The Effect of Using Processed Wastewater on the Content of Soil and Aubergine of Toxic Micro and Macro Nutrients

HALA ARSHAD ALI[1*], FARHAN MOHAMMAD JASIM[2], MOHAMMED F. ABOOD[3]

[1]University of Anbar, Upper Euphrates Basin Developing Centre, Iraq.
Email: halah.ali267@uoanbar.edu.iq
[2]University of Anbar, College of Agriculture, Iraq.
Email: ag.farhan.mohammad@uoanbar.edu.iq
[3]University Anbar, College of Education for Pure Sciences, Iraq.
Email: eps.mohammed.fadhel@uoanbar.edu.iq

*Correspondence: halah.ali267@uoanbar.edu.iq

Data of the Article

First Received: 20 April 2024 | Last Revision Received: 02 June 2024
Accepted: 04 June 2024 | Published Online: 02 August 2024
DOI: 10.17170/kobra-202412201

Keywords

Heavy Elements
Processed Wastewater
Aubergine Plant
Macro Nutrients
Wastewater Use In Agriculture
Sustainable Agriculture

Agriculture often faces the challenge of water scarcity, which pushes to the use of alternative water such as processed wastewater, and this practice gains attention for its potential to reduce water shortages while maintaining agricultural productivity, however, the use of processed wastewater has effects on soil properties and its content of macronutrients and crop health, so our study revealed the effect of processed wastewater on the soil content of micro and macro nutrients and their subsequent effects on the aubergine plant and its growth, as the study was designed according to completely randomized blocks. Considering the treated wastewater used in the irrigation of four treatments (0, 30%, 60%, 90%) and three replications and two stages in the presence of sterile organic fertilizer (animal waste) for the soil by 333 g / kg and the second (0) and the absence of organic matter (control treatment). The results of the study showed a significant increase in the elements of the soil extract and for all treatments compared to the control treatment and the level of addition was 30% significant effect in the concentration of nitrates as it reached 13.7 mg./kg , but the irrigation levels didn't influence calcium and phosphorus levels, while the level of 90% with organic material showed a significant increase in manganese, magnesium, ferric and zinc and in brome, nickel and copper without adding the organic substance. In addition, the irrigation level has affected eggplant leaves and roots; so, The effect of the level of 60% of processed water with organic matter in a significant increase of phosphorus, nitrate and magnesium concentrations in the roots of the plant as it reached 1.600, 2.937, 0.3370 mg / kg respectively and increased nitrates and calcium in the leaves compared to the control treatment. Level 90% irrigation has contributed to the significant increase of brome, zinc, copper, ferric and nickel in plant roots and stems. This increase, either in soil extract or plant parts, was within the authorized normal limits and didn't reach the critical or toxic limits that caused plant and soil contamination with these elements that would, in turn, affect humans and animals.

1. Introduction

Agriculture in arid and semi-arid areas, including Iraq, depends mainly on the use of running or groundwater to irrigate crops for food production, but Iraqi agriculture is facing a major challenge in the face of the shortage of water resources with the impact of Turkish projects established and the deterioration in water quality and reducing the water share allocated to agricultural land, which affects the development of agriculture and thus affects the future of national food security (Al-Raw, 2000).

The development witnessed by most countries of the world and the increase in population and the high standard of living led together to a significant rise in the demand for water and created an imbalance between the available quantities of water and the actual demand for it, which led to the trend towards the search for non-conventional resources to cover the growing needs and exploit the largest possible amount of them in various ways (Ben Mahmoud, 2009).

Therefore, efforts have focused on finding alternative water resources like wastewater and reusing it for irrigation because when it's used without processing, it results in the deterioration of irrigation water quality and soil contamination, which may cause damage to human and animal health (FAO, 1992).

The treated draining waters are considered a permanent source of irrigation water for agricultural purposes; so, it could be used to solve the problem of the required and available water with other benefits, not only to meet the crop's water requirements but to support the soil microorganisms for the organic substances it carries (Becerra-Castro et al., 2015; García-Orenes et al., 2015), especially the plant nutrients like phosphorus that support crop productivity and other features (Abdoulkader et al., 2015), and it is also considered a good source of organic substances that enhance the soil's physical and chemical characteristics. It also increases water fertility and plant productivity (Caravaca et al., 2002). Heavy elements that are within the contents of wastewater are a source of concern due to their impact on the properties of soil, plants, groundwater and the environment in general, especially when mixed with industrial wastewater, it is necessary to estimate the concentrations of micronutrients in wastewater and rely on this mainly in determining the suitability of their use for agricultural purposes as they gather near the rhizosphere of crops with the possibility of contamination of parts of edible crops (Al-Hadithy et al., 2011).

