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Assessment of Municipal Waste Water of Duhok District and Its Usefulness for Irrigation

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ABSTRACT

Nowadays there is a water crisis, farmers usually use wastewater and well water for agricultural cultivation. A pot experiment was used to investigate the influence of Duhok municipal wastewater for irrigation of broccoli plants of the genus (Brassica oleracea var. Italica (Broccoli) as compared to fresh water on broccoli parts and morphology of the plant. Municipal wastewater can be a rich source of necessary nutrients for plant growth when used as irrigation water. In this investigation, the municipal wastewater was preserved in plastic bottles taken from sewage sludge called (Hishkero) river, while the utilized soil got around the Misuriké district under a loamy soil texture class. The result showed that the broccoli plant was significantly affected by wastewater compared to freshwater in increasing potassium, lead, and copper (1.92 ± 0.05 %), (1.70 ± 0.05 %), (0.66 ± 0.02 mg/kg-1), (0.56 ± 0.02 mg/kg-1), (0.23 ± 0.03 mg/kg-1), (0.05 ± 0.03 mg/kg-1) respectively. While the broccoli plant for macro-nutrient accumulation (NPK) was significantly accumulated in shoot and head more than roots (1.45 ± 0.04 %), (1.41 ± 0.04 %), (0.24 ± 0.03 %), (0.33 ± 0.03 %), (2.17 ± 0.07 %), (2.11 ± 0.07 %) respectively. In conclusion, the nutrient content in broccoli was improved by wastewater as it has high nutrient contents with permissible levels of hazardous heavy metals of as lead and cadmium especially in the eaten part.

INTRODUCTION

Among other factors, the rise in population, urbanization, consumption per person, water pollution, and climate change all have an impact on the availability of freshwater resources. Lack of access to water is a major indication of health and a problem of poverty that primarily affects residents of rural areas with large population densities (FAO, 2012). A significant alternative source of water for crop irrigation is municipal wastewater. However, in addition to plant nutrients, it may also include a variety of organic materials that are highly detrimental to human and animal health (Mahmood & Ebrahim, 2015). Municipal wastewater has a rather high salt content, which can build up in the soil when used for irrigation and have hazardous effects on plant growth (Zavadil, 2009).

Reusing sewage wastewater may have advantages for managing water resources and agriculture, but there are also significant concerns to public health. Moreover, soil and groundwater pollution may result in chemical concerns for plants and the ecosystem. The potential environmental dispersal of macro and micronutrients, the build-up of heavy metals in soil and plants, and pollution brought on by microbial diseases are the main issues with wastewater reuse (Gatta et al., 2020).

Every day, large amounts of wastewater are produced in agriculture, industry, and dwellings. Wastewater accounts for 50 to 80 percent of domestic water use in households, and the worldwide wastewater discharge was anticipated to be 400 billion m3/year, polluting over 5500 billion m3 of water annually (Clack, 2020). Typically, wastewater is composed of 99% water and 1% dissolved, suspended, and colloidal particles (Hussain et al., 2019; Hanjra et al., 2012; Zhang et al., 2017). Given that it provides organic carbon, nutrients (NPK), and inorganic micronutrients (Pb, Cd, Cr, Zn, and Cu) to the plants, municipal water has a high ability for application in agricultural irrigation (Alcalde-Sanz & Gawlik, 2017; Asif et al., 2020). Particularly wastewater, in terms of higher crop output (Hanjra et al., 2012; Maab et al., 2018). Heavy metals such as Zn, Pb, Cd, Cr, and Cu were more readily absorbed by crops after wastewater treatment, which includes (cauliflower, mustard, broccoli, radish, chard, celery, spinach, and other vegetables) (Gupta et al., 2008; 2010; Priya & Tamilselvi, 2023), respectively. Sharma et al. (2006) demonstrated that variations in the adsorption and accumulation of vegetables resulted in varying uptake rates for different crops during distinct seasons (Nurhidayati, 2017). The purpose of the present work is to evaluate the municipal wastewater for broccoli plant irrigation and comparing with tap freshwater, by providing beneficial nutrients and organic matter to the soil, by using leafy plants (broccoli) to absorb dangerous trace metals and other pollutants (Abdiani et al., 2019).

