinstein (Israel). Octadecyltrimethylammonium (ODTMA)-bromide was obtained from Sigma Aldrich. Sulfuric acid (H_2SO_4: 95-97%), potassium dichromate ($K_2Cr_2O_7$). Silver sulfate (Ag_2SO_4). Mercury (II) sulfate ($HgSO_4$). De-ionized water was used to prepare all solutions. Microbiology growth media were obtained from Difco, USA (213000, 273620, and 267720 for total plate count, total coliform, and fecal coliform count, respectively).

2.5 Instruments:

pH-EC-TDS meter (Hanna 18752), Spectrophotometry (Hack DR 2010), UV–Visible Spectrophotometer (Shimazo 1601), Atomic Absorption Flame Emission (Shimadzu 6200) Spectrophotometer, Flame Photometer (JenwayHeraeussepatech), Oximeter (WTW, Germany), Centrifuge(Labofuge 200), Oven, (D-63450 Kendro), electronic balance(Shimadzu), Autoclave (Tuttnauer Autoclave, steam sterilizer, Model 2340M, USA), Water bath (Type JBL, England), BIAF Laboratory furnaces multistage electro therm (model MS 8).

2.6 Sampling and Standard Preparation

An average samples were collected from effluents and influents. A standard stock solution for COD, NH_4^+, PO_4^{-3}, Na^+, K^+, Mg^{+2}, Ca^{+2}, Cl^- were prepared then different concentrations were prepared from these stock solutions. The concentrations of the measured samples were calculated from the standards calibration curve.

Chapter Three:

Results and Discussions:

This chapter present results of two sections. The first one, the efficiency of using Epuvalisation technique to treat secondary treated wastewater using Rosemary and Geranium plants. While the second one shows the results of investigations the efficiency of filters based on micelle-clay complex towards polishing tertiary treated wastewater generated from ultra-filtration unit using hollow fiber membranes.

3.1 Epuvalisation Experiment

The biological treatment effluent of wastewater treatment plant at Al-Quds University was applied for irrigation of Rosemary and Geranium plants using Epuvalisation technique. The water quality, plant growth parameters and chemical plant tissue were measured and analyzes during irrigation of Rosemary and Geranium plants using both irrigation types (TWW and FW).

3.1.1 Rosemary

3.1.1.1 Water Quality

Chemical, physical and biological Characteristics of secondary treated wastewater and fresh water used in Epuvalisation system experiment were presented on Table 1. Treated wastewater was concentrated of fecal coliform, total coliform and total plate count, with high turbidity more than 4 NTU which is normally over the limits of drinking water in Palestine. (Palestinian Water Authority, Palestinian Standards for

Drinking Water.), The maximum limits according to WHO standards is 1500 (µS/cm) of electrical conductivity of drinking water, FW result was accepted but of TWW was not accepted. (World Health Organization, 2008)

Table 1: Chemical, physical and biological parameters of secondary treated wastewater (TWW) from Al-Quds wastewater treatment plant and fresh water (FW) with fertilizers.

Parameter	FW	TWW
pH	7.5±0	7.7±0
EC (µS/cm)	1060±50	1830±50
TDS (mg.L^{-1})	510±50	1100±50
TSS (mg.L^{-1})	1±0	76±3
Turbidity (mg.L^{-1})	1±0	52±2
COD (mg.L^{-1})	117±20	192±55
BOD (mg.L^{-1})	58±5	117±30
Mg^{2+} (mg.L^{-1})	12±3	26±1
Ca^{2+} (mg.L^{-1})	28±15	60±0
K^{+} (mg.L^{-1})	16±26	38±5
Na^{+} (mg.L^{-1})	47±3	78±2
TN as NH^{4+} and NO^{3-} (mg.L^{-1})		102±25
PO_4^{3-} (mg.L^{-1})		15.7±2
FC (cfu/ml)	0	3*103
TC (cfu/ ml)	<1000	5*103
TPC	<1000	20*103

EC in (µS/cm) of TWW was 1830 (µS/cm), which is higher than EC of FW due to high salts included in TWW. The maximum limits for EC in drinking water is 1500 (µS/cm) according to WHO standards. According to Palestinian standards TWW classified as medium quality depends on BOD and FC values. But for pH, COD and TDS its acceptable, The treated effluent can be used in these purposes (discharge to sea at distance of 500 m, irrigation of dry fodders, irrigation of industrial crops and seeds and irrigation of forests and forest trees). (PWA, 2003)

Table 2: Physical and chemical quality of hydroponic recycled water after 10 days of Epuvalisation treatment, FW compared to TWW during the same period. Mean values ± standard deviations (SD).

The influent and effluent quality of TWW was monitored during the Epuvalisation experiment. Water samples were collected and analyzed during and after 10 days.

	FW		**Removal (%)**	**TWW**		**Removal (%)**
Parameter	**Influent**	**Effluent**		**Influent**	**Effluent**	
pH	7.5 ± 0	7.1 ±0		7.1 ± 0	7.4 ±0	
EC ($\mu S.cm^{-1}$)	990 ± 215	610 ± 7	38	1680 ± 290	1225 ± 50	27
TDS ($mg.L^{-1}$)	340 ± 105	300 ± 0	12	840 ± 170	620 ± 14	26
TSS ($mg.L^{-1}$)	2 ± 1	1 ± 1	50	76 ± 3	52 ± 8	32
TUR (NTU)	1 ± 0	1 ± 0		52 ± 2	37 ± 2	29
COD ($mg.L^{-1}$)	117± 10	98± 10	16	270 ± 10	235± 10	13
BOD ($mg.L^{-1}$)	58 ± 7	41± 10	29	120± 10	91±10	24
Mg^{2+}($mg.L^{-1}$)	2.2±0	1.68±0	24	27±0	1.63±0	94
Ca^{2+}($mg.L^{-1}$)	1.1±0	0.59±0	46	55±13	0.67±0	99
K^{+}($mg.L^{-1}$)	36±5	25±5	31	36±10	24±5	33
Na^{+}($mg.L^{-1}$)	47±10	40±2	15	83±27	51.1±2	38

Results are presented in Table 2 reveals the decreasing of chemical oxygen demand and total dissolved solid with a reduction of 13% and 26%, respectively for the effluent of TWW. Whereas, the effluent of FW showed 16%, and 50%, reduction for the same parameters as compared to the influent. Potassium results for both treatment shows decreasing in concentration with 31% and 33% for the effluents of FW and TWW this can be attributed to the uptake of K as major nutrients for plants and the same trend for other nutrients as Ca, Mg and Na.

In general treated wastewater effluent can classified as slightly saline due to its range between 500-2000 $mg.L^{-1}$. Rosemary also can classified as moderately tolerant for salt as ornamental shrubs that maximum permissible for EC 6000-8000 $\mu S.cm^{-1}$ (Food Agency Organization, 2007), showing the possibility of Rosemary adaptation in TWW.

Haddad, and Mizyed, (2011) studied the hydroponic system as decentralized wastewater treatment and reuse, they chose different types of plants and trees, Rosemary plants treated raw wastewater using barrels, it shows the ability of Rosemary plants to treat wastewater. BOD removal efficiency was 20% butin the present work, it was improved to 24%, TDS in the effluent of wastewater increased, in this work, it decreased into 26%.

The electrical conductivity (EC) and Total dissolved solids (TDS) during the closed cycle:

Figures (4 and 5) summarize the variation of EC and TDS with the time of the cycle using TWW and FW in the closed loops which extended for ten days. On the 1st day from the beginning of the hydroponic cycle, two doses of the same quantity of fertilizers were added to both tanks containing the TWW and FW. Results for both cases are included in Figure 4 and 5 for comparison. EC and TDS concentration are the highest after the addition of fertilizers and then there is a gradual decreasing of EC and TDS values during the monitoring period as a function of time. This reduction can be attributed to the plant uptake of various nutrients. The largest decreasing was at the first 48 hours.

For EC results the initial was 1680 $\mu s.cm^{-1}$ and the final was 1225 $\mu s.cm^{-1}$ for TWW, the removal efficiency was 27%. Whereas in FW, EC results initiated with 990$\mu s.cm^{-1}$ and the final result was 610 $\mu s.cm^{-1}$, the removal efficiency was 38%. For TDS it starts with 840 $mg.L^{-1}$ and end with 620 $mg.L^{-1}$ in TWW with removal efficiency about 26%, but for FW it starts with 340 $mg.L^{-1}$ and ends with 300 $mg.L^{-1}$with removal efficiency about 12%.

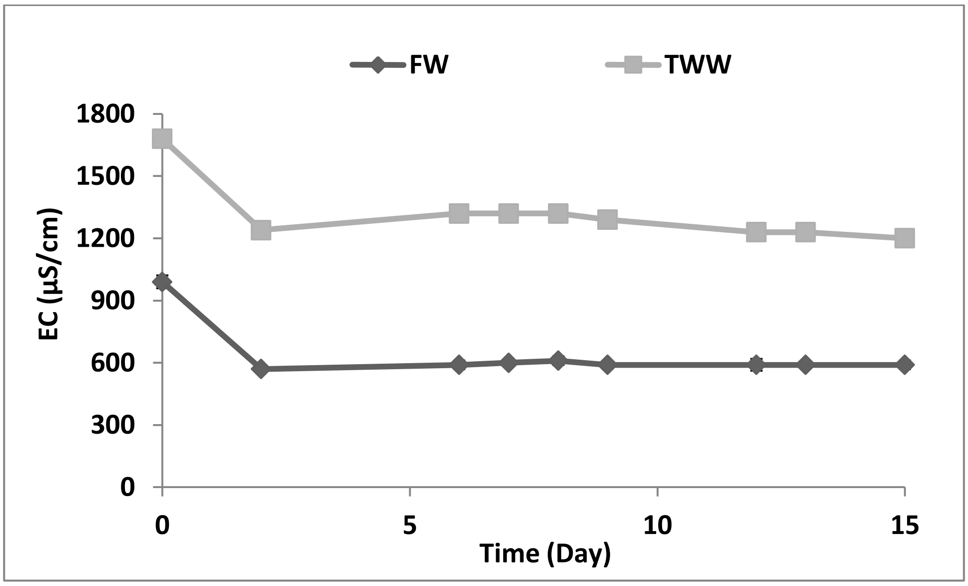


Figure 4: Variation of EC with time (days) using Secondary Treated Wastewater TWW compared to Fresh Water FW as control. Both treatments contained the same quantity of macro and micronutrients.