But despite these benefits, their use in agriculture involves many risks to human, animal and plant health by containing many toxic heavy elements, some of which are in large concentration and sufficient to affect human health (Wu et al., 2007). Hence, this water cannot be used directly in irrigating the farthest crops by making some of the necessary processing and adjustments to mitigate its effects, which are based on documented and confirmed scientific and research foundations and results to ensure the protection of the environment and public health. Accordingly, the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), as well as local organizations from different countries, have issued standards and controls for the use of this water in agriculture (FAO, 1989), turning it into a safer and less polluting economic resource.

2. Objectives and Importance of Research

The importance of research lies in the use of wastewater as an alternative to traditional irrigation water in irrigating crops and has a positive impact on the economic resources of farmers because this water contains important mineral elements for plants, which leads to reducing the use of chemical fertilizers in addition to that it is considered a safe way to discharge it, which limits its negative effects on the environment and on this basis our study aimed at the possibility of using processed wastewater as an alternative to traditional irrigation water in Iraq and by determining the level of diluted processed water negatively or positively affecting the soil content of micro and macro nutrients toxic to the plant in the presence or absence of organic matter and the accumulation of those nutrients in the parts of the aubergine plant

3. Materials and Procedures

3.1 Samples Collect Locations

This research was carried out in the greenhouse located in the Upper Euphrates Basin Developing Centre research station / University of Anbar during the period from 15/2 to 30/4, 2023, which is 20 minutes away from the sewage processing plant of Ramadi Teaching Hospital for Women and Children, which is within the hospital site. located in the south-west side of Ramadi City, which functions in drainage capacity 350m3/hour/day. The process operation includes ventilation, physical processing with filters and then exposure to ultraviolet beams and after that, these waters are thrown directly into the river.

Processed wastewater samples were taken from the processing plant by 30 litres every 10 days, as the samples were collected in 10-liter plastic containers washed and sterilized, and the samples were collected after washing them with sample water 3 times and transferred to the laboratory and kept at a temperature of 4 ° C, To perform physical, chemical and biological analyses of water, according to the methods mentioned in APHA (2003), Bartram & Ballance (1996), APHA (1985), APHA (1998) and Gopal (2007).

Table 1: Features of Treated Waters in the Processing

Station of Ramadi Hospital for Maternity and Paediatrics.

E.C ms/cm	T.D.S mg/l	BOD5 mg/l	COD mg/l	SO4 mg/l	Ni Mg/l	K mg/l	Zn mg/l	T.B.C Cfu/ml
303	1.58	350	251	500	0.340	2000	1.30	6.0×10^{-6}
NO_2 mg/l	$NO_{3\,mg/l}$	$CaCo_{3\,mg/l}$	Chloride mg/l	$PO_{4\,mg/l}$	Cu mg/l	Br mg/l	Fe mg/l	Mn mg/l
21	11.3	45.5	2.91	22.4	1.95	2.05	1.40	0.8
Mg mg/l	Ca mg/l							
0.6	10.5							

Illustrates some of the physical, chemical and biological properties of the treated water used in the study.

To study the effect of using processed wastewater resulting from the processing plant and diluted with neutral irrigation water on the aubergine plant and its content of nutrients during the spring period, four irrigation treatments were used as mixtures with wastewater and the treatments were as follows:

0% processed wastewater (tap) i.e. 100% ordinary irrigation water control treatment.
30% processed wastewater (30% processed wastewater mixed with 70% tap water).
60% processed wastewater (60% processed wastewater mixed with 40% tap water).
90% processed wastewater (90% processed wastewater mixed with 10% tap water).

3.2 Soil Preparation

The soil used in the experiment was brought from agricultural land in the city of Ramadi from the surface layer (0-30) cm, air dried and passed through a 2 mm diameter sieve and analysed to know its physical and chemical properties before planting (Black et al., 1965; Lindsay & Norvell, 1978), and Table 2 shows the used soil traits.

Table 2: Traits of Soil Used in the Experiment.

Sand	50.80%	Available Nitrogen	1.06%
silt	44.00%	Available potassium	200 ppm
clay	5.20%	Available phosphorus	0.033 ppm
Texture	Loamy sand	Sulfate	456 ppm
pH	7.8		
E.C ds m^{-1}	1.3		

The soil was packed in plastic pots with a diameter of 30 cm and a height of 30 cm with a capacity of 10 kg, an experiment was carried out using the design of completely randomized blocks design RCBD and three replications, and four levels of processed wastewater: 0, 30%, 60%, and 90%. In two stages, the three levels of processed wastewater were added alone without fertilization, and the second level was added to it one level of fertilization (organic-sterile animal waste) by 333 g / 10 kg of soil, thus the total treatment became eight treatments and in the following order:

0% Wastewater Treatment, (Control Treatment).
30% Processed Wastewater.
60% Processed Wastewater.
90% Processed Wastewater.
0% Wastewater Treatment, (Control Treatment).
30% processed wastewater + F (organic matter).
60% processed wastewater + F (organic matter).
90% processed wastewater + F (organic matter).

