Research Article

Hazardous Impact of Industrial Wastewater Utilization on Quality Parameters of Tomatoes

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Abstract | Due to shortage of good quality water and being enriched in nutrients industrial wastewater is commonly employed for irrigation of crops. The industrial state of Sargodha directly discharges its effluents that flow into a stream. This industrial wastewater was taken for this trial. The contaminants of the stream water were utilized for this trial to check its impacts on soil properties and growth of tomato plants. The physiochemical parameters of the soil such as pH, EC, organic matter, heavy metals and physiological parameters of the tomato plants were observed. Most of the soil parameters were proved higher with the irrigation of the industrial wastewater effluents than the soil irrigated with canal water. The tomato plants were grown at the different ratios of industrial wastewater. The experiment of the tomato plants was arranged according to complete randomized design (CRD) using 06 treatments replicated four times. Treatments included T_1 = 100% CW (canal water) irrigation; T_2 = 100% WW (wastewater) irrigation; T_3 = CW 75% + WW 25%; T_4 = CW 50% + WW 50%; T_5 = CW 25% + WW 75% and T_6 = Cyclic/alternate use of CW and WW. Findings of present research implied that irrigation with wastewater significantly improved the growth and nutrient acquisition of tomato plants. Highest values for N (5.8%), P (0.88%) and K (2.4%) content of tomatoes were recorded when 100% wastewater was applied as a source of irrigation. However, it is the cyclic use of wastewater with canal water that can safely be used for getting good quality tomatoes and to mitigate hazardous impact of heavy metals contained in wastewater.

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Introduction

Tomato (*Lycopersicon esculentum*) is an herbaceous member of the nightshade family Solanaceae. Edible portion is technically a fruit but commonly used as vegetable. This herbaceous plant typically grows tall and stem sprawl over the ground. Various cultivars differ on the basis of fruit shape, size, diameter and color. Several forms of consumption of tomatoes are pulp, salad, sauces, ketchup etc. (Rowles *et al*., 2018). Tomato is a nutritious being enriched in antioxidants, vitamins, essential amino acids, sugars etc. (Javed *et al*., 2020). Consumption of highly nutritious tomatoes protect the human body from various diseases such as cancer, maintain the healthy blood pressure, and minimize the glucose level of diabetes-infected peoples and release lutein and lycopene, which provides protection to the eyes from light induced mutilation (Ware, 2017). Tomato is being cultivated on 4.8 million hectares in all over the world the world with global production of 160.0 million tons (Khapte *et al*., 2019). National average yield of tomato is very low in Pakistan than rest of world. Although, tomato is a short-season crop but due to low average yield unable to fulfill consumer requirement as it faces severe water deficits during growth (Chand *et al*., 2021).

Water shortage is an important challenge for all organisms including plants and water availability to agriculture have been decreased up to 17% that poses severe reductions to crop yields. Plants require 70 to 80% water to maintain various vital biochemical, photochemical, and physiological phenomena to grow and survive (Rasheed *et al*., 2020). Water resources are very limited at global scale and in Pakistan as well because three-fourth of the country receives annual rainfall less than 250 mm. The available freshwater is not sufficient to meet the demand of growing population. It has also been predicted that global water use will increase up to 55% by the mid of 21st century (Chaoua *et al*., 2019). Available water resources are under serious threat of shortage due overuse in domestic, industrial, and agricultural sectors. Currently, 4000 km^3 water is being pumped out per year and 70% of pumped water is used to irrigate the crops which are still not sufficient enough to get satisfactory production. As elevated temperature is also affecting the groundwater level in response to continuous evaporation that ultimately increasing the soil salinization (Coppola *et al*., 2004).

Globally, 16% of agricultural lands are under severe drought where crop yield reductions ranged from 51% to 82% (Khan *et al*., 2017). Hence, use of wastewater coming from domestic, agricultural and industrial sources for irrigation have been an acceptable solution to overcome the high yield losses and initially supported by local communities across the world (Moran-Salazar, 2016). Gradually, wastewater usage for irrigation of agricultural crops has been increased in both developing and developed countries of world. An annual increase in waste water usage for crop production in China, European Union and United States of America is up to 10-29% and 41% in Australia (Kobaissi *et al*., 2014).