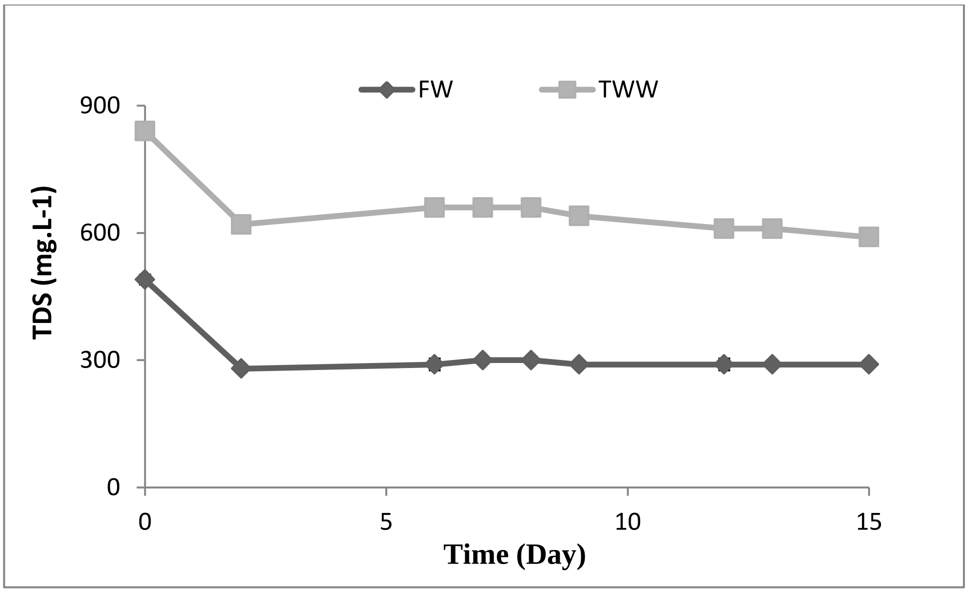


Figure 5: Variation of TDS with time (days) using Secondary Treated Wastewater TWW compared to Fresh Water FW as control. Both treatments contained the same quantity of macro and micronutrients.

Table 3 summarized the average results of three cycles during irrigation of rosemary of both TWW and FW. The results of both BOD and COD show reduction in their concentration of 27% and 23% for FW; whereas TWW show reduction of 23% and 29% respectively. Ca^{2+}, Mg^{2+} and Na^{+} show variation due to uptake.

Table 3: Represented physical and chemical characteristics of hydroponic recycled water of Epuvalisation treatment for Fresh Water and Treated Wastewater as average of 3 cycles that hold during the season. Mean values ± standard deviations (SD).

	FW		Removal %	TWW		Removal %
Parameter	**Influent**	**Effluent**		**Influent**	**Effluent**	
pH	7.1±0	7.2±0		7.4±0	8.2±0	
EC (µS.cm⁻¹)	1067±25	763±35	29	1837±25	1350±20	27
TDS (mg.L⁻¹)	540±12	407±15	25	1067±20	670±15	37
SS (mg.L⁻¹)	1.7±0	1.2±0	29	64±5	44±5	31
TUR (NTU)	0.7±1	0.3±1	57	49±11	32±2	35
COD(mg.L⁻¹)	107±15	77±8	27	217±23	162±15	25
BOD(mg.L⁻¹)	46±3	34±2	23	86±2	64±5	23
Mg^{2+}(mg.L⁻¹)	2.32±0	1.71±0	26	24±1	18±1	22
Ca^{2+} (mg.L⁻¹)	1.26±0	0.86±1	32	58±1	42±1	26
K^{+}(mg.L⁻¹)	4.32±0	1.77±0	59	38±2	31.7±1	14
Na^{+}(mg.L⁻¹)	37.9±1	26.8±1	29	76±2	51.8±1	6

3.1.1.2 Plant Growth Parameters

Plant growth parameters were monitored during and at the end of the growing period of Rosemary plant (plant height, fresh weight, dry weight, number of branches and number of flowers).

The plants grew very well in hydroponic system. During the season of plantation, the height of Rosemary plants are summarized in Figure 6whereas the fresh weight and dry weight results are summarized in figure 7, the average number of branch of plants irrigated with both media are summarized in figure 8,and finally figure 9summarized the number of flowering among the plantation season. The plants height was found to increase normally with time. There was no significant difference between plant height in the case of TWW and FW irrigation, the average plant height of TWW was (26.8 cm) and for FW was (26.35 cm). These results were in agreement with (Bozdogan, et al., 2013). Both of the two years plants that were irrigated with treated wastewater had higher average plant height (7.02 cm) more than plants irrigated with fresh water (6.21 cm) more. (Bozdogan, et al., 2013) shows that reuse of treated wastewater for ornamental plants irrigation effect positive plant growth, it’s determined that plant diameter and shoot length were increased by using TWW as irrigation water.

The results of both dry and fresh weight Rosemary plants show no significant change was observed in type of irrigation, and the same trend was observed for numbers of branching there are no significant difference between plants irrigated with TWW and FW, Plants in both type of irrigation grown with time. Irrigation with TWW had no negative effects on growth and flowering. These results were similar to that obtained by (Gerhart, et al., 2006) and (Bozdogan, et al., 2013) with Rosemary (Rosmarinus officinalis).

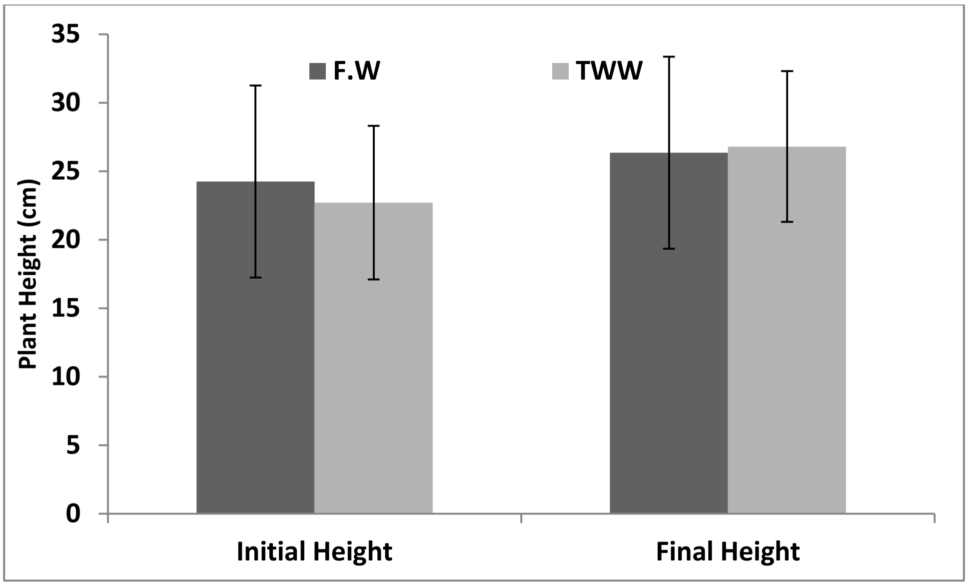


Figure 6: Variation of Rosemary plant height(cm) during season of Epuvalisation experiment which irrigated with both type of water (TWW and FW).

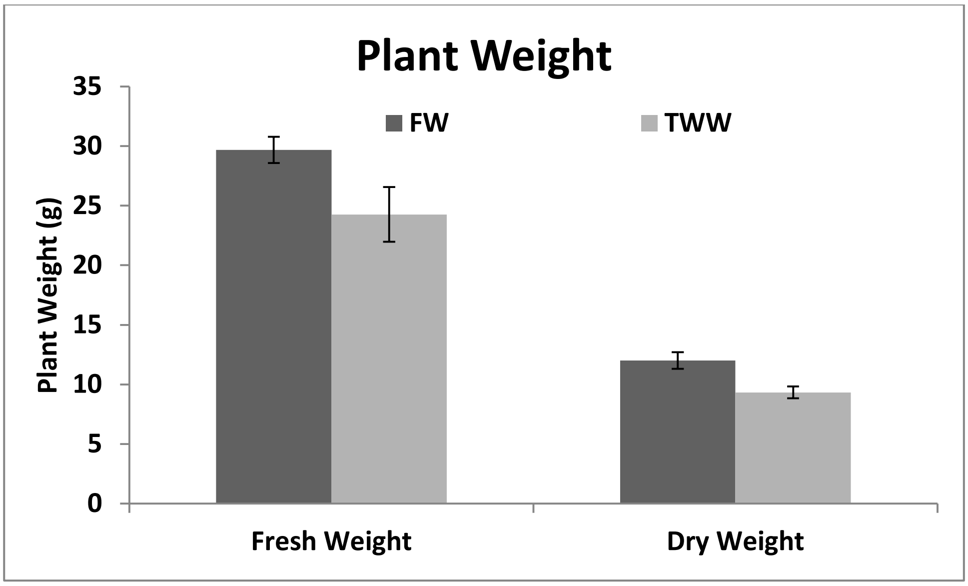


Figure 7: Rosemary plant weight in fresh and dry weight in (g) after the end of irrigation using TWW and FW after harvesting.

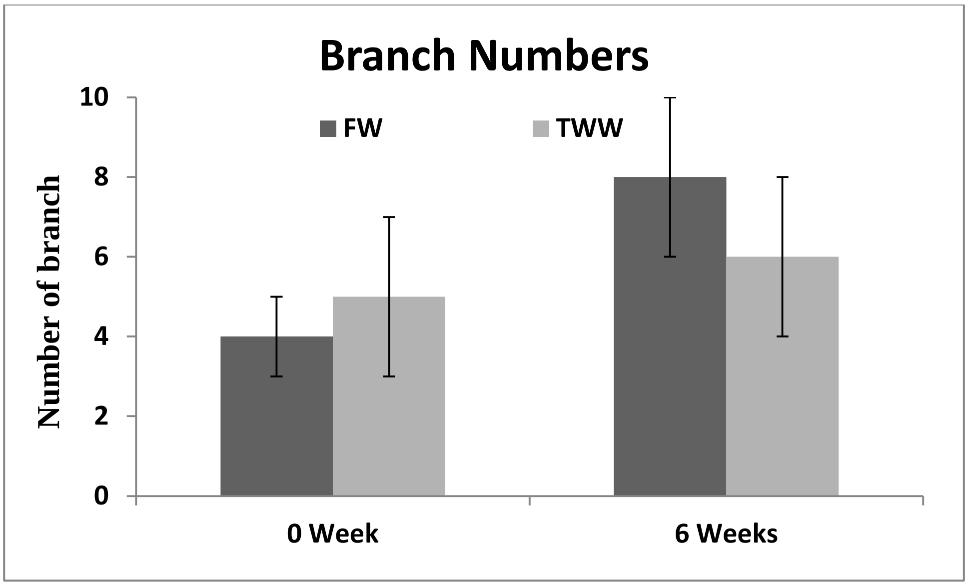


Figure8: Variation of average Rosemary branching number of plants irrigated with TWW and FW at the beginning of experiment and after 6 weeks.