3.3 Effect of Treated Water on Soil and Plant Properties

Pots were filled with 10 kg of soil after mixing some of them according to the plan with manure by 333 g / 10 kg soil according to the treatments. Five seeds of the aubergine plant planted and then reduced after ten days. The process of irrigation began with diluted processed water while maintaining soil moisture 70-80% of the field capacity and after 60 days the plants were carefully displaced to maintain the root system and the vegetative total was separated from the root system and then dried at a temperature of 60° centigrade for 48 hours. Soil samples were taken for all treatments after air drying and the necessary chemical analyses were carried out for the soil and plant:

1- NO_3 and Heavy elements (Ni ، Cu ، Fe، Br ، Zn): estimated according to method (Jackson, 1958) and measured in mg/g soil; and heavy elements were determined in leaves and roots according with methods (APHA, 1975) and the result was expressed as mg/kg dry weight.
2- Soil total phosphorus was determined according to Olsen & Sommers (1982) and results were estimated in ppm, while the plant phosphorus PO_4 was measured according to Page, Miller, & Keeney (1982).
3- Each Mg and Ca and $CaCO_3$ were determined according to Richard (1954) and results were written in mg.
4- plant NO_3 was measured using Multi parameter Photometer Hi83200 machine after the sample was taken according to instructions used to measure.

3.4 Statistical Analysis

The results were analysed statistically according to the applied design and the averages of the treatments and their interactions were compared using the Duncan multi-range test with a probability level of 0.05, and according to this test, the averages followed by similar alphabetical letters do not differ from each other significantly and followed by different letters, they differ from each other significantly using the Statistical Analysis System (SAS) 2001 program.

4. Results and Discussion

4.1 The Effect of Treated Water on the Soil Content of Elements

Table 3 refers to some minimum mean values of some micro and toxic elements in soil extract in different irrigation treatments of tertiary treated waters and the level of organic matter addition (cow wastes).

It is clear that significant differences have happened at 0.05% significant difference compared with control treatment irrigated with normal water (faucet water). So, there was a gradual significant increase in the mean values of NO_3 at 30% to reach 13.7 mg/kg in comparison to other treatments and control unit, whereas in the mean values of phosphorus and calcium, there's no significant differences among the treatments in the presence or absence of organic substance irrigated in different irrigation treatments; so. Calcium concentrations were higher than magnesium and manganese in the irrigated soil extract with different levels of dilution for treated water, while there were significant differences in Mn element; so, the highest mean value has reached 0.367 mg/kg at 90% dilution with the presence of organic matter. While or magnesium Mg element, significant differences have been noticed among treatments; so, the treatment 90% had the highest mean value,, either with or without organic matter addition to reach 0.2767mg/kg, followed by level 90% with mean value 0.2567 mg/kg, while for calcium carbonate, $CaCO_3$, treatments has affected its mean values to lower its value to reach 20.50 – 4.67 mg.kg, compared with the control unit (control treatment) which was 58.5 mg/kg. the treated waters have effected in lowering soil calcium carbonate with the increased level of treated waters the more the treated waters concentration was, with the presence of organic matter, compared to control unit. The Gadhia et al. (2014) has suggested that the treated drainage water is more suitable for plant growth and important to preserve water resources as it contains more nutrients than faucet. So, the wastewater effect the concentrations of macronutrients like N, P and K and micronutrients like Mn,Fe,Zn and Cu extracted from soil, so, adding 100% and 50% of phosphate factory wastewater has given high significant increase in the concentrations of soil extracted elements (Al-Hadithi, Al-Rubaie, & Hassoun, 2012). The effects of drainage water the contain different contents according to sources; house, factory, trade or agriculture depending on treatment level: primary, secondary or tertiary in soil features or its content of elements. So, using drainage water of food industries has led to decrease the dissolved calcium concentration, increasing magnesium concentration and also the mean concentration value of sodium and manganese with high level in soil irrigated with these waters; there was, also, a little increase in the concentrations of nitrogen and phosphorus (Al-Mansouri, Al-Wadaei, & Othman, 2016); but Harmoush (2013) has suggested that drainage water would add elements to soil that precipitate by time, including calcium and magnesium elements.

Table 3: States the Element Distribution Ratio (mg/kg) in Soil Cultured with Eggplants After Irrigation with House Wastewater.