Today, yield and quality of agricultural crops are two major thrusts of scientific communities. Being a potential source of nutrients and organic matter, wastewater irrigation significantly increases the yield thereby lowering the fertilizer cost. Likewise, excessive nitrogen uptake may extend the vegetative growth phase and retard fruit formation and ripening as reported in rice, sugar beet and sugarcane (Ibrahim *et al*., 2012; Becerra-Castro *et al*., 2015). It has also been reported that wastewater adds some toxic elements and compounds in soil result in retardation of plant growth and developmental processed and ultimately causes yield losses also pose severe impacts on health of human environment. Previous studies at global scale and in Pakistan reported that level of these toxic and hazardous heavy metals have crossed the allowable limits and standard set by the World Health Organization. These metals are toxic, mobile and of persistent nature. Their transfer into food chain through plant uptake is a well-known dilemma as they are absorbed by roots, competes and hinders the phyto-availability of essential nutrients, accumulated in aerial parts consumed by animal and plants (Aleem and Malik, 2003; Khan *et al*., 2013). Metal accumulation lowers the crop yield in response of stunted growth and biomagnifications to human causes severe mental illness, bone and skin diseases, renal dysfunction, hypertension and cancer (Faryal *et al*., 2007).

Therefore, present study was conducted to explore impact of canal and industrials wastewater irrigation on soil quality by growing tomatoes.

Materials and Methods

The research was performed in the research area of the Department of Soil and Environmental Sciences during winter, 2020 at. College of Agriculture, University of Sargodha, Pakistan (932.0737° N, 72.6803° E). Soil was collected from normal field after necessary analysis. Sieving of soil was done through 2 mm sieves followed by drying in air for a day. Afterward, measurement of various physicochemical properties including EC, pH, organic matter, nutrients (N, P, and K) and soil texture was performed (Table 1). Pots were filled with soil @ 7 kg per pot. The seedlings of tomato were collected from the Agronomy Farm of the University of Agriculture Faisalabad (UAF), Faisalabad. Three seedling plants of tomato were planted in each pot. The recommended dose of fertilizer (1g urea/pot) was applied for proper growth and development of the plants. The source of NPK fertilizers was urea, (SSP) and (MOP) respectively. Pre analysis of the soil was done before sowing. Wastewater was analyzed chemically for various parameters (Table 2). Treatments were incorporated using completely randomized design (CRD). There were six treatments used along with four replicates. Treatments included T_1= 100% CW (canal water) irrigation; T_2 = 100% WW (wastewater) irrigation; T_3 = CW 75% + WW 25%; T_4 = CW 50% + WW 50%; T_5 = CW 25% + WW 75% and T_6 = Cyclic/alternate use of CW and WW.

Table 1: *Soil characteristics of experimental area (pre-analysis).*

Determinations	Unit	Value
pH_s	-	8.2
EC_e	dSm^{-1}	1.27
Soil Organic matter	%	0.51
Available K	ppm	110
Available P	ppm	7.81
$Ca^{+2} + Mg^{+2}$	$mmol_e L^{-1}$	3.2
Sodium Adsorption Ratio	-	5.48
Soil textural class	Sandy clay loam	

Table 2: *Analysis of irrigation water (canal and industrial wastewater).*

Characteristics	Units	Waste water	Canal water
EC	$dS\ m^{-1}$	3.1	0.21
TSS	$m\ mol_c\ L^{-1}$	31	2.1
Carbonates	$m\ mol_c\ L^{-1}$	3.7	Nil
Bicarbonates	$m\ mol_c\ L^{-1}$	10.7	1.3
Chloride	$m\ mol_c\ L^{-1}$	4.9	0.7
Sulfate	$m\ mol_c\ L^{-1}$	11.7	0.1
Calcium+ Magnesium	$m\ mol_c\ L^{-1}$	12.2	2.0
Sodium	$m\ mol_c\ L^{-1}$	16.5	0.1
SAR	$(m\ mol\ L^{-1})^{1/2}$	6.70	0.1
RSC	$m\ mol_c\ L^{-1}$	2.20	Nil
Cadmium	$mg\ L^{-1}$	3.5	-
Lead	$mg\ L^{-1}$	5.5	-
Nickel	$mg\ L^{-1}$	2.5	-

Soil analysis

Before and after the experiment, analysis of soil was done. Sampling of soil was done using soil auger. Methods as published in Hand Book 60 of US Laboratory Workers (1969) were adopted for various parameters. Soil texture, organic matter, saturation percentage, EC, pH and nutrients (N, P, K) of soil was determined using methods described in ICARDA manual (Estefan *et al*., 2013).

Plant sampling and analysis

Leaf and fruit tissues of tomato plants irrigated with wastewater were collected at time of harvest. After wet digestion samples were subjected to determination of minerals (nitrogen, phosphorus, potassium) contents following the laboratory methods as published in Hand Book 60 of U.S Laboratory Workers (1969). For determination of P spectrophotometer was used. Flame photometer was used for estimation of K. All collected data was analyzed statistically and Statistix 8.1 was being applied to make analysis of variance (ANOVA). Significance of treatment means was compared through Tukey's (LSD) test at 5% probability level (Steel *et al*., 1997).