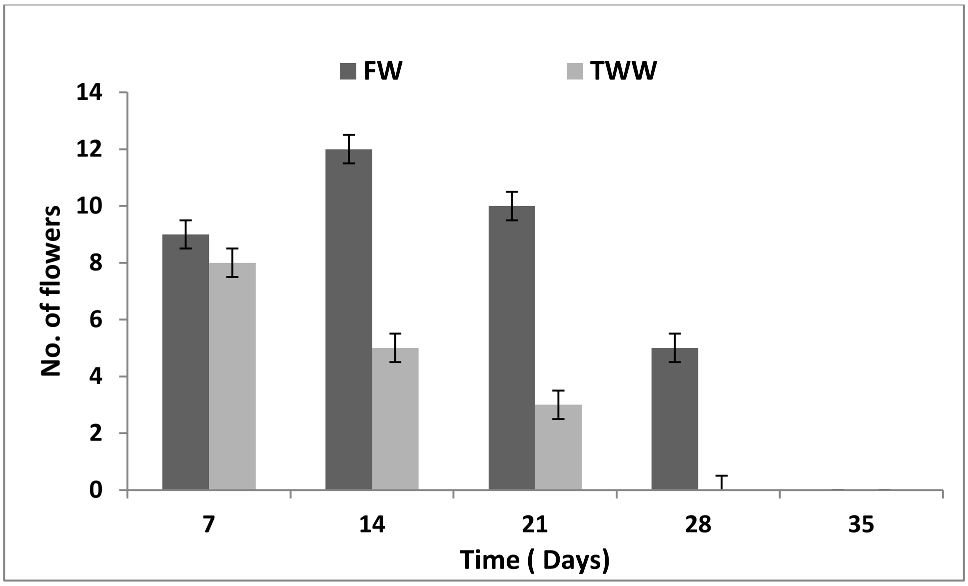


Figure9: Variation of average Rosemary flowering number of plants irrigated with TWW and FW at the beginning of experiment and after 6 weeks. The initial numbers of flower was zero at the beginning of this experiment.

3.1.1.3 Chemical Composition of Plants Tissues

Rosemary plants were harvested after the end of irrigation, dried and separated into roots, stems and leaves. Finally, plant parts were prepared for chemical analysis of various nutrients content as shown in figure 10, 11and 12.

Rosemary plants grown in treated wastewater accumulated higher total nitrogen on roots compared to plants irrigated by using fresh water (Figure 10). Both TWW and FW treated plants accumulated the same amount of total potassium and phosphorous, with low amount of Na^+ and Cl^-showing no salinity effect of TWW on the plants content.

Figure 11 shows higher accumulation of total potassium in TWW on stems compared to plants irrigated by FW.

The macronutrients P and K in roots and leaves of Rosemary grown in TWW and FW did not show any significant difference between both irrigation water, in stem potassium concentration results of TWW was higher than in FW. Nitrogen was accumulated in higher amounts compared to the other macronutrients. Sodium content was found in low concentration in all plants irrigated with TWW and FW. No particular accumulation of chloride was observed in the roots, stems and leaves of Rosemary plants.

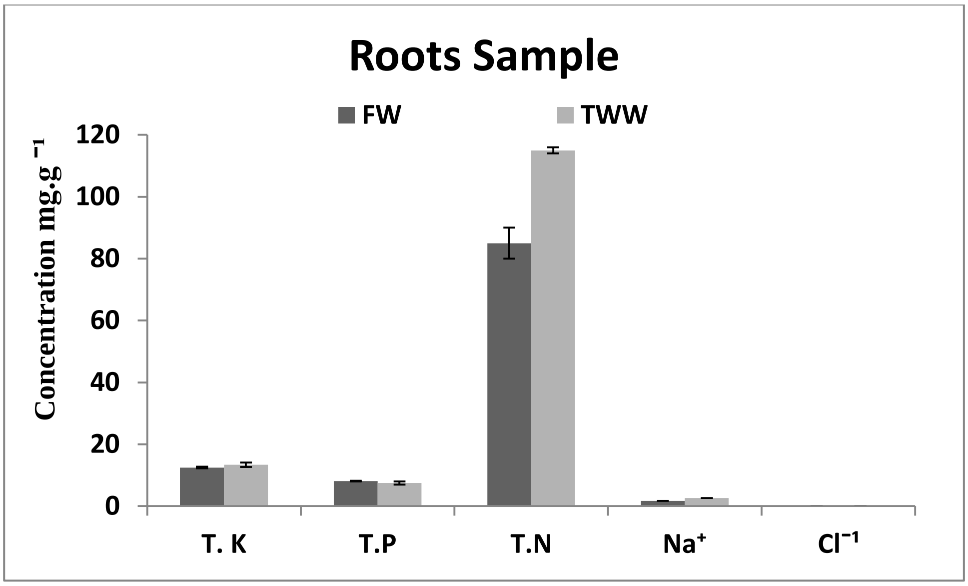


Figure 10: Variation of total nutrients content of Rosemary roots after 6 weeks of Epuvalisation experiment compared treated wastewater with fresh water as control. Mean values ± standard deviations (SD) of three replicates.

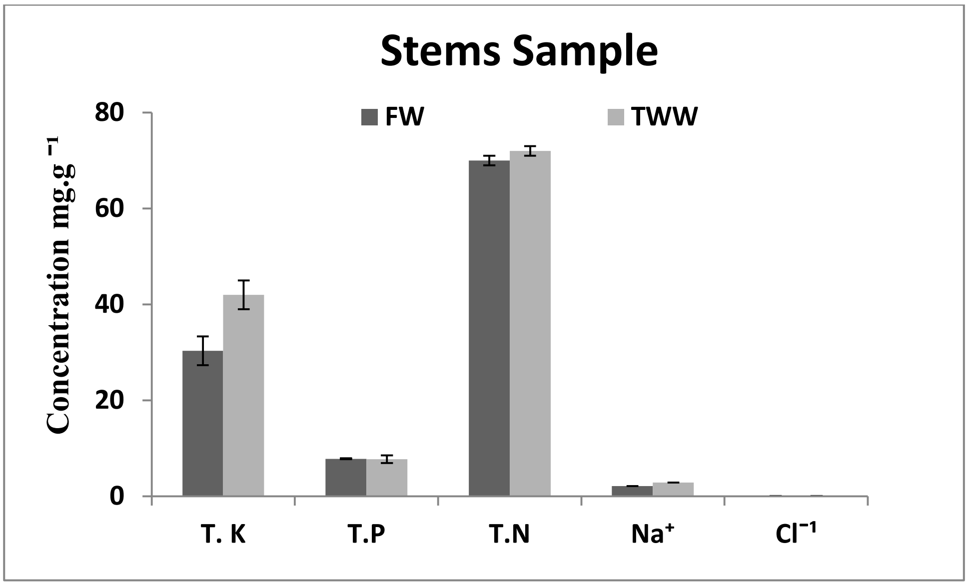


Figure 11: Variation of total nutrients content of Rosemary stems after 6 weeks of Epuvalisation experiment compared treated wastewater with fresh water as control. Mean values ± standard deviations (SD) of three replicates.

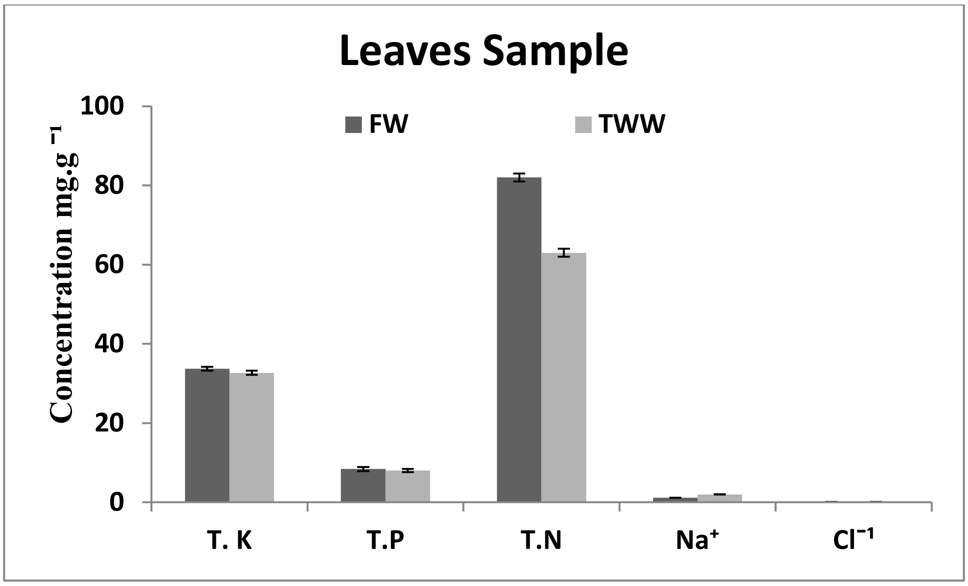


Figure 12: Variation of total nutrients content of Rosemary leaves after 6 weeks of Epuvalisation experiment compared treated wastewater with fresh water as control. Mean values ± standard deviations (SD) of three replicates.

3.1.2 Geranium Result:

The second experiment of application of secondary treated wastewater using Epuvalisation system was applied for geranium plants.

3.1.2.1 Water Quality

Chemical, physical and biological characteristics of secondary treated wastewater and fresh water used in the Epuvalisation system experiments and results are presented on Table 4.

Table 4: Chemical, physical and biological parameters of secondary treated wastewater TWW from Al-Quds wastewater treatment plant and fresh water FW without fertilizers.