Elements Treatments	NO_3	T.P.	Mn	Mg	Ca	$CaCO_3$
30%	13.17 a	0.633 a	0.300 a	0.0867 d	2.83 a	9.82 cd
60%	1.70 bc	0.633 a	0.167 a	0.1633 c	4.88 a	20.50 b
90%	3.40 b	0.867 a	0.133 b	0.2567 a	3.00 a	11.00 c
F+30	3.30 b	0.700 a	0.133 b	0.2267 ab	1.83 a	9.17 cd
F+60	3.30 b	0.733 a	0.200 a	0.1967 bc	1.17 a	4.67 d
F+90	5.97 b	0.700 a	0.367 a	0.2767 a	3.33 a	4.83 d
Control	0.37 c	0.500 a	0.133 b	0.1467 c	2.83 a	58.5 a

4.2 Mean Values Followed with the Same Letter in Columns Have no Significant Difference at 0.05 Significant Level

Drainage water has a number of elements and minerals which some could be useful for plant to cause increasing its productivity and some could be harmful to plant and soil beside animal and human depending on water type, soil characteristics, climate circumstances and followed agriculture operations (Elamin & Saeed, 2019). The research results in Table 4 referred to irrigation treatment effects with diluted drainage water on soil extract content of plant toxic elements after 60 days and treatments had effects via significant increase in average values, compared with the control unit, irrigated with faucet water. So, the 90% irrigation treatment with or without organic matter addition has recorded increase in average concentrations of Br,Ni,Cu,Zn ,Fe compared with the control unit; so, differences for nickel Ni, brome Br and copper Cu have reached 0.0900 mg/kg, followed by 90% irrigation treatment f+60% which was 0.0467 mg/kg compared with soil irrigated in faucet water that reached 0.0006 also ferric Fe which quantity has recorded in soil treated 90% with organic water 4.037 mg/kg, followed by level 90% of treated water which element quantity in soil has reached 2.497 mg/kg compared with soil irrigated with faucet water. Regarding zinc, quantity has reached 0.2670 mg/kg when irrigating soil with treated water, diluted 90% with organic substance added to soil, while the diluted level 90% of treated drainage water has recorded quantity 0.1300 mg/kg compared to control unit soil. The quantity of zinc has reached 0.0377 mg/kg and these elements concentrations in soil irrigated with tertiary treatment water and diluted below the borders of toxicity in agricultural soils; so, Badda et al. (2022) suggested to insignificant increase in boron quantities in soils irrigated with treated grey water to reach 0.34 mg/kg that is below the limit of toxicity, studied in agricultural soils as the authorized limits (3-5) mg/kg as Adriano (1986) suggested and Ahmed & El-Hedek (2017) also showed in their study to increase in zinc, ferric, copper and manganese availability in high percentages in soil superficial layer, irrigated with drainage water for 50 years because ferric doesn't cause high toxicity in neutral soils; so, it made 105% increase in soils irrigated with wastewater for (50) years and the addition of untreated wastewater has led to high significant increase in concentrations of elements (Fe,Mn,Zn,Cu,Cd,Pb) in soil extract (Al-Abadi, 2018) and the critical or toxic limits of each element copper, zinc and nickel in soil were (5, 30, 100) mg/kg, successively (Al-Hadithi, 1987).

Table 4: Shows the Average Rate of Toxic Elements (mg/kg) in Soil Cultured with Eggplants After Irrigation with the Treated Wastewater.

Elements Treatments	Br	Ni	Fe	Cu	Zn
30%	0.0433 b	0.0433 b	1.970 bc	0.0433 b	0.0400 c
60%	0.0367 b	0.0367 b	1.197 d	0.0367 b	0.0533 c
90%	0.0900 a	0.0900 a	2.497 b	0.0900 a	0.1300 b
F+30	0.0400 b	0.0400 b	1.097 d	0.0400 b	0.0367 c
F+60	0.0467 b	0.0467 b	1.873 c	0.0467 b	0.0533 c
F+90	0.0433 b	0.0433 b	4.037a	0.0433 b	0.2670 a
Control	0.0006 c	0.0006 c	1.200 d	0.0006 c	0.0337 c

Mean values followed with the same letter in columns have no significant difference at 0.05 significant level

4.3 The Effect of Treated Water on the Element Content of Eggplant Plants

Also, Table 5, and Table 6 refer to the average eggplant content of micro and toxic elements and analytical overall variation ANOVA at significance level 0.05%.