MATERIALS AND METHODS

Sample Preparation

The research was carried out during the period of late summer - early autumn at the Agriculture College University of Duhok in 2023. The raw municipal wastewater samples were collected from the pipeline of Duhok governorate Sewage sludge, while the growing soil samples for broccoli planting were taken from Misuriké (clay loam soil texture) of Latitude and longitude (36o51′9.47″ N), (42o48′12.01″ E).

Pot Experiment

The soil samples were distributed in (12) pots with an equal weight of about (11kg), then the broccoli seedlings of the genus (Brassica oleracea var. Italica (Broccoli) was sown separately, Then the broccoli seedlings were irrigated with municipal wastewater by comparison with tap water near 10 – 12 weeks during the whole investigation as shown in (figure 1). After that, some chemical properties of utilized soil were taken for analysis, for example (pH, EC, NPK) and heavy metals (Pb, Cd, Cr, Zn, and Cu). Nevertheless, chlorophyll, morphological characteristics, and some chemical properties of broccoli plant's dry matter were taken such as (NPK) and heavy metals (Pb, Cd, Cr, Zn, and Cu).

Chemical Analysis

The chemical characteristics were carried out according to the standard practical procedures, the soil pH was analyzed by using the pH meter (Jackson, 1958), but the soil electrical conductivity EC was determined by an EC meter as described by (Rowell, 1996). The total nitrogen was determined by the Kjeldahl apparatus, potassium by flame photometer, and phosphorus by spectrophotometer according to the method suggested by (Ryan et al., 2001), and Olsen, Sommers (1982) respectively. While heavy metals such as (Pb) lead, (Cu) copper, (Zn) Zink, (Cd) cadmium, and (Cr) chromium were determined by taking 0.5 g of the sieved soil sample and then digested with a 3:1 mixture of concentrated $HClO_4$ and H_2SO_4 as inquired by (Barman and Lal 1994). The soil chemical properties was illustrated in Table 1.

Figure 1. Production of Brassica oleracea var. Italica (Broccoli) of the study

Table 1. Some of the chemical properties of the study soil

Chemical properties	Mean	± S. E	Soil ranges
pH	7.30	0.04	5.5-10.5
EC (ds/m)	0.27	0.01	0-2
N (%)	1.39	0.06	< 0. 02%-5
P (%)	0.06	0.006	0.1-0.5
K (%)	2.32	0.06	1.20-5.0
Zn (mg.kg-1)	0.23	0.01	20.0
Cr (mg.kg-1)	0.63	0.08	5.0-1000
Cd (mg.kg-1)	0.17	0.002	0.01-2.00
Pb (mg.kg-1)	0.18	0.01	2.0-300
Cu (mg.kg-1)	0.08	0.01	2.0-100

S.E. = standard error of the mean

On the contrary, for broccoli analysis, the broccoli samples (roots, shoots, heads) were harvested and washed gently with distilled water, then cut into small pieces and transferred to the oven for drying about 48 hr. Then oven-dried plant samples were crushed by an electric mixer and 0.5 g of the powder samples were taken and correctly digested with H2SO4 and HClO4 concentrated 3:1 mixture. At the time, the collected extracts were taken for analysis (N, P, K, Pb, Cu, Zn, Cd, and Cr) through an atomic absorption spectrophotometer (Gupta et al. (2008) and (2010).

Data Analysis

The collected data was submitted to the SPSS program (SPSS, 2019), to analyze it statistically. Descriptive statistics to study the effect of municipal wastewater (MWW) on the interrelationships of macro, micronutrients, heavy metals, and physical and chemical properties of soil cultivated with Brassica oleracea var italica (broccoli) (Ahmad et al., 2018). T-test (for the effect of both water types; and the effect of both studied soil or locations, separately) and One-way ANOVA (for the effect of the three studied plant parts)(Ahmad et al., 2019). However, the means within ANOVA were separated using Duncan's multiple-range test (Duncan, 1955).