Parameter	FW	TWW
PH	7.3±0	7.4±0
EC (μS/cm)	563± 15	1177±6
TDS ($mg.L^{-1}$)	277±6	587±6
SS ($mg.L^{-1}$)	0±0	79±0
Turbidity ($mg.L^{-1}$)	0±0	125±2
COD ($mg.L^{-1}$)	198±10	342±2
BOD ($mg.L^{-1}$)	26±6	65±5
Mg^{2+} ($mg.L^{-1}$)	18±0	13±0
Ca^{2+} ($mg.L^{-1}$)	36±0	68±0
K^{+} ($mg.L^{-1}$)	2.5±0	15±0
Na^{+} ($mg.L^{-1}$)	60±0	154±0
TN as NH^{4+} and NO^{3-}($mg.L^{-1}$)	0±0	24±0
PO_4^{3-}($mg.L^{-1}$)	0±0	11±0
Cl^{-}($mg.L^{-1}$)	80±0	186±0

Table 5: Physical and chemical quality of hydroponic recycled water after 10 days of Epuvalisation treatment, FW compared to TWW during the same period. Mean values ± standard deviations (SD).

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

The results of water quality analysis of both TWW and FW using Geranium plants showed a decrease in biological oxygen demand with a reduction of 23% for TWW and FW. The percentage removal of electrical conductivity was the same in FW (48%) and (52%) in TWW, almost the same in TDS 49% and 53% respectively. The removal percentage in TWW of suspended solids was 95%, PO_4^{-3} was 89%, Cl^{-} was 60%, TN was 98% and K^{+} was 59%.

Plants uptake nutrients needed and pure water from the flowing wastewater in the hydroponic system (Papadopoulos et al., 2004).Suspended solid removal in the influent of TWW was 81 $mg.L^{-1}$to 4 $mg.L^{-1}$ with removal efficiency 95%.For COD results removal efficiency was about 67% in FW and 41% in TWW as a removal efficiency.

Total nitrogen in FW influent was 4.4 decreased to 0$mg.L^{-1}$. While the TWW influent was 24 decreased to 0.4 $mg.L^{-1}$. The removal efficiency was 100% and 98% respectively.

Papadopoulos et al., (2004). Found that the addition of fertilizer at 120 ppm N produced fewer flowers than addition of 60 ppm N showing that addition of fertilizer above 60 ppm N had a negative effect on flower production

Total phosphorous in the FW was ranging from 39 to 0, and 61 to 7 in TWW from the beginning of the cycle to the end. The removal efficiency was 100% and 89% for TWW, the removal rates are due to plant nutrient uptake and adsorption processes in the media, which is more than the removal efficiency in Haddad study, the average of removal efficiency was 37% (Haddad et al., 2011).

The effluent of TWW could be classified according to Palestinian standards of the treated wastewater to high quality of the treated wastewater depends on these parameters (TSS, TDS, pH, NO_3-N, NH4-N, TN, Cl, Na, Mg, Ca and PO_4) (PWA, 2003; Haddad and Mizyed, 2011).

The electrical conductivity (EC) and Total dissolved solids (TDS) during the closed cycle:

Figures (13 and 14) summarize the variation of (EC) and (TDS) with the time of the cycle using treated wastewater and fresh water in the closed loops which extended for ten days. On the 1st day from the beginning of the hydroponic cycle, two doses of the same quantity of fertilizers were added to both tanks containing the treated wastewater (TWW) and fresh water (FW). Results for both cases are included in figure 13 and

14for comparison. The high concentration initially due to addition of fertilizers, then there is a gradual decreasing of EC and TDS values during the monitoring period. This reduction can be attributed to the plant uptake of various nutrients. For EC results it starts with 2106 µs.cm^{-1} and end the cycle after 10 days with 1003 µs.cm^{-1} in TWW, the removal efficiency was 52%. Whereas in FW, EC results starts with 1257µs.cm^{-1} and end the cycle after 10 days with 640 µs.cm^{-1}, the removal efficiency was 48%. For TDS it starts with 1053 mg.L^{-1} and end with 500 mg.L^{-1} in TWW with removal efficiency about 53%, but for FW it starts with 627 mg.L^{-1} and ends with 320 mg.L^{-1} with removal efficiency about 49%. EC and TDS results shows the same uptake of nutrient which means there is no difference between the uptake in FW and TWW.

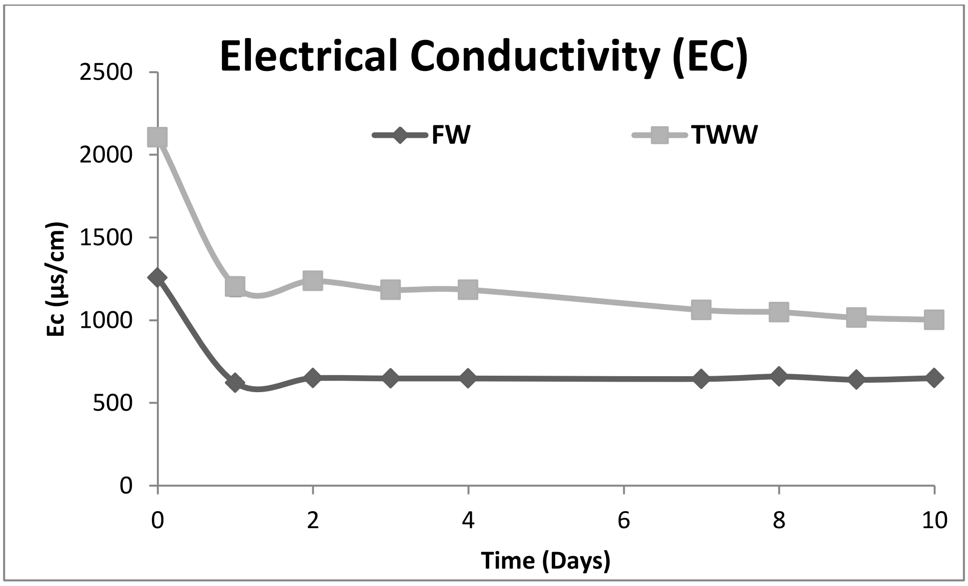


Figure 13: Variation of EC with time (days) using Secondary Treated Wastewater TWW compared to Fresh Water FW as control. Both treatments contained the same quantity of macro and micronutrients.

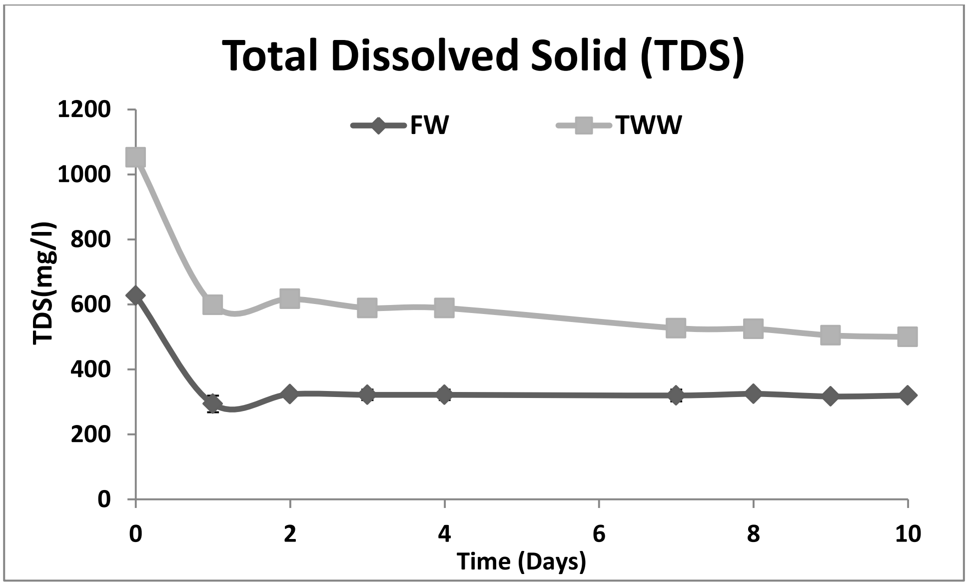


Figure 14: Variation of TDS with time (days) using Secondary Treated Wastewater TWW compared to Fresh Water FW as control. Both treatments contained the same quantity of macro and micronutrients.

One of the cycles from the beginning of the experiment is shown in table 6,Physical and chemical quality analysis of hydroponic recycled water after 10 days of Epuvalisation treatment was applied, for both types of water (FW compared to TWW) during the same period of time. The results shown decreasing in EC, it was 39% and 38%for FW and TWW respectively, which shows no significant difference between the uptake in FW and TWW.

Removal efficiency for TDS was equal between FW and TWW (39%), for COD and BOD the removal percentage 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 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.PO_4^{-3} was 99% in FW and79% in TWW,

TN was 97% and K^+ was 40%.

Table 6: Physical and chemical quality of hydroponic recycled water after 10 days of Epuvalisation treatment, FW compared to TWW during the same period. Mean values ± standard deviations (SD).

	FW		Removal (%)	TWW		Removal (%)
Parameter	**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	0±0	0±0		7±2	0.2±0	97
FC (cuf/ml)	0	0		10500	0	100
TC (cfu/ml)	0	0		13500	0	100

3.1.2.2 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 are summarized in figure 15 whereas the fresh weight and dry weight results summarized in figure 16. The plant height was found to increase normally with time. There was no significant difference between plant height in the case of TWW and FW treatment. No significant change of fresh and dry weight of Geranium plants in both types of water. Figure 17 summarized the number of branch between FW and TWW in the beginning and the end of the cycles. Then the number of flower for each plant as average is summarized in figure 18.

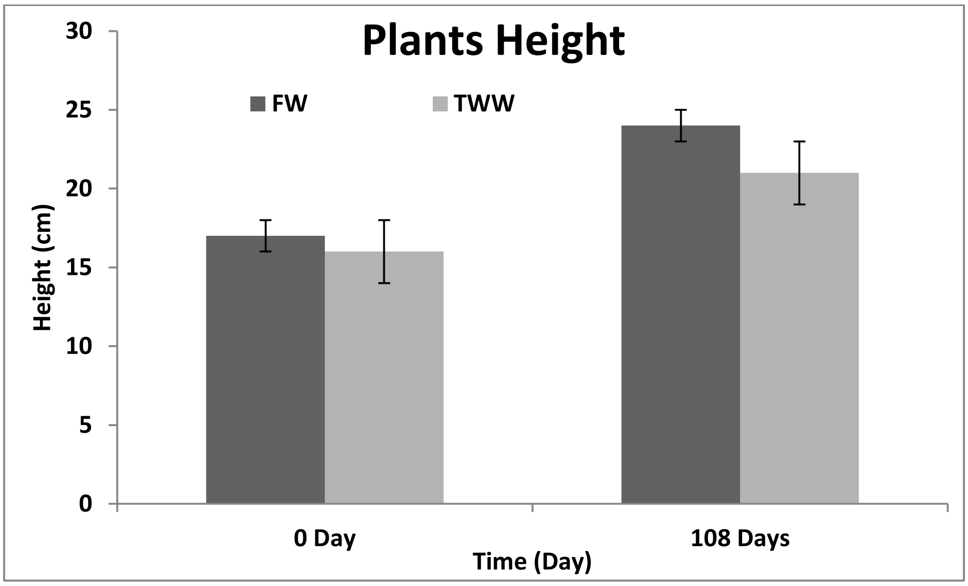


Figure 15: Variation of Geranium height (cm) during season of Epuvalisation experiment which irrigated with both type of water (TWW and FW).