The average values shown in Table 5 refer to irrigation treatments results effect on some microelements concentration on eggplant roots and leaves in 60 days, where there's gradual significant increase in the treated drainage water concentration in the irrigation water from the treatment (30%) to the sixth treatment (90% with organic matter), compared to control treatment irrigated with faucet water. It could be attributed to the increased elements in drainage water treated and used in irrigation as shown in Table 1 where the phosphorus concentrations have significantly increased in roots and plant leaves at 60% dilution of wastewater in the presence of organic matter to reach 1.600 mg/kg. Its concentration was, significantly, the highest in eggplants roots and leaves when irrigated with NO_3 treated water at 60% with organic matter to reach 2.937 in roots and 0.3000 mg/kg in leaves. The table results refer that manganese, magnesium and calcium had average concentrations in roots and leaves of plants irrigated with different levels of drainage water were the highest if compared with control unit, irrigated with faucet water. Calcium has recorded 2.420 mg/kg in leaves and 1.7833 in roots when 90% water diluted. Thus, the plant microelements content didn't reach the level of toxicity for plants during the growth period in all the irrigation treatments, to confirm that plants have a limited and particular mechanism to translocate and store the micronutrients, and these mechanisms themselves cooperate in absorption, translocation and storing the toxic elements (Egiarte et al., 2005).

It is similar to what scholar (Alderfasi, 2009) obtained that the treated drainage water has enhance wheat crop quality as a protein and nutrients content, and the heavy minerals were within the range and weren't harmful to plant and also animal and human.

ISSN-Internet 2197-411x OLCL 862804632

Table 5: Shows the Average Value of Elements Concentrations (mg/kg) in Eggplant Roots and Leaves After Irrigation With Treated Wastewater.

Elements	P		NO3		Mn		Mg		Ca	
Treatments	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves
30%	1.133 cd	0.7800 c	0.1333 c	0.0100 c	0.1000 e	0.0233 d	0.0200 b	0.0367 e	1.4570 b	0.293 b
60%	1.067 de	1.3667 a	1.1000 c	0.0100 c	0.2333 c	0.1667 c	0.2100 a	0.0133 e	1.3167 b	1.500 a
90%	0.900 e	1.3330 ab	0.9567 b	0.0133 c	0.3667 a	0.2667 ab	0.1200 a	0.1733 c	1.7833 a	2.420 a
F+30	1.300 b	1.2067 b	0.9333 b	0.0100 c	0.1667 d	0.3000 a	0.2030 a	0.5770 a	1.1433 c	1.130 a
F+60	1.600 a	0.8733 c	2.9370 a	0.3000 a	0.1667 d	0.0233 d	0.3370 a	0.2767 b	1.3467 b	1.527 a
F+90	1.233 bc	1.3330 b	2.7770 b	0.2667 b	0.2667 b	0.0200 d	0.2933 a	0.2367 b	1.4633 b	2.203 a
Control	0.033 f	0.3000 d	0.0133 d	0.0066 d	0.0100 e	0.2000bc	0.0133 b	0.1100 d	0.8670 d	0.353 b

Mean values followed with the same letter in columns have no significant difference at 0.05 significant level

While Table 6 has referred to significant differences in statistical analysis results for average eggplant root and leave content of toxic elements and the gradual increase by increasing the drainage water used in irrigation, either with or without the organic matter; so, the 90% irrigation treatment was the most effective in increasing the toxic element concentration in roots and leaves.

So, the ferric and nickel values were successively 2.5700 and 2.2270 mg/kg in eggplant leaves, compared with the control treatment irrigated with pure water to vary between 0.0000 and 0.9030 mg/kg per leaf, while for zinc, its average concentration in root was higher than in leaf to reach 0.0800 in comparison with control treatment that reached 0.0005 mg/kg; while for brome, element concentration was 0 in control treatment and in eggplant root in irrigation treatment 90% was higher than in leaf to reach 0.233 mg/kg compared to leaf that reached 0.0800 mg/kg. the heavy element is a concerning issue in fact that must be observed to block more risks on environment and health as the accumulation of heavy elements and micronutrients might be caused directly by the treated drainage water or indirectly by resolving the soil insoluble heavy minerals as a result of removing a heavy mineral or acidizing to drainage water applied by Mohammad Rusan, Hinnawi, & Rousan (2007), so, Ahmed (2012) noticed the increased content of copper and copper supported by corn plant and soil to reach (0.0399 and 0.2330) mg/g plant and mg/kg soil, successively for being irrigated with diluted industrial wastewater 1:1 and 1:3 whereas irrigation with treated and untreated wastewater has led to increase nickel values (0.594 – 0.191) mg/kg soil dry weight and zinc to 4.58 mg/kg soil dry weight for Purslane plant (Saleh, 2012). It is suggested that the toxic limits for each zinc, copper and nickel in crops was (15, 19 and 200) mg/kg successively (FAO, 1992) and this is what Gadhia et al. (2014) confirmed that the treated wastewater hasn't shown negative effect in the chemical structure of vegetables but it made improvement in xylem, phloem tissues and cellular material production at irrigation with drainage water and higher precipitation of cellulose and pectin in the planted supporting branch. When we compared the mean values of root and leaf content for minor elements shown in Table 5 and the toxic element shown in Table 6 with elements concentration that leads to plant toxicity as Adriano (1986) mentioned, it is realized that the plant content of these element hasn't reached the level that makes it toxic for all the irrigation treatments. Thus, we can say that eggplant irrigated with treated drainage water is safe in the side of harmful heavy elements concentration for human and animals to meet the terms of Environment Protection Agency.

