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Wastewater Irrigation and Accumulation of Heavy Metals in Vegetable Crops (Broccoli and Cauliflower)

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ABSTRACT

The present study was conducted aiming to determine the effects of different irrigation water sources on some heavy metal uptake by winter crops (Cauliflower and Broccoli). This experiment was laid in a Randomized Complete Block Design (RCBD) with three replications, and three water irrigation sources (Clean water, Wastewater, and alternate use of the a clean-water followed by two Wastewater irrigation, under the surface irrigation system, during the growing seasons in 2018-2019. The results showed that Broccoli crops heavy metal uptake (Pb, Cd, Fe and Cu) were significantly higher in broccoli irrigated with clean and waste water sources alternatively (B-W2 Treatment) (0.0250 ± 0.000, 0.0421 ± 0.001, 4.2247 ± 0.001, and 0.1513 ± 0.001),respectively, compared to the rest of other treatments while the lowest concentrations of the studied heavy metals (Pb, Cd, Fe and Cu) recorded in cauliflower irrigated with clean water (C-C1 treatment) (0.0239 ± 0.000, 0.0383 ± 0.001, 4.2077 ± 0.001 and 0.1447 ± 0.001), respectively.

السقي بمياه الصرف الصحي وتراكم العناصر الثقيلة في محاصيل الخضر (البروكلي والقرنابيط)

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الخلاصة

أجريت هذه الدراسة لتحديد تأثير مصادر مياه الري المختلفة على امتصاص بعض العناصر الثقيلة من قبل المحاصيل الشتوية (القرنبيط والبروكلي). نفذ هذا البحث باستخدام تصميم القطاعات العشوائية الكاملة (RCBD) بثلاث مكررات، وثلاث مصادر للري (مياه نظيفة، مياه صرف صحي والري بمياه عذبة يتبعها ريتين بمياه الصرف الصحي ، تحت نظام الري بالمروز، خلال الموسم الخريفي (2018-2019) في محطة بحوث كلية الزراعة جامعة السليمانية. أظهرت النتائج أن امتصاص نبات البروكلي للعناصر الثقيلة (الرصاص ، الكادميوم ، الحديد ، النحاس) كان أعلى بكثير في معاملتي الري بمياه نظيفة ومياه الصرف الصحي مقارنة بمعاملة الري البديل (0.000 ± 0.0250 ، 0.001 ± 0.0421 ، 0.001 ± 4.2247 ، و 0.001 ± 0.1513) على التوالي بينما سجلت أقل تراكيز للعناصر الثقيلة المدروسة (الرصاص والكادميوم والحديد والنحاس) في القرنبيط المروي بالماء النظيف (0.000 ± 0.0239) ، 0.001 ± 0.0383 ، 0.001 ± 4.2077 و 0.001 ± 0.1447) على التوالي

الكلمات المفتاحية: الري، مياه الصرف الصحي، العناصر الثقيلة، القرنابيط، البروكلي.

INTRODUCTION:

The resources of fresh water in the world are very limited, just 0.6% of the total world water resources is fresh water (Fakayode, 2005), Due to increasing human activity, the water's resources decreased and this amount may not able to meet the requirement of human in the future (Qadir *et al*., 2008). However, about 80% of the water resources are uses for irrigation in agriculture sectored. Nowadays rapid urbanization and industrialization has greatly increased, that leads the discharge of huge amount of wastewater accompanied with many different toxic chemicals. In view of the fact that the use of freshwater is not accessible for irrigation practices all the time, wastewater irrigation is gain popularity to solve this problem in mostly agricultural areas (Khan *et al*., 2018a; Ahmad., *et al* 2018), which becoming a global phenomenon especially in peri-urban areas (Abaidoo *et al*., 2010). It is estimated that about 2 million km^2, approximately 7%, of agricultural lands are irrigated with wastewater. Thus, this issue is receiving new attention day after day (WHO, 2006; Hamilton *et al*., 2007).

Wastewater irrigation enriched with different types of metals (Amman *et al*., 2002; Ahmad *et al*., 2019) that affects agricultural soils due to the different organic and inorganic elements occur in wastewater, this effect can be useful if it has no adverse effects on soil pollution, food crops' yields, and humans healthhealth of humans (WHO, 1996; USEPA, 2010). The most vital part of wastewater accumulated as consequence of different environmental activities is heavy elements, because of their non-renewable and steady nature (Zhuang *et al*., 2009; Khan *et al*., 2019a). The long-term usage of wastewater makes these metals accumulate in soil and increase es the absorption and accumulation of the plants (Luo *et al*., 2012; Ugulu *et al*., 2019). Therefore, soils, crops and groundwater would have to be assessed (Yadav *et al*., 2015). Some studies showed that heavy metals in long-term sewage irrigated soils may still be below the maximum permissible limit (Bao *et al*., 2014; Salakinkop and Hunshal, 2014).