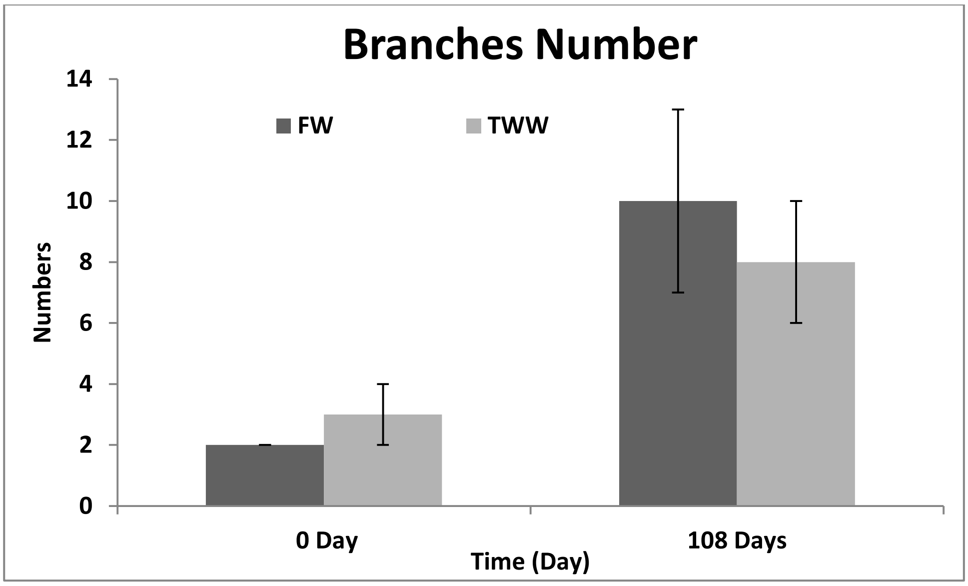


Figure 16: Variation of Geranium branch number during season of Epuvalisation experiment which irrigated with both type of water (TWW and FW).

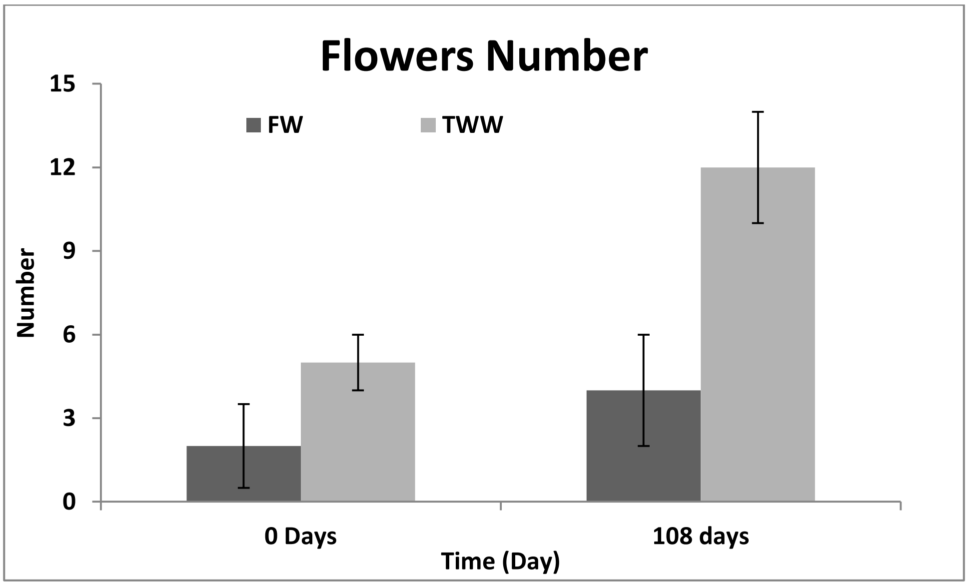


Figure 17: Variation of Geranium flower number during season of Epuvalisation experiment which irrigated with both type of water (TWW and FW).

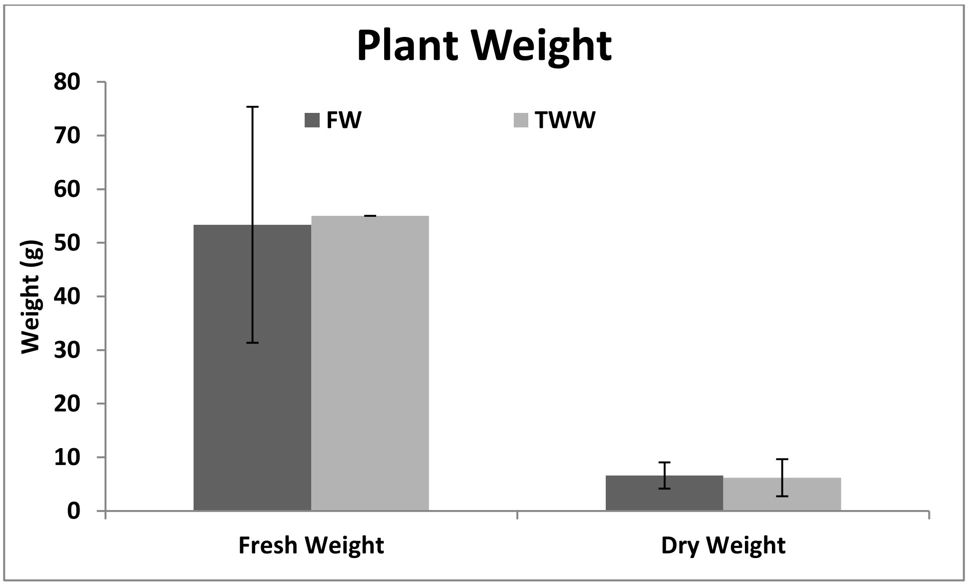


Figure 18: Variation of Geranium plant weight in fresh and dry condition on (g) after the end of irrigation using TWW and FW.

3.1.2.3 Chemical Composition of Plant Tissues

Geranium plants were harvested after the end of irrigation, then dried, and separated into roots, stems, flowers and leaves. Finally digested for chemical analysis of various nutrient content (K^+, Na^+, Cl^-, TP and TN) as shown in figures19, 20, 21 and 22.

Potassium has the highest concentration of all chemical contents in roots, stems, flowers and leaves range between 445 $mg.g^{-1}$ to 1155 $mg.g^{-1}$ in FW plant, and TWW plant has a range between 190 $mg.g^{-1}$ to 885 $mg.g^{-1}$. Total nitrogen has found in low concentration in roots, stems, flowers and leaves, which range between 4 $mg.g^{-1}$ to 5 $mg.g^{-1}$ in FW and TWW plants. Total phosphorous has a concentration ranged between 40 $mg.g^{-1}$ to 115 $mg.g^{-1}$, the lowest concentration found in leaves and the highest concentration found in flowers in FW plants. For TWW plants the lowest concentration was 45 $mg.g^{-1}$ found in leaves and the highest was 113 $mg.g^{-1}$ found in roots. Chloride concentration in FW plants ranged between 120 $mg.g^{-1}$ to 162 $mg.g^{-1}$, the lowest concentration found in roots and the highest found in leaves, the highest concentration of Cl^- in TWW plants found in leaves (151$mg.g^{-1}$) and the lowest concentration found in stems (137 $mg.g^{-1}$). Sodium concentrations ranged between 175 $mg.g^{-1}$found in leaves to 250 $mg.g^{-1}$found in stems.

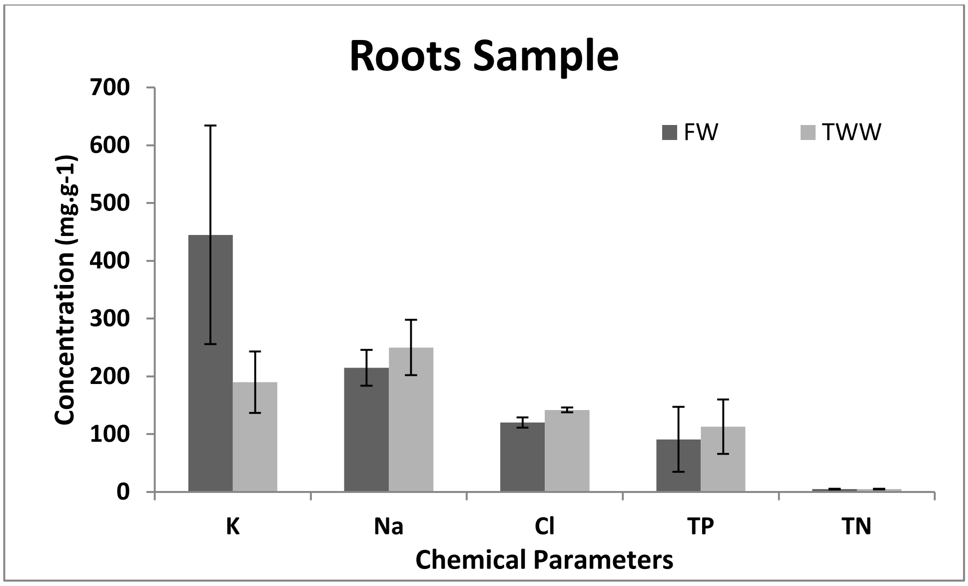


Figure 19: Variation of total nutrients content of Geranium roots after 10 weeks of Epuvalisation experiment compared the treated wastewater with fresh water as control. Mean values ± standard deviations (SD) of three replicates.