RESULTS AND DISCUSSION

The values exhibited in Table 2 show the chlorophyll and some morphological properties of broccoli plants were measured during this study as affected by the type of water. The results revealed that the tap water and waste water had a non-significant effect on the plant's chlorophyll and the whole morphological properties (Raksun, 2019). However, it noticed there was a slight increase in the value of chlorophyll for tap water (69.70 ± 4.02 SPAD) and wastewater (63.86 ± 1.52 SPAD); this may be attributed to low content of nitrogen in soil and wastewater which is essential for chlorophyll formation (Irsan, 2021). Also, a slight increase was noticed in the root length of the broccoli plant in wastewater (49.00 ± 10.14 cm) compared to (41.33 ± 2.96 cm) in tap water, which reflects that the waste water has positive effects on root promotion due to various organic and inorganic substances that it contains. The leaves number recorded (17.33 ± 2.60 cm) for tap water and (20.00 ± 0.57cm) for wastewater for the same reasons; these findings are in harmony with those cleared by (Rahim, Bayan. 2023).

Nevertheless, slight differences were presented for flower diameter, stem diameter, plant height, and head numbers in the following order under the effect of tap and wastewater (6.00 ± 0.57 cm)-(7.67 ± 0.33 cm), (1.93 ± 0.06 cm)-(2.00 ± 0.00 cm), (47.00 ± 3.05 cm)-(46.00 ± 2.08 cm), (8.67 ± 1.20)-(9.33 ± 1.45) respectively. While the dry and wet weight of broccoli head showed non-significant effects as well (6.25 ± 0.63 gm) to (11.27 ± 3.24 gm), (46.96 ±2.08gm) to (51.66 ± 6.63 gm) were noticed. Similar results were recorded by (Rahim, Bayan, 2023).

Table 2. Chlorophyll and morphological properties of Broccoli plant in Misuriké clay loam soil as affected by the type of water

parameters	Water	Mean	± S. E	t-test value	Sig. (p-value)
Chlorophyll	Tap Water	69.70	4.02	1.357	NS (0.246)
(SPAD)	Waste Water	63.86	1.52		
Flower diameter	Tap Water	6.00	0.57	-2.500	NS (0.067)
(cm)	Waste Water	7.67	0.33		
Stem diameter (cm)	Tap Water	1.93	0.06	-1.000	NS (0.374)
	Waste Water	2.00	0.00		
Plant Hight (cm)	Tap Water	47.00	3.05	0.271	NS (0.800)
	Waste Water	46.00	2.08		
Leave number	Tap Water	17.33	2.60	-1.000	NS (0.374)
	Waste Water	20.00	0.57		
Head - dry weight	Tap Water	6.25	0.63	-1.516	NS (0.204)
(gm)	Waste Water	11.27	3.24		
Head - wet weight	Tap Water	46.96	1.13	-.697	NS (0.524)
(gm)	Waste Water	51.66	6.63		
Head number	Tap Water	8.67	1.20	-.354	NS (0.742)
	Waste Water	9.33	1.45		
Root length (cm)	Tap Water	41.33	2.96	-.725	NS (0.509)
	Waste Water	49.00	10.14		

S.E. = standard error of mean, NS = Non-Significant ($p>0.05$)

The data in Table 3 represent the nutrient content of broccoli dry matter under the effect of water types. The nitrogen and phosphorus contents were non-significantly affected by tap and wastewater (1.35 ± 0.03%) to (1.41 ± 0 .03%) for N, (0.23 ± 0.02%) to (0.21 ± 0.02%) for P, but the potassium content significantly affected by the types of water (1.70 ± 0.05%) in tap water and elevated to (1.92 ± 0.05%) in wastewater, that meant potassium content in broccoli plant affected by wastewater more than tap water (Darwanto, 2016). This may return to the positive effect of wastewater in increasing K solubility from the mineral part of the soil that contains originally high K content and more than phosphorous. The same findings were recorded by (Kalavrouziotis et al., 2008). The heavy metals content of broccoli plants, in general, was very low, however, lead significantly affected at ($p<0.05$) by wastewater about (0.66 ± 0.29 mg.kg-1) than tap water (0.56 ± 0.02 mg.kg-1) but less than permissible level set by WHO, compared to copper had a highly significant ($p<0.05$) affect by wastewater (0.23 ± 0.03 mg.kg-1), meanwhile, this Cu concentration not meet the sufficient requirements of broccoli optimum growth (Khan et al., 2018). While (Zn, Cr, and Cd) revealed non-significant effects in tap and wastewater, especially both micronutrient Zn and Cr which also did not reach the growth requirements limits of broccoli.