Table 6: States the Average Element Concentrations (mg/kg) in Eggplant Roots and Leaves After Irrigation with the Treated Wastewater.

Element	Br		Zn		Cu		Fe		Ni	
Treatment	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves
30%	0.0267 b	0.03333 b	0.0320 c	0.0300 c	0.0333 b	0.0233 b	1.460 bc	0.2833 c	0.2953 c	0.4310 d
60%	0.0200 b	0.02333 c	0.0433 c	0.0400 c	0.0367 b	0.0265 b	1.317 c	0.1733 c	0.7000 b	0.4377 d
90%	0.2333 a	0.08000 a	0.1200 b	0.1000 b	0.0800 a	0.0700 a	1.807 a	2.5700 a	1.2330 a	2.2270 a
F+30	0.0300 b	0.01333 d	0.0323 c	0.0327 c	0.0300 b	0.0220 b	1.107 d	0.1400 d	0.9130 b	0.7187 c
F+60	0.0233 b	0.01333 d	0.0423 c	0.0433 c	0.0367 b	0.0327 b	1.367 c	0.0567 cd	1.2670 a	1.0050 b
F+90	0.2100 a	0.02667bc	0.2250 a	0.2100 a	0.0333 b	0.0310 b	1.360 c	1.1500 b	1.2200 a	0.9713 b
Control	0.0000 c	0.0000 c	0.0320 c	0.0290 c	0.0005 c	0.0004 c	1.533 b	0.9030 b	0.00003 d	0.0337 e

Mean values followed with the same letter in columns have no significant difference at 0.05 significant level

ISSN-Internet 2197-411x OLCL 862804632

5. Discussions and Recommendations

Through our study we conclude the following:

Processed wastewater from Ramadi Hospital can be used for agricultural irrigation purposes after diluting it in medium-texture soils with monitoring salts in the soil and the concentration of micronutrients after the end of each season.

It is preferable to mix the processed water in the hospital processing plant with the neutral water by 30% to reduce the dissolved salts.

Organic fertilizers contribute to fertilizing the soil before using this water for irrigation in small quantities to give better productivity. The irrigation with partially processed wastewater is one of the ways to dispose of water safely and reduce the harmful effects when discharged randomly, so we recommend taking advantage of this water as a rich source of nutrients important to the plant, not to reduce the use of chemical fertilizers and reduce fresh water consumption.

1- Conducting intensive and serious scientific experiments and research in Iraq regarding the use of treated wastewater in agriculture and the use of this water with other types of crops, vegetables, fruit trees and others and on other types of soils.
2- Extensive study on the accumulation of heavy elements in plants and soil as a result of the use of this water in irrigation.
3- The processed wastewater is an alternative source of traditional water in Iraq, which can be used in the irrigation of vegetable and non-vegetable plant crops according to the determinants of health and environmental protection organizations and the Food and Agriculture Organization of the United Nations and the national determinants of the use of processed water in agricultural irrigation and preferably dilute the processed water in proportions according to the type of plant and mix it with river tap water to reduce salts and some elements and thus benefit from this water without causing environmental and health damage.

References

Abdoulkader, B. A., Mohamed, B., Nabil, M., Alaoui-Sossé, B., Eric, C., & Aleya, L. (2015). Wastewater Use in Agriculture in Djibouti: Effectiveness of Sand Filtration Treatments and Impact of Wastewater Irrigation on Growth and Yield of Panicum Maximum. *Ecological Engineering, 84*, 607-614. doi: https://doi.org/10.1016/j.ecoleng.2015.09.065

Adriano, D. C. (1986). *Trace Elements in the Terrestrial Environment*. Springer New York, NY. doi: https://doi.org/10.1007/978-1-4757-1907-9

Ahmed, W., & El-Hedek, K. (2017). Some Chemical Properties of Soil Affected by Long-Term Application of Primary Treated Wastewater. *Journal of Soil Sciences and Agricultural Engineering, 8*(9), 467-474. doi: https://doi.org/10.21608/jssae.2017.37619