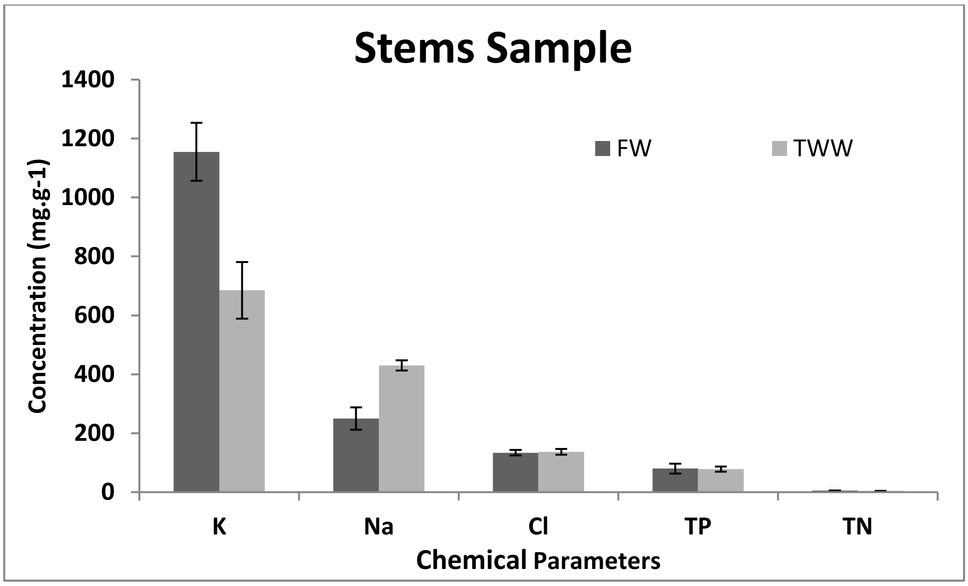


Figure 20: Variation of total nutrients content of Geranium stems after 10 weeks of Epuvalisation experiment compared the treated wastewater with fresh water as control. Mean values ± standard deviations (SD) of three replicates.

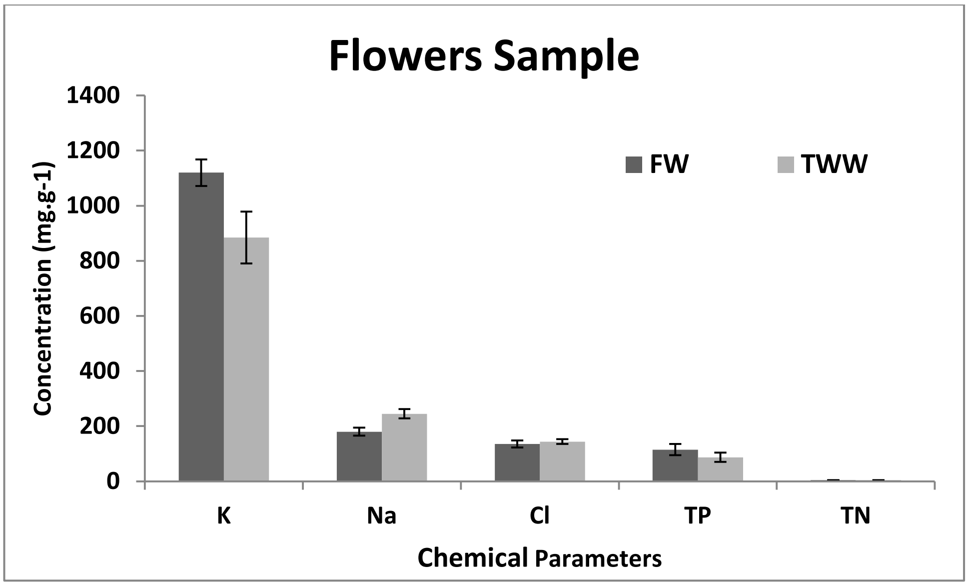


Figure 21: Variation of total nutrients content of Geranium Flowers after 10 weeks of Epuvalisation experiment compared the treated wastewater with fresh water as control. Mean values ± standard deviations (SD) of three replicates.

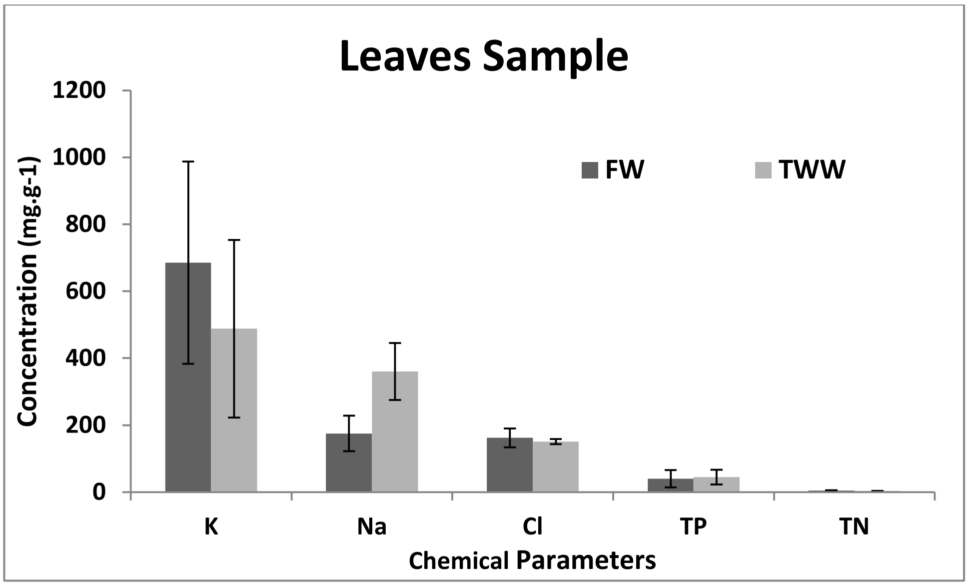


Figure 22: Variation of total nutrients content of Geranium Leaves after 10 weeks of Epuvalisation experiment compared the treated wastewater with fresh water as control. Mean values ± standard deviations (SD) of three replicates.

3.2 MCXC Experiment

Water samples from UF-HF were collected for physical, chemical and biological analysis. The MCX column was installed after the UF-HF unit. The effluent of UF-HF was the influent of MCX column. The influent and effluent of MCXC were collected and analyze after adjusted the flow rate of MCXC effluent and continuous flow as function of time to compare it with UF-HF membrane, to investigate the performance of MCXC in purifying treated wastewater. Water quality was analysis according to physical, chemical and biological parameters. UF-HF effluent was first pumped to UF-SW column then initial and final flow rate were measured in terms of volume and time. The MCXC effluent was pumped to UF-SW and initial and final flow rate were measured. Finally MCXC effluent and UF-SW effluent were analyzed chemically and physically to compared there water quality.

3.2.1Water Quality of UF-HF Effluent

The Hollow fiber ultra-filtration effluent was monitored before starting the experiment to assess the water quality and performance. Table 7 summarized physical, chemical and biological characteristics of UF-HF effluent (permeate). The results show there are temporal variations in water quality in which the COD values ranged between 68 mg/l to 240 mg/l. Similar trend is observed for BOD values. These can be attributed to the activated sludge performance which is highly fluctuated due to the change in the institution wastewater quality received which includes black and grey wastewater.

Table 7: Physical, chemical and biological quality of the UF-HF effluent (permeates).

Sample	pH	EC µS/cm	TDS mg/l	TSS mg/l	Turbidity FAU	COD mg/l	BOD mg/l
Effluent 1	7.2±0	1630±10	810±10	88	44±5	240±30	125±25
Effluent 2	7.4±0	1210±5	600±2	62±1	138±10	188±15	91±15
Effluent 3	7.4±0	1260±4	630±2	20±1	16±1	100±15	56±5
Effluent 4	7.4±0	1100±5	550±3	44±1	67±2	137±5	74±5
Effluent 5	7.5±0	1370±5	690±2	54±1	63±5	147±15	82±15
Effluent 6	6.9±0	1350±5	670±2	86±1	134±5	103±10	62±5
Effluent 7	6.8±0	1420±5	710±2	19±0	30±1	68±5	42±5

Water samples were taken from UF-HF effluent and MCX effluent for biological, chemical and physical analysis. Table 8 summarizes the variation of microbial analysis in (CFU/ml) between UF-HF and MCX between the influent and effluent. The results show variation which could be related to the fluctuation of water flow during summer semester.

According to (Abbadi et al., 2012) results of the microbial indicators screened using the hollow fiber membranes (total plate count TPC, total coliforms TC, faecal coliforms FC, Escherichia coli, Enterococus spp.) demonstrated that these microbes were not completely retained. This means that the only use of this technology is ineffective to eliminate the microbial health hazards and must be coupled with a further treatment process.(Brook et al., 2013) proved that MCX was efficient of removed all pathogenic bacteria found in gray water from showers and sinks included several million of fecal coli per 100 ml, in this experiment MCX removed fecal coliform, total coliform and total plate count. According to these results MCXC is better than UF-HF according to effluent analysis**.**

Table8: Microbiology analysis comparison between UF-HF and MCX effluents.

Sample	Fecal Coliform	Total Coliform	Total Plate Count	Sample	Fecal Coliform	Total Coliform	Total Plate Count
UF-HF Effluent	Null	Null	30	MCX Effluent	Null	Null	0
UF-HF Effluent	Null	Null	50	MCX Effluent	Null	Null	0
UF-HF Effluent	Null	Null	30	MCX Effluent	Null	Null	0
UF-HF Effluent	Null	Null	200	MCX Effluent	Null	Null	0
UF-HF Effluent	Null	Null	20	MCX Effluent	Null	Null	15
UF-HF Effluent	10	Null	100	MCX Effluent	Null	Null	10
UF-HF Effluent	2	5	60	MCX Effluent	Null	Null	300
UF-HF Effluent	27	35	500	MCX Effluent	Null	Null	160

3.2.2 Performance of Micelle-Clay Complex Column (MCXC)

Table 9 summarizes the chemical, biological and physical characteristics of micelle-clay complex effluent samples during column experiment. The column including mixture of micelle-clay complex and sand in ration 1:3 (w/w) and flow rate 200 l/h.

Inspection of Table 9 reveals that there is an efficient removal of COD during the several days of operation. No breakthrough points were observed. The percentage removal of COD ranged from 53 to 95% at the end of filtration. As expected, there is no pH variation during filtration. Turbidity, as expected, reached very low values indication the removal of macromolecules, suspended particles and colloids from water.

The samples in this table were taken in systematic way according to time and flow rate, in which the WWTP was operated and 7 samples were collected and analyzed almost every time. For example the first sample at volume 0 L, COD result was 240 mg/l then after 800 L it reduced into 13 mg/l, EC started with 1630 µS/cm and finished with 1180 µS/cm, BOD started with 125 mg/l and finished with 10 mg/l. The whole table is shown in the appendices.