The deficiency of cationic micronutrients such as Cu, Zn, and Cr as well as toxic non-essential heavy metals such as Pb and Cd in the broccoli return to the fact that they precipitated in soil pH over 6.5, so, there availability for plant absorption highly decreased and the whole broccoli growth was not at satisfied level, especially the maturity of the pant that depends in micronutrients that act as enzyme cofactors in metabolism, also found trace quantities of heavy metals in the soil of Badinan province, Kurdistan Region, Iraq. Also, these findings were in alignment with those reported by (Kalavrouziotis et al., 2008).

Table 3. The nutrient contents and heavy metals of broccoli dry matter planted in Misuriké clay loamy soil (Effect of Water-type)

Nutrient Contents	Water	Mean	± S. E	Sig. (p-value)	FAO/WHO limit (Bambara et al 2023)
N (%)	Tap Water	1.35	0.03	NS (0.234)	2.70 – 3.20 %
	Waste Water	1.41	0.03		
P (%)	Tap Water	0.23	0.02	NS (0.584)	0.20-0.50
	Waste Water	0.21	0.02		0.20 – 0.30 %
K (%)	Tap Water	1.70 b	0.05	* (0.023)	1-5
	Waste Water	1.92 a	0.05		
Zn (mg.kg-1)	Tap Water	0.14	0.007	NS (0.066)	1.50 – 2.00 %
	Waste Water	0.16	0.007		
Cr (mg.kg-1)	Tap Water	0.61	0.06	NS (0.474)	-
	Waste Water	0.58	0.06		20 mg/kg-1
Cd (mg.kg-1)	Tap Water	0.02	0.01	NS (0.720)	0.20
	Waste Water	0.02	0.01		
Pb (mg.kg-1)	Tap Water	0.05 b	0.02	* (0.032)	2.3 mg/kg-1
	Waste Water	0.06 a	0.02		
Cu (mg.kg-1)	Tap Water	0.05 b	0.03	** (0.002)	73
	Waste Water	0.23 a	0.03		

S.E. = standard error of the mean

This means having different superscripts within each Chemical property have differed significantly. NS = Non-Significant ($p>0.05$); * = Significant ($p<0.05$); ** = significant ($p<0.01$)

The obtained data in Table 4 exhibit that the translocation of the three macronutrients N, P, and K from roots to upper parts of shoots was more than the translocation of micronutrients Cu, Zn, and Cr as well as the two toxic heavy metals Cd and Pb (Ugulu et al., 2019). This result proves that the mobility of macronutrients was much greater than the micronutrients as the same finding was reported by (Ali et al., 2019). The three macronutrients (NPK) were high and significantly ($p<0.05$) affected the broccoli parts in the shoot and head more than the roots; however, the potassium accumulation was higher than nitrogen and phosphorus in the broccoli parts. The shoot and head contents by NPK were around (1.45± 0.04%) - (1.41 ±0.04%), (0.24 ± 0.03%) - (0.33 ± 0.03%), (2.17 ± 0.071%) - (2.11 ± 0.07%) respectively (Huang et al., 2021). On the other hand, the broccoli parts were non-significantly ($p<0.05$) affected by (Zn, Cr, and Cd) accumulation, while the broccoli parts root and shoot were high significantly ($p<0.05$) affected than head through Pb accumulation (0.71 ± 0.03 mg.kg-1), (0.70 ± 0.03 mg.kg-1), (0.42 ± 0.03 mg.kg-1) respectively. On the contrary, the Cu accumulated in roots greater than shoot and head (0.32 ± 0.03 mg.kg-1), (0.05± 0.03 mg.kg-1), (0 .04 ± 0.03 mg.kg-1) respectively. These findings were in harmony with those reported by (Rahim, Bayan, 2023) such as (Pb, and Cd) concentrations in edible parts of broccoli plants were showed (0.0250 ± 0.000, 0.0421 ± 0.000) respectively.