However, limited published data are available on heavy metals concentrations in the soils and vegetables in Sulaimani city . Therefore, the present study aimed to determine the concentrations of some heavy metals in edible vegetables (cauliflower and broccoli crops) grown at periurban sites in Sulaimani city.

MATERIALS AND METHODS

Field experiment

A field experiment was conducted during the growing seasons 2018-2019, in the experimental research field station (35°32'40.9"N 45°21'55.2"E) of the College of Agricultural Engineering Sciences, University of Sulaimani, in Bakrajo district, the Sulaymaniyah city, Kurdistan Region of Iraq. The experiment was laid in a Randomized Complete Block Design (RCBD) with three water irrigation sources under the surface irrigation system (Furrow irrigation) , and three replications: clean water(C), Wastewater [Tanjrw river (W)], and alternatively mixed (A) including (one river water irrigation followed by two sewage water irrigation) during all growing season. Irrigation water was applied through a plastic pipe network connected to an electric pump and water meter to measure the quantities of water applied to each experimental plot, when 35% of the available water was depleted based on gravimetric method. The share-plough was use to plowed the land and softened with rotary-plough. Furrow with 1.5 m width was ditched between the plots to avoid lateral movement of water. The land was plowed twice and the furrow irrigation method was used in this experiment based on the traditional farmers' method practiced around the Tanjero river. The cauliflower (Brassica oleracea var. botrytis L) and Broccoli (Brassica oleracea var. Italica) seedlings were planted on 20/9/2018 on trench and the space between the plants was 45 cm and 100 cm between the rows. and harvest was on 1/2/2019. Compound fertilizer (N-P_2O5-K_2O 18-18-18) was applied to all treatments according to recommendation of Agriculture Ministry in Sulaimani government/Kurdistan region. All required management practices were applied equally as required.

Data Collection:

Wastewater samples: samples of wastewater were collected from Tanjero river where the municipal wastewater of Sulaymaniyah city drains in. The water samples were collected in plastic bottles and brought to the laboratory for chemical analysis. The wastewater samples were filtered before chemical analysis. Water analyzes were conducted according to the methods listed in APHA (1999).

Soil samples: Soil samples were collected from the fields at the depth of 0-10, 10-20, and 20-40 cm. The collected soil samples from each layer were air-dried under the shade, ground, sieved and mixed thoroughly. The representative samples were collected from the composite samples.

Plant samples: Edible portion of the vegetables were randomly collected. The vegetable samples were washed with distilled water, dried under shade, ground, and mixed thoroughly to get representative samples for chemical analysis.

Sample Analysis: Collected soil samples were analyzed to determine the main characteristics and physicochemical properties, as shown in Table (2), according to standard methods (Black , 1965),

The heavy metals in the plant samples (edible parts) were determined using Walsh (1973) method; by digesting the samples using nitric acid and pyro chloric acid and the elements Fe, Cu, Cd and Pb were determined by atomic absorption spectrometer

Data Analysis:

The collected data were statistically analyzed using XLSTAT Software 2019. The means were compared according to Tukey's multiple range tests ($P \leq 0.05$).

RESULTS AND DISCUSSION:

The results in Table 1 shows some wastewater sample analysis taken from the Tanjaro river outlet pumps and used for irrigation in this study.The value of pH (7.70) was within the safe limit for irrigation.To assess potential infiltration problem, values of EC and SAR were used together (Ayers and Westcot,1994). The values of EC and SAR were (0.70 $dS.m^{-1}$), (2.24) respectively, had no restriction in use for irrigation. Soluble cations and anions(Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, Cl^{-} and HCO_3^{-}) were in usual range according USDA (1954).

Table 1. Some properties of wastewater.

Properties	wastewater
pH	7.7
EC	0.70 $dS.m^{-1}$
Ca^{+2}	12 mg l^{-1}
Mg^{+2}	7.3 mg l^{-1}
N^{+}	8.52 mg l^{-1}
K^{+}	2.96 mg l^{-1}
Cl^{-}	23.01 mg l^{-1}
$HCO3^{--}$	0.8 mg l^{-1}
SAR	2.74

Results in Table (2) show the main soil physicochemical properties of studied soil, the soil generally had alkaline reaction and low salinity, also low content ao carbonate and organic matter.

Table 2. Physiochemical characteristics of the cultivated soil.