The column experiment of micelle clay complex shows that the column becomes saturated after 15800 liter due to low variation difference between influent and effluent of COD values The percentage removal was 20%, which could be refer to the high accumulation of organic matter on the MCXC, in other words, fouling could prevent UF-HF effluent to pass through the column and the organic matter will occupy the available surface, in which no more organic matter could be removed from water. At the end of this experiment the UF-HF station was turned off by its own according to high pressure from MCXC due to fouling.

Table 9: The variation of physical, chemical and biological characteristics of some influent and effluent samples of micelle clay complex column.

Volume L	**pH**	**EC µS/cm**	**TDS mg/l**	**TSS mg/l**	**Turbidity FAU**	**COD mg/l**	**BOD mg/l**
0	7.2±0.2	1630±10	810±10	88	44±5	240±30	125±25
20	7.9±0.2	1400±5	700±10	0	0	195±25	92±10
50	7.6±0.2	1300±5	650±10	0	0	173±10	84±10
100	7.5±0.2	1260±5	630±5	0	0	153±10	74±10
200	7.4±0.2	1250±5	620±5	0	0	135±5	62±5
400	7.4±0.2	1200±5	590±5	0	6±0.1	22±5	15±5
800	7.3±0.2	1180±5	590±2	0	3±0.1	13±2	10±2
15800	7.6±0.1	1280±2	640±5	55±0.5	79±0.5	500±5	255±5
15900	7.5±0.1	1220±2	610±5	17±0.5	20±0.5	358±5	189±20
16220	7.0±0.1	1430±2	670±5	62±0.5	91±0.5	450±5	231±15
16700	7.0±0.1	1320±2	670±5	8±0.5	2±0.5	413±5	213±5

3.2.3 Flow Rate of Influent of UF-SW Membrane:

To achieve our goal of adjust the flow rate before entering UF-SW 10500 liter was entered to UF-SW to compare between the flow rate of effluents of MCX Column and UF-HF without using MCX as shown in table 10. Three types of water were used, first UF-HF effluent before using MCX then fresh water was used for flushing and finally MCX effluent was used, initial and final flow rate (l/h) was recorded, then variation of flow rate was calculated, and the operation time was counted.

Table 10: Comparison between flow rate of effluents of MCX Column and UF-HF without using MCX.

Treatment Process	Water Type	Volume	Initial Flow Rate l/h	Final Flow Rate l/h	Variation of Flow Rate	Operation time (min)
UF-HF → UF-SW	UF-HF	4500 L	650	590	60	360
	Fresh	1500 L	750	740	10	120
UF-HF →(MCX) UF-SW	MCX	3000 L	600	590	10	240
UF-HF →(MCX) UF-SW	MCX	1500 L	750	740	10	120

The results indicated that the variation of flow rate between initial and final of UF-SW after360 minutes was 60l/h whereas the flow rate variation using micelle clay complex column was shown approximately 10 l/h. MCXC improved the water quality by adsorption of dissolved organic substances during the operation time.

3.2.4 Water Quality:

Two samples were taken from UF-SW influent and effluent. Table 11 shows the difference between influent and effluents of UF-SW and what is the benefit for using effluent of MCX according to physical and chemical characteristics. According to these results MCX has the same characteristics of UF-SW and the values of MCX were less than UF-SW which means UF-SW could be replaced with MXC column.

Table 11: Water Quality of influent and effluent of UF-SW.

	Average Sample		Average Sample	
Parameter	**Effluent of MCX column**	**Effluent of UF-SW**	**Influent of MCX column**	**Effluent of UF-SW**
pH	7.6 ±0	7.6±0	7.4±0	7.6±0
EC (μS/cm)	1160±6	1160±6	1140±6	1130±6
TDS (ppm)	580±6	580±6	570±6	560±6
Turbidity (FAU)	0±0	3±0	0±0	0±0
COD (ppm)	32±2	53±9	48±7	68±26
SS (ppm)	0±0	0±0	0±0	0±0

MCX proved its efficiency in adsorption of anionic detergents, suspended solid and microorganisms on account of its large surface area, positive charge, and existence of large hydrophobic domains. The results show the effect of filtration on several parameters, which characterize the tertiary treated wastewater after the UF-HF, indicated that the performance of micelle clay complex column was efficient in removing organic compound as UF-SW membrane. This is in agreement with the study of (Khamis et al., 2012) that approved the efficiency of MCX of removal amoxicillin and Cefuroxime axetil from polluted water in high concentrations and (Polubesova et al., 2005) approved that MCX is very efficient for water purification from organic contaminants.(Brook et al., 2013) proved that MCX was efficient for removal of anionic detergents for synthetic water (130 and 30 ppm), and (Karaman et al., 2012) also said that micelle clay filter will remove anionic pollutants very efficiently.

(Polubesova et al., 2005) also studied the removal of anionic pollutants (imazaquin, sulfentrazone, sulfosulfuron) and neutral pollutants (alachlor, acetochlor, chlorotoluron, bromacil) from water by micelles pre adsorbed on montmorillonite. Micelles of octadecyltrimethylammonium and benzyldimethylhexadecylammonium (BDMHDA) were used. The micelle-clay systems (1% w/w) removed 87-99% of the pollutants from their water solutions containing herbicide. The nature of the head group of the organic cation, which forms the micelles, is critical.

Finally we can observe that those results show no difference between influent and effluent of UF-SW. The results suggested that micelle clay complex can decrease the fouling as a results of organic matter removal, so we can use the effluent of MCX directly for RO membrane without passing through UF-SW due to the water quality analysis for both effluents of MCXC effluent and UF-SW effluent which mean we can use MCXC instead of UF-SW.

Chapter Four:

Conclusion and Recommendations:

4.1 Conclusion

The application of Epuvalisation technique is a multi-objective of achieving sustainable environmental, economic and social benefits for many countries including Palestine. This work demonstrates that the Epuvalisation system is simple, flexible, easy to use and managed, low cost, has shown purification efficiency and a good alternative for small communities.

Rosemary and Geranium plants showed a good efficiency in term of purification, their ability in purifying the treated wastewater proved from the results of chemical analysis of treated wastewater during the cycles. Reduction of the organic matter (COD, BOD), suspended matter and decreasing in electrical conductivity which reflect this conclusion.

The results of MCXC have shown efficient removal of COD during the operation time. The removal efficiency of organic matter varied between 53 to 95%. Turbidity results shows efficient removal by micelle-clay complex due to adsorption of colloids, microemulsion, macromolecules and suspended particles by both the complex and sand. The results showed that integrating clay-micelle complex after the UF-HF enhanced the water quality and decreased the fouling rate of the UF-SW membrane in the subsequent ultra-filtration unit. The results support/encourage the insertion of micelle clay complex column as pre-treatment stage before UF-SW and RO Al-Quds University WWTP and UF-SW could be replaced by MCXC.

Improvement of AUWWTP Using Epuvalisation technique and MCXC was useful and helpful, so it can be used in AUWWTP and other wastewater treatment plants.

4.2 Recommendation

- Epuvalisation Experiment showed no negative impact on the operation of the Wastewater Treatment Plant or on the environment, instead it showed improvements on the quality of treated water, it's a good alternative for the small communities in the developing countries, so we recommend to keep going with this installation.
- Micelle clay complex column experiment is the first stage in a comprehensive evaluation of how micelle-clay complexes can be incorporated in a multi-stage procedure of treatment of wastewater from the results that support and encourage insertion of micelle clay complex column as pre-treatment stage before UF-SW and RO Al-Quds University WWTP according to its efficiency in removing organic matter as a result the age of membrane will extend.
- Micelle clay complex column could be efficient if applied on other Waste water Treatment Plant.
- The results suggested inserting micelle clay complex column as pre-treatment stage before advanced membrane technology system in large wastewater treatment plant.
- Further experiments to investigate the regeneration process of micelle clay complex using physical and chemical treatment.

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Appendices:

Variation of physical, chemical and biological characteristics of influent and effluent samples of micelle clay complex column (MCXC).

Volume L	pH	EC μS/cm	TDS mg/l	TSS mg/l	Turbidity FAU	COD mg/l	BOD mg/l
0	7.2±0.2	1630±10	810±10	88	44±5	240±30	125±25
20	7.9±0.2	1400±5	700±10	0	0	195±25	92±10
50	7.6±0.2	1300±5	650±10	0	0	173±10	84±10
100	7.5±0.2	1260±5	630±5	0	0	153±10	74±10
200	7.4±0.2	1250±5	620±5	0	0	135±5	62±5
400	7.4±0.2	1200±5	590±5	0	6±0.1	22±5	15±5
800	7.3±0.2	1180±5	590±2	0	3±0.1	13±2	10±2
820	7.5±0.2	1180±5	590±2	0	5±0.1	47±5	25±5
850	7.4±0.2	1170±2	590±2	0	5±0.2	27±2	18±2
900	7.4±0.2	1170±2	580±2	0	3±0.2	27±2	20±2
1000	7.5±0.2	1170±2	590±2	4±0.2	29±0.5	45±5	26±2
1200	7.4±0.2	1180±2	590±2	8±0.2	17±0.2	30±5	16±1
1400	7.4±0.2	1190±2	590±2	0	28±0.5	37±2	19±1
1420	7.8±0.2	1160±4	580±2	0	0	123±10	66±5
1450	7.7±0.2	1130±3	560±2	0	0	85±5	52±2
1500	7.7±0.2	1140±5	570±4	4±0.1	0	85±5	42±2
1600	7.6±0.2	1130±5	570±5	3±0.2	0	58±2	33±3
1800	7.6±0.2	1120±3	560±3	7±0.2	0	58±7	29±5
2200	7.4±0.2	1130±5	560±5	0	0	43±5	31±3
2220	7.8±0.2	1100±3	550±2	0	0	58±3	38±5
2250	7.6±0.2	1110±5	550±2	0	0	53±4	36±5
2300	7.5±0.2	1090±5	540±5	0	0	60±10	35±2
2400	7.5±0.2	1090±4	540±5	0	6	47±2	28±5
2600	7.4±0.2	1080±5	540±5	0	4	48±2	28±5
3000	7.4±0.2	1120±5	560±5	0	4	87±7	29±5
3020	7.7±0.2	1110±5	550±5	0	0	43±5	22±5
3050	7.6±0.2	1130±5	560±4	0	0	27±5	21±10