Results and Discussion

Concentration of nickel (ppm) in soil

The application of wastewater as source of irrigation (T_2= 100 % waste water) significantly contributed toward the nickel concentration into the soil (Figure 1). The maximum nickel (11.5 ppm) was obtained from the T_2 (100% wastewater). The minimum nickel concentration (0.025 ppm) was obtained from control treatment (T_1 = 100 % canal water). Irrigation with wastewater proved more efficient than canal water for nickel concentration of soil. Honarmandrad *et al*. (2020) noticed the same trend; particularly, the presence of heavy metal such as Pd, Cd, Ni, Fe in soil beyond the permissible limit that ruin the soil health and crop quality when source of irrigation was wastewater. According to the long-term application of wastewater, there was severe threat observed to soil via plant because due to non-bio-degradable nature (Eissa and Negim, 2018).

Lead (ppm) concentration in soil

The data in Figure 2 illustrated that the lead concentration in soil was considerably increased due to the application of wastewater along with canal water at various levels. The maximum lead (6.8 ppm) was obtained from the T_2 (100% wastewater). The minimum lead (0.21 ppm) was obtained from control treatment (T_1= 100 % canal water). Application of wastewater proved more efficient than canal water for lead concentration into the soil. Khan *et al.* (2017) applied the wastewater with organic matter to check the concentration of Cd in soil while the results showed that Cd, Ni and Pb decreased by the combined application of organic matter and help to reduce the toxicity of metal in food. Likewise, Sarwar *et al.* (2020) applied the untreated wastewater to check the metal suck as Cd, Cr, Cu, Fe, Ni, and Zn in soil and results showed that all the metal were on safe limit except Fe. This was also supported by the findings of Bashir *et al.* (2014) and Khan *et al.* (2014).

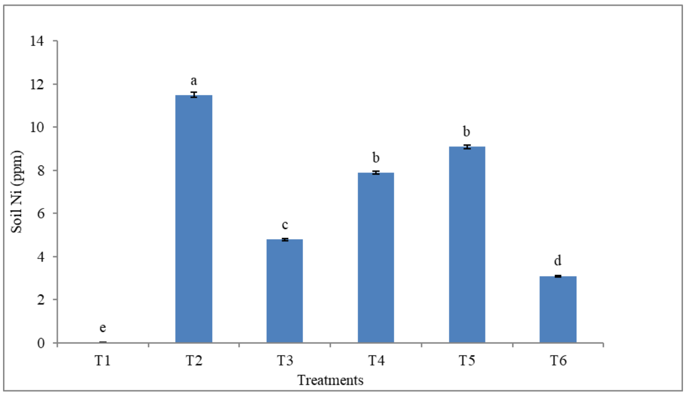

Figure 1: *Hazardous impact of industrial wastewater utilization on Ni content (ppm) in soil. T_1 = 100% CW (canal water) irrigation; T_2 = 100% WW (wastewater) irrigation; T_3 = CW 75% + WW 25%; T_4 = CW 50% + WW 50%; T_5 = CW 25% + WW 75% and T_6 = Cyclic/alternate use of CW and WW.*

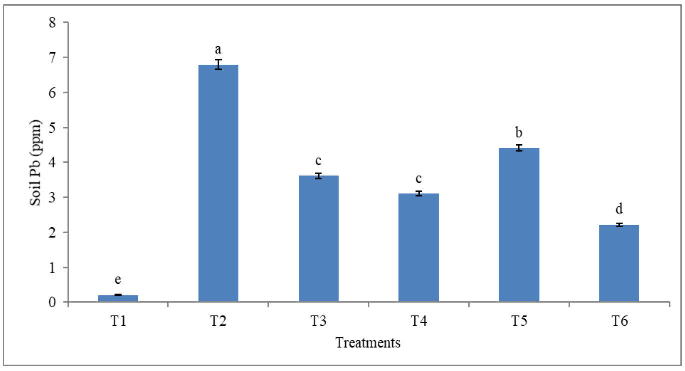

Figure 2: *Hazardous impact of industrial wastewater utilization on Pb content (ppm) in soil. T_1 = 100% CW (canal water) irrigation; T_2 = 100% WW (wastewater) irrigation; T_3 = CW 75% + WW 25%; T_4 = CW 50% + WW 50%; T_5 = CW 25% + WW 75% and T_6 = Cyclic/alternate use of CW and WW.*

Cadmium (ppm) concentration in soil

Figure 3 illustrated that the cadmium concentration in soil was considerably increased due to the application of wastewater along with canal water at various levels. The maximum cadmium (0.163 ppm) was obtained from the T_2 (100% wastewater). The minimum cadmium (0.028 ppm) was obtained from control treatment (T_1= 100 % canal water. Application of wastewater proved more efficient than canal water for cadmium concentration into the soil (Afshan *et al.*, 2015). Sabeen *et al.* (2019) applied the industrial wastewater to soil to check the different metal concentration such as Cd, Cr, Fe, Ni, Pb while obtained data demonstrated