Soil Characteristics	Test Values
Particle Density	2.53 mg cm^{-3}
Bulk Density	1.26 mg kg^{-3}
Texture	Silty Clay
Organic Matter	22.40 g kg^{-1}
Electrical Conductivity	0.45 dSm^{-1}
pH	7.30
$CaCO_3$	270 mg kg^{-1}

The results of (Pb, Cd, and Fe) concentration showed in Table (3) and the vales were, (0.0250 ± 0.000, 0.0421 ± 0.000, and 4.2247 ± 0.001) respectively, are significantly higher in edible parts of broccoli irrigated with wastewater compared to other treatments, while no significant difference were found between B-W2 and B-A2, while both B-W2 (0.1513 ± 0.001) and B-A2 (0.1483 ± 0.001) were significantly different from B-C2 (0.1437 ± 0.001) for the concentration of Cu. However, the concentration of all the studies heavy metals were higher in the dried edible parts of broccoli plant in comparison to the other treatments, the recorded amounts had not exceeded the FAO and WHO permissible limits for human consumption (WHO, 1989).

Table 3. The concentrations of Pb, Cd, Fe, and Cu in in the studies dried edible parts of broccoli plant μg g^{-1}

Treatments	Pb (μg g^{-1})	Cd (μg g^{-1})	Fe (μg g^{-1})	Cu (μg g^{-1})
B-W2	**0.0250 ± 0.0006 a**	**0.0421 ± 0.0007 a**	**4.2247 ± 0.0009 a**	**0.1513 ± 0.0003 a**
B-A2	0.0245 ± 0.0003 b	0.0403 ± 0.0003 ab	4.2173 ± 0.0003 b	**0.1483 ± 0.0003 a**
B-C2	0.0241 ± 0.0003 c	0.0387 ± 0.0006 b	4.2117 ± 0.0007 c	0.1437 ± 0.0012 b
Pr > F	0.000	0.004	0.000	0.001

The results in Table (4) showed that Pb uptake had not been affected in Cauliflower crop within the all treatments while Fe uptake were significantly higher in C-W1 than other treatments. No significant differences were found in Cu uptake by Cauliflower crop between C-W1 and C-A1 while both treatments were significantly different from C-C1. But Cd uptake was significantly higher in C-A1 compared to C-W1 and C-C1. The recorded concentration of heavy metal in the dried edible parts of Cauliflower had not exceeded the FAO and WHO permissible limits for human consumption (WHO, 1989). The recent study results are in conformity with the previous findings of (Amir *et al*., 2017). The results of present study are also in conformity with the findings of (Chandel *et al*.,2020).

Using sewage water for irrigation is recognized to contribute potentially the heavy metal contents to the soils and ultimately in vegetables (Mapanda *et al*., 2005). So, the results indicated that irrigation water source amendments reflected metals available to the studied plants, the overall concentrations of the four studied heavy metals in cauliflower and broccoli heads revealed that broccoli was relatively higher accumulators of Pb, Cd, Fe and Cu metals. The higher concentrations of the studied heavy metals found in broccoli irrigated with wastewater. So, it less favorable crop to be irrigated with wastewater.

Table 4. The concentrations of Pb, Cd, Fe, and Cu in the studies dried edible parts of cauliflower plant (μg g^{-1})

Treatments	**Pb (μg g^{-1})**	**Cd (μg g^{-1})**	**Fe (μg g^{-1})**	**Cu (μg g^{-1})**
C-W1	0.0240 ± 0.0000 a	0.0397 ± 0.0006 ab	**4.2190 ± 0.0005 a**	**0.1510 ± 0.0006 a**
C-A1	0.0242 ± 0.0003 a	**0.0417 ± 0.0003 a**	4.2130 ± 0.0015 b	**0.1487 ± 0.0003 a**
C-C1	0.0239 ± 0.0007 a	0.0383 ± 0.0009 b	4.2077 ± 0.0017 b	0.1447 ± 0.0007 b
Pr > F	0.095	0.033	0.003	0.001

The data showed in the Tables (3 and 4) depict that cauliflower irrigated with clean water had lowest uptake of heavy metals while Broccoli irrigated with one time clean followed by two times wastewater recorded significantly highest uptake of heavy metals. It has been observed that, broccoli crops were significantly higher in heavy metal uptake (Pb, Cd, Fe and Cu) in B-W2 treatment compared to other treatments.