3100	7.5±0.2	1110±3	550±1	0	0	42±10	22±5
3200	7.5±0.2	1070±5	530±2	0	0	45±5	23±5
3400	7.6±0.2	1130±5	570±2	0	0	40±5	25±5
3800	7.5±0.2	1140±2	570±2	0	0	38±5	20±5
3820	7.7±0.2	1200±2	600±2	0	4	35±5	23±5
3850	7.6±0.2	1190±5	590±2	0	3	25±5	21±5
3900	7.5±0.2	1190±5	590±2	0	3	25±10	20±5
4000	7.4±0.2	1170±5	580±2	0	3	20±5	15±5
4200	7.6±0.2	1150±5	570±2	0	2	18±2	10±2
4600	7.5±0.2	1170±5	590±2	0	0	20±5	12±5
4605	7.4±0.2	1210±5	600±2	62±0.5	138±10	188±15	91±15
4620	7.6±0.2	1220±5	600±2	0	0	73±10	41±5
4650	7.5±0.2	1220±5	610±2	0	0	65±5	40±5
4700	7.5±0.2	1220±5	610±3	0	0	73±5	38±5
4800	7.5±0.2	1230±3	610±1	0	0	72±5	36±5
5000	7.5±0.2	1250±5	620±2	0	0	53±5	31±5
5400	7.5±0.2	1250±5	630±1	0	0	63±5	32±5
5405	7.4±0.2	1260±4	630±2	20±0.5	16±1	100±15	56±5
5420	7.6±0.2	1280±5	640±2	5±0.1	0	90±15	51±5
5450	7.5±0.2	1280±3	640±1	5±0.2	0	77±5	41±5
5500	7.4±0.2	1280±4	640±2	3±0.1	0	80±5	40±5
5600	7.4±0.2	1280±5	640±2	5±0.1	0	82±5	40±5
5800	7.6±0.2	1260±5	630±2	8±1	0	60±5	32±5
6200	7.5±0.2	1260±5	630±2	11±0.5	0	57±5	25±5
6205	7.4±0.2	1100±5	550±3	44±1	67±2	137±5	74±5
8620	7.6±0.2	1370±5	690±2	0	2	43±5	24±5
8650	7.5±0.2	1370±4	690±1	0	2	33±5	21±5
8700	7.5±0.2	1340±5	670±2	0	4	40±5	18±5
8800	7.5±0.2	1390±5	690±2	0	2	52±5	28±5
9000	7.6±0.2	1390±3	690±2	5±0.5	4	55±5	25±5
9400	7.5±0.2	1400±5	700±2	22±0.5	27±2	88±5	45±5
9405	7.5±0.2	1370±5	690±2	54±0.5	63±5	147±15	82±15

9420	7.6±0.2	1400±5	800±2	5±0.1	0	63±5	35±5
9450	7.5±0.2	1420±5	710±2	4±0.2	0	52±5	26±5
9500	7.4±0.2	1420±5	710±2	4±0.1	0	50±5	32±5
9600	7.4±0.2	1400±5	700±2	4±0.1	0	58±5	31±5
9800	7.4±0.2	1390±5	690±2	7±0.5	0	70±5	35±5
10200	7.5±0.2	1400±5	700±2	11±0.1	0	78±5	36±5
10205	6.9±0.2	1350±5	670±2	86±0.5	134±5	103±10	62±5
10220	7±0.2	1530±5	760±2	2±0.1	9±2	28±5	21±5
10250	7.1±0.2	1450±5	720±2	3±0.1	6±0.5	20±5	15±5
10300	7.6±0.2	1420±5	710±2	2±0.1	6±0.5	12±3	10±5
10400	7.1±0.2	1460±5	730±2	3±0.1	9±0.5	15±5	15±5
10600	7.1±0.2	1450±5	730±2	3±0.1	10±0.5	12±5	15±5
11000	6.9±0.2	1460±5	730±2	6±0.1	0	12±5	15±5
11005	6.8±0.2	1420±5	710±2	19±0.1	30±0.5	68±5	42±5
11020	6.9±0.2	1560±5	780±2	5±0.1	5±0.5	18±5	15±5
11050	6.9±0.2	1480±5	740±2	2±0.1	1±0.1	15±5	12±5
11100	6.9±0.2	1450±5	730±2	3±0.1	1±0.1	18±5	15±5
11200	6.8±0.2	1450±5	720±2	4±0.5	4±0.1	25±5	15±5
11400	7.2±0.2	1420±5	710±2	8±0.5	14±0.5	32±5	20±5
11800	7.1±0.2	1400±5	700±2	7±0.5	14±0.5	38±5	25±5
12805	7.2±0.2	1260±5	630±2	9±0.5	15±0.5	72±5	36±5
12820	7.3±0.2	1240±5	620±3	2±0.5	4±0.5	25±5	15±5
12850	7.3±0.1	1280±2	640±5	3±0.5	6±0.5	22±5	17±5
12900	7.3±0.1	1280±2	640±5	3±0.5	7±0.5	23±5	16±5
13000	7.0±0.1	1240±2	620±5	3±0.5	8±0.5	32±5	22±5
13200	7.3±0.1	1220±2	610±5	5±0.5	8±0.5	22±5	19±5
15800	7.6±0.1	1280±2	640±5	55±0.5	79±0.5	500±5	255±5
15900	7.5±0.1	1220±2	610±5	17±0.5	20±0.5	358±5	189±20
16220	7.0±0.1	1430±2	670±5	62±0.5	91±0.5	450±5	231±15
16700	7.0±0.1	1320±2	670±5	8±0.5	2±0.5	413±5	213±5

تحسين محطة معالجة مياه الصرف الصحي على نطاق واسع باستخدام تقنية إبوفاليزاشيون وفلتر الطين والميسيل

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المشرف: د. مهند قريع

الملخص

العديد من الدول تتجه نحو بناء فلاتر على مستوى موسع بالاعتماد على محطات معالجة المياه العادمة لاستخدامها لاغراض الري الغير مقيدة. الخارج من عملية المعالجة الثانوية في محطة جامعة القدس لمعالجة المياه العادمة تم معالجته باستخدام عملية الابفاليزاشون. تقنية الابفاليزاشون، هي تقنية الزراعة المائية، تستخدم لمعالجة المياه العادمة الثانوية وتنقيتها. نبات اكليل الجبل، الحصلبان, ونبات الخبيزة تم اختيارهن لنظام الابفاليزاشون, المياه العذبة والمياه العادمة المعالجة ثانويا تم تطبيقها على النظام في بيت بلاستيكي بحلقة مغلقة لأيام عديدة.

نتائج تحليل جودة المياه للمياه العادمة المعالجة والمياه العذبة باستخدام نبات اكليل الجبل عرضت انخفاض في الطلب على الاكسجين البيولوجي بنسبة مئوية 29% للمياه العذبة و24% للمياه العادمة المعالجة ثانويا, بينما الطلب على الاكسجين الكيميائي كان 16% للمياه العذبة و13%. في حين ان النسبة المئوية للازالة في نبات الخبيزة لنفس المتغيرات على التوالي كانت 23%,و23%و 67% و41%. كانت نتائج نسبة الزالة التوصيل الكهربائي في نبات الخبيزة 48% للمياه العذبة و52% للمياه العادمة المعالجة, ونسبة الازالة للمواد الذائبة الكلية كانت 49% و53% على التوالي. بينما للمواد الصلبة العالقة كانت 95% للمياه العادمة المعالجة ثانويا وللفوسفور 89% وللكلور 60% والنيتروجين الكلي 98% والبوتاسيوم 59%.

متغيرات نمو (طول النبتة، وزنها الرطب والجاف وعدد الأغصان والأزهار) نبات اكليل الجبل والخبيزة اظهر عدم وجود اختلاف بين الري بنوعي المياه سواء عذبة او معالجة فكلاهما نمى بشكل ملحوظ. نتائج تحليل النبات من جذور، اوراق، سيقان وازهار اظهرت عدم تأثر النبات بنوعية المياه المستخدمة في الزراعة.

النتائج تقترح أن نظام الابفاليزاشن هو تقنية واعدة لتنقية المياه العادمة المعالجة باستخدام نبات اكليل الجبل والخبيزة.

المياه العادمة المعالجة معالجة متقدمة باستخدام تكنولوجيا الفلاتر تنتج مياه عادمة معالجة لاستخدامات الزراعة غير المقيدة. بالرغم من أن تكنولوجيا الفلتر تطور تصنيعها بشكل كبير في السنوات الاخيرة، الا انه، ما زال التراكم حول الفلتر من مساوئ هذه التكنولوجيا.

الهدف من هذا العمل لبحث كفاءة فلتر الميسيل الطيني المعقد لمعالجة المياه العادمة المعالجة ثانويا المستخدمة في محطة معالجة المياه العادمة. الفلتر ملئ بخليط من الميسيل الطيني المعقد والرمل وتم اضافته لمحطة معالجة المياه العادمة في جامعة القدس, والي بين ان جودة المياه من الفلتر مشابهة لجودة المياه الناتجة من فلتر اللولبي بتكلفة أقل.

فلتر الميسيل الطيني المعقد مكون من اوكتاديسيل تراي ميثيل امونيوم بروميد ومونتموريلونيت الطيني. الرمل تم غسله بمياه عذبة وتجفيفه. تم تحضير الخليط من الرمل والميسيل الطيني المعقد بنسبة 3:1 (وزن/وزن). معدل التدفق ووقت التشغيل كان مضبوط على 200 لتر لكل ساعة لمدة 4 ساعات في اليوم.

العينات الداخلة والناتجة أخذت بشكل مستمر بوحدة الحجم 20 , 50, 100, 200, 400 و 800 لتر. هذه الدورات تم اعادتها لعدة أيام. العينات تم تحليل جودتها الكيميائية والفيزيائية والحيوية باستخدام الطرق المستخدمة لمعايير فحص المياه والمياه العادمة.

النتائج اظهرت كفاءة بالازالة لاعتماد الاكسجين الكيميائي خلال فترة أيام التشغيل. كفاءة الازالة تراوحت بين 53 الى95%. نتائج العكورة تعرض كفاءة الازالة للميسيل الطيني المعقد بناءا على امتزاز الغرويات، والمستحلب الجزئي، والجزيئات الكبيرة والجسيمات المعلقة في الميسيل الطيني المعقد والرمل. خصائص الترشيح الالترا اللولبي والميسيل الطيني المعقد كان متشابه مما يعني أن ترشيح الالترا اللولبي يمكن استبداله باستخدام فلتر الميسيل الطيني المعقد.

النتائج تقترح ادخال فلتر الميسيل الطيني المعقد كمرحلة معالجة مسبقة قبل نظام تكنولوجيا الفلاتر المطور في محطات معالجة المياه العادمة الكبيرة.