Table 4. Some nutrient and heavy metals contents of broccoli dry matter planted in Misuriké clay loamy soil (Effect of Broccoli part)

Nutrient Contents	Broccoli part	Mean	± S. E	Sig. (p Value)	FAO/WHO limit (Bambara et al., 2023)
N (%)	Root	1.27 b	0.04	* (0.032)	2.70 – 3.20%
	Shoot	1.45 a	0.04		
	Head	1.41 a	0.04		
P (%)	Root	0.11 b	0.03	** (0.001)	0.20 – 0.30%
	Shoot	0.24 a	0.03		
	Head	0.33 a	0.03		
K (%)	Root	1.14 b	0.07	** (0.001)	1.50 – 2.00%
	Shoot	2.17 a	0.07		
	Head	2.11 a	0.07		
Zn (mg.kg-1)	Root	0.17	0.008	NS (0.066)	20 mg/kg-1
	Shoot	0.14	0.008		
	Head	0.15	0.008		
Cr (mg.kg-1)	Root	0.67	0.07	NS (0.555)	2.3 mg/kg-1
	Shoot	0.57	0.07		
	Head	0.55	0.07		
Cd (mg.kg-1)	Root	0.02	0.01	NS (0.667)	0.02 mg/kg-1
	Shoot	0.02	0.01		
	Head	0.02	0.01		
Pb (mg.kg-1)	Root	0.07 a	0.03	** (0.001)	0.3mg/kg-1
	Shoot	0.07 a	0.03		
	Head	0.04 b	0.03		
Cu (mg.kg-1)	Root	0.32 a	0.03	** (0.001)	40 mg/kg-1
	Shoot	0.05 b	0.03		
	Head	0.04 b	0.03		

This means having different superscripts within each Chemical property have differed significantly. NS = Non-Significant (p>0.05); * = Significant (p<0.05); ** = significant (p<0.01).

The values shown in Table (5) represent the interaction between the utilized water and the broccoli parts (root, shoot, and head) for macro-nutrient contents (Khan et al, 2019). Regarding nitrogen and phosphorous contents, the best interactions were noticed between tap water and broccoli head recording 1.87% and 0.42% respectively. However, the wastewater slightly increased the amount of N and K in broccoli roots and shoots by comparing with tap water, and the best combination found with potassium contents in the shoot was about (2.35 ± 0.10%). According to Moreno et al. (2006), broccoli is a good source of, potassium, phosphorus, zinc, and copper and rich with chromium (Arumingtyas, 2020).

Since wastewater gives plants organic carbon, nutrients (NPK), and inorganic micronutrients, it has a high concentration of nutrients and therefore a great potential for use in agricultural irrigation (Alcalde-Sanz & Gawik, 2017). Due to their antagonistic relationships, these interactions may either help plants grow by providing nutrients through their synergistic effects or by decreasing or inactivating (fixing) certain unwanted soil heavy metals. These interactions may have a significant effect on both the environment and plant growth (Beneduce et al., 2017).

Table 5. The Interaction between utilized water and the broccoli parts for NPK

Parameters	Water	Broccoli part	Mean	± S. E	95% Confidence Interval	
					Lower Bound	Upper Bound
N (%)	Tap Water	Root	0.81	0.06	0.67	0.94
		Shoot	1.37	0.06	1.23	1.50
		Head	1.87	0.06	1.73	2.00
	Waste Water	Root	1.73	0.06	1.59	1.87
		Shoot	1.54	0.06	1.40	1.67
		Head	0.96	0.06	0.82	1.10
P (%)	Tap Water	Root	0.12	0.04	0.02	0.21
		Shoot	0.17	0.04	0.07	0.26
		Head	0.42	0.04	0.32	0.51
	Waste Water	Root	0.10	0.04	0.005	0.19
		Shoot	0.31	0.04	0.21	0.40
		Head	0.24	0.04	0.14	0.33
K (%)	Tap Water	Root	1.00	0.10	0.78	1.22
		Shoot	2.00	0.10	1.78	2.21
		Head	2.11	0.10	1.89	2.33
	Waste Water	Root	1.29	0.10	1.07	1.50
		Shoot	2.35	0.10	2.13	2.57
		Head	2.11	0.10	1.89	2.33