Ahmed, W. A. A. (2012). The Effect of Irrigation With Industrial Waste Water on the Content of Copper and Lead in Plants and Their Readiness in the Soil. *Basra Research Journal (Scientific), 38*(1), 53-63. Retrieved from https://iasj.net/iasj/article/53574

Al-Abadi, L. A.-I. S. (2018). The Use of Wastewater and Public Sewage Water in Irrigation and Growth of the Jatropha Plant. *Iraqi Research Journal of Agriculture, 23*(2), 119-126. Retrieved from https://www.iasj.net/iasj/article/173482

Al-Hadithi, A. H. (1987). *The Effect of Adding Baghdad Sewage Waste on the Growth and Production of Yellow Corn and the Potential for Chemical Soil Contamination* (Master's Thesis, College of Agriculture, University of Baghdad).

Al-Hadithi, A. H., Al-Rubaie, M. S., & Hassoun, E. A. M. (2012). Reuse of Wastewater Phosphate Plant Treatment in Irrigation and Its Effect on the Growth of Yellow Corn Crops and Some Soil Properties. *Al-Mustansiriyah Journal of Science, 23*(8), 91-98. Retrieved from https://www.iasj.net/iasj/article/93660

Al-Hadithy, A. H., Motlag, K. H., Sharaf, M. E., & Hashim, L. Q. (2011). Using of Rustumiya sewage water for irrigation:1- its effect on some soil properties and corn growth. *Baghdad Journal of Science, 8*(1), 313-318. doi: https://doi.org/10.21123/bsj.2011.8.1.313-318

Al-Mansouri, J. A. Q., Al-Wadaei, A. M., & Othman, M. W. M. (2016). Estimation of Quality Indicators in Land Irrigated With Industrial Wastewater in the Al-maraw'a Area in Hodeidah - Republic of Yemen. *Journal of the Association of Arab Universities for Agricultural Sciences, Ain Shams University, Cairo, 24*(2), 417-430. doi: https://doi.org/10.21608/ajs.2016.14335

Al-Raw, A. O. (2000). The Future of Agriculture in Iraq in Light of the Water Variable at the Beginning of the Next Century. *Arab Journal of Water Management, 2*, 7-25.

Alderfasi, A. A. (2009). Agronomic and Economic

Impacts of Reuse Secondary Treated Wastewater in Irrigation Under Arid and Semi-Arid Regions. *World Journal of Agricultural Science, 5*(3), 369-374. Retrieved from https://www.idosi.org/wjas/wjas5(3)/18.pdf

APHA. (1975). *Standard Methods For the Examination of Water and Wastewater.* American Public Health Association. Retrieved from https://www.standardmethods.org/doi/book/10.2105/SMWW.2882

APHA. (1985). *Standard and carbon allocation in two reed beds (Phragmites australis) and Ponds* (2nd ed.). American public health Association.

APHA. (1998). *Standard Methods for the Examination of Water and Wastewater* (20th ed.). American Public Health Association, American Water Works Association and Water Environmental Federation, Washington DC.

APHA. (2003). *Standard Methods for the Examination of Water and Wastewater* (20th ed.). American Public Health Association, Washington. DC, USA.

Badda, M., Bakour, M., Al-Hayek, R., & Hegazy, A. (2022). The Effect of the Use of Gray Water on the Chemical Characteristics of the Soil and the Productivity of Spinach. *Damascus University Journal of Agricultural Sciences, 38*(1), 199-216. Retrieved from https://search.emarefa.net/detail/BIM-1503416

Bartram, J., & Ballance, R. (1996). *Water quality monitoring: A practical guide to the design and implementation of freshwater quality studies and monitoring programmes.* UNEP/WHO. Retrieved from https://www.who.int/publications/i/item/0419217304

Becerra-Castro, C., Lopes, A. R., Vaz-Moreira, I., Silva, E. F., Manaia, C. M., & Nunes, O. C. (2015). Wastewater Reuse in Irrigation: A Microbiological Perspective on Implications in Soil Fertility and Human and Environmental Health. *Environment International, 75*, 117-135. doi: https://doi.org/10.1016/j.envint.2014.11.001

Ben Mahmoud, K. R. (2009). Experience of the Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD) in the field of non-conventional water use in the Arab region. In *Fourth Conference on Modern Technologies in Agriculture Egypt: Cairo University, College of Agriculture* (pp. 378-392).

Black, C. A., Evans, D. D., White, J. L., Ensminger, L. E., & Clarck, F. E. (1965). *Methods of Soil Analysis. Part 1. Physical Propertiess.* American Society of Agronomy, Madison, Wisconsin.