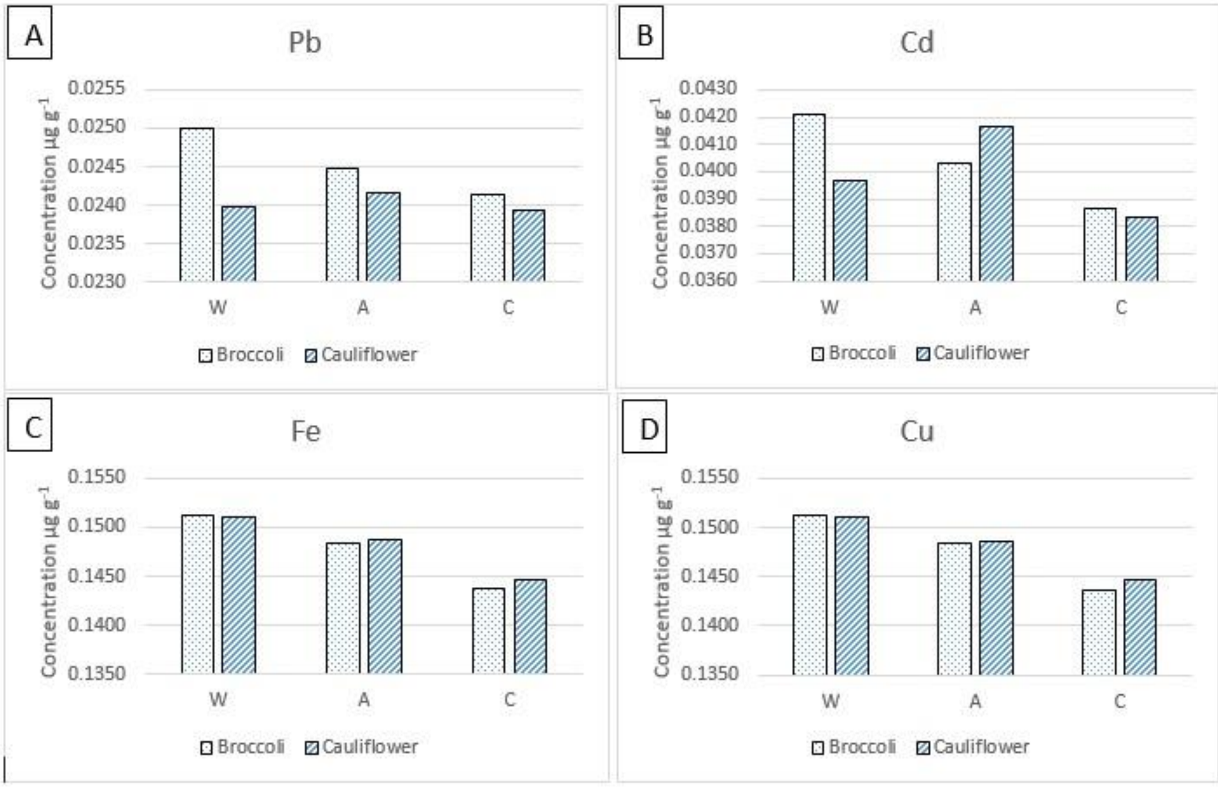

Figure 1. Comparison of the mean total: a- Lead (Pb), b- Cadmium (Cd), c- Iron (Fe), d- Copper (Cu) concentrations for edible parts of the vegetables (Broccoli; Cauliflower) and for different treatments (W=Wastewater; A= Altering water sources; C= Clean water).

The maximum concentration of the studied heavy metals (Pb, Cd, Fe, Cu) were always associated with broccoli irrigated with wastewater treatment (Fig.1). The irrigation treatment with clean and waste water sources alternatively has decreased the accumulation of the studied heavy metals except for Cd in Cauliflower which increased significantly in comparison to wastewater.

Despite the fact, it is proven from previous studies that leafy vegetables have higher accumulation of heavy metals compared to fruity and other vegetables (Ali and Al-Qahtani, 2012; Zhou, *et al*., 2016; Huang, *et al*., 2021) especially broccoli (Schaeffer and Esbenshade, 2018) and cauliflower (Farooq, *et al*., 2008), none of the studied elements in this study had exceeded the health limit in accordance to the permissible limits of heavy metals in vegetables determined by WHO, FAO and USDA.

CONCLUSION

In conclusion, it is observed from this field experiment, the sided heavy metal uptake (Pb, Cd, Fe and Cu) was significantly higher in broccoli irrigated with clean and waste water sources alternatively, compared to the rest of other treatments while the lowest concentrations recorded in cauliflower irrigated with clean water (C-C1 treatment) while all the determined concentration were below the WHO permissible limits for human consumption. That means, despite the people's concern of municipal waste water drain to the rivers without the presence of any treatment stations, still the stream water is clean in terms of heavy metals for winter crops. Even though, sewage and wastewater treatment stations are needed to be installed to protect the river from further contamination due to the increase of urban areas and establishment of further factories around the rivers near the urban areas in Sulaymaniyah City.

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