S.E. = standard error of the mean

Table 6. The Interaction between utilized water and the broccoli parts for heavy metals

Parameters	Water	Broccoli part	Mean	± S. E	95% Confidence Interval	
					Lower Bound	Upper Bound
Zn (ppm)	Tap Water	Root	0.16	0.01	0.13	0.18
		Shoot	0.11	0.01	0.08	0.13
		Head	0.17	0.01	0.14	0.19
	Waste Water	Root	0.18	0.01	0.16	0.21
		Shoot	0.17	0.01	0.15	0.20
		Head	0.14	0.01	0.11	0.16
Cr (ppm)	Tap Water	Root	0.61	0.10	0.37	0.85
		Shoot	0.51	0.10	0.27	0.75
		Head	0.71	0.10	0.47	0.95
	Waste Water	Root	0.72	0.10	0.48	0.96
		Shoot	0.63	0.10	0.39	0.87
		Head	0.39	0.10	0.16	0.63
Cd (ppm)	Tap Water	Root	0.20	0.02	0.15	0.26
		Shoot	0.22	0.02	0.16	0.28
		Head	0.25	0.02	0.19	0.30
	Waste Water	Root	0.22	0.02	0.17	0.28
		Shoot	0.25	0.02	0.19	0.30

		Head	0.22	0.02	0.17	0.28
Pb (ppm)	Tap Water	Root	0.67	0.05	0.56	0.78
		Shoot	0.56	0.05	0.45	0.67
		Head	0.45	0.05	0.34	0.55
	Waste Water	Root	0.74	0.05	0.63	0.85
		Shoot	0.84	0.05	0.73	0.94
		Head	0.39	0.05	0.28	0.50
Cu (ppm)	Tap Water	Root	0.07	0.05	0.04	0.19
		Shoot	0.03	0.05	0.08	0.15
		Head	0.04	0.05	0.07	0.16
	Waste Water	Root	0.56	0.05	0.44	0.68
		Shoot	0.07	0.05	0.04	0.19
		Head	0.04	0.05	0.07	0.16

Table 6 illustrates another interaction of five heavy metals (Pb, Cu, Zn, Cd, and Cr) in broccoli parts root, shoot, and head and how their ratios were affected by tap and wastewater. The interactions showed that Broccoli parts for up-taking heavy metals (Pb, Cd, Cu, Zn, and Cr) were changed a little bit for both tap water and wastewater (Chandel et al., 2020). High Zn, Cr, and Cu accumulation were found in the interaction between broccoli roots and wastewater, this reflects the ability of this vegetable to reduce the solubility of heavy metals by rhizofilteration mechanisms, and their mobility to plant upper parts is low.

While the high amounts of both toxic heavy metals Cd and Pb were found between plant shoots and wastewater, which reflects the ability of broccoli to absorb them by bio-accumulation or bio-concentration mechanisms In general, the essential micronutrients Zn and Cu concentrations were very low in broccoli parts because the calcareous soil reduces the availability of (Zn, and Cu) and both have been precipitated in soil and the plant can't absorb them, although they are essential for plant growth. The whole plant growth parameters were negatively affected, also found the minimum concentration of heavy metals in groundwater samples in these regions (Amir., 2017).

CONCLUSION

From this investigation can be concluded that the reusing of wastewater for irrigation has many benefits but also side effects. The wastewater did not satisfy most macro and micronutrient requirements for best plant growth. So, the dependence on wastewater as a whole source of nutrients for plant growth is not a useful alternative to chemical fertilizers and the soil should be supplied by nutrients either by organic or in organic fertilizer. However, the requirement for expensive fertilizers may be reduced by the presence of nutrients in wastewater that can be advantageous for plant growth (Brassica oleracea var. italica (Broccoli). Although the threat of soil pollution by heavy metals in calcareous soil is very rare. On the other hand, the most frequent downsides are increased soil salinity problems and a risk to human health from exposure to pathogens. Water resources, agriculture, and human health are all may be impacted by wastewater. Therefore, additional investigations were required to assess the interaction between wastewater and organic and in organic fertilizer.

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