Caravaca, F., Garcia, C., Hernández, M. T., & Roldán, A. (2002). Aggregate Stability Changes After Organic Amendment and Mycorrhizal Inoculation in the Afforestation of a Semiarid Site With Pinus Halepensis. *Applied Soil Ecology, 19*(3), 199-208. doi: https://doi.org/10.1016/S0929-1393(01)00189-5

Egiarte, G., Camps Arbestain, M., Alonso, A., Ruíz-Romera, E., & Pinto, M. (2005). Effect of Repeated Applications of Sewage Sludge on the Fate of N in Soils Under Monterey Pine Stands. *Forest Ecology and Management, 216*(1), 257-269. doi: https://doi.org/10.1016/j.foreco.2005.05.038

Elamin, A. W. M., & Saeed, A. B. (2019). Impact of Using Treated Wastewater for Irrigation on Soil Chemical Properties, Plant Growth and Forage Yield. *University of Khartoum Journal of Agricultural Sciences, 16*(1), 75-87. Retrieved from https://www.researchgate.net/publication/275030203

FAO. (1989). *Wastewater Quality Guidelines for Agricultural Use: Irrigation and Drainage Report*. FAO, Rome, Italy. Retrieved from https://www.fao.org/4/T0234E/T0234E00.htm

FAO. (1992). *Management of Wastewater Use in Irrigation*. Food and Agriculture Organization of the United Nations, Regional Office for the Near East. Cairo. Egypt. Retrieved from https://www.fao.org/4/T0551E/t0551e00.htm

Gadhia, M., Ansari, E., Prajapati, R. C., Thanki, Y. J., & Ujjania, N. C. (2014). Effect of Treated Wastewater on Growth of Vegetable Crops. *Nature and Science, 12*(7), 46-49. Retrieved from https://www.sciencepub.net/nature/ns1207/008_23578ns120714_46_49.pdf

García-Orenes, F., Caravaca, F., Morugán-Coronado, A., & Roldán, A. (2015). Prolonged Irrigation With Municipal Wastewater Promotes a Persistent and Active Soil Microbial Community in a Semiarid Agroecosystem. *Agricultural Water Management, 149*, 115-122. doi: https://doi.org/10.1016/j.agwat.2014.10.030

Gopal, K. (2007). *Water & Waste Water.* APH Publishing. Retrieved from https://quickbuyservices.com/Water-and-Waste-Water-by-Krishna-Gopal

Harmoush, M. (2013). *The Effect of Continuous Irrigation With Treated Wastewater on Some Physical and Chemical Properties and the Accumulation of Heavy Metals in Soil and Plants* (Master's Thesis, Al-Baath University – Syria).

Jackson, M. L. (1958). *Soil Chemical Analysis*. Prentice

Hall, Englewood Cliffs, NJ.

Lindsay, W. L., & Norvell, W. A. (1978). Development of a Dtpa Soil Test for Zinc, Iron, Manganese, and Copper. *Soil Science Society of America Journal, 42*, 421-428. doi: https://doi.org/10.2136/sssaj1978.03615995004200030009x

Mohammad Rusan, M. J., Hinnawi, S., & Rousan, L. (2007). Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. *Desalination, 215*(1), 143-152. doi: https://doi.org/10.1016/j.desal.2006.10.032

Olsen, S. R., & Sommers, L. E. (1982). Phosphorus. In A. L. Page (Ed.), *Methods of Soil Analysis Part 2 Chemical and Microbiological Properties* (pp. 403-430). American Society of Agronomy, Soil Science Society of America, Madison. doi: https://doi.org/10.2134/agronmonogr9.2.2ed.c24

Page, A. L., Miller, R. H., & Keeney, D. R. (1982). *Chemical and Microbiological Properties* (2nd ed.). American Society of Agronomy, Madison, Wisconsin USA.

Richard, L. A. (1954). *Diagnosis and Improvement of Saline and Alkali Soils*. US Department of Agriculture. Agricultural Handbook No. 60, Washington DC. Retrieved from https://www.ars.usda.gov/pacific-west-area/riverside-ca/agricultural-water-efficiency-and-salinity-research-unit/docs/publications/handbook-no-60

Saleh, F. S. (2012). Study of the Effect of Irrigation With Sewage Water on the Mineral Composition of the Berbene Plant. *Journal of Education and Science, 25*(3), 78-92. Retrieved from https://search.emarefa.net/detail/BIM-322823

Wu, Q.-T., Hei, L., Wong, J. W. C., Schwartz, C., & Morel, J.-L. (2007). Co-cropping for phyto-separation of zinc and potassium from sewage sludge. *Chemosphere, 68*(10), 1954-1960. doi: https://doi.org/10.1016/j.chemosphere.2007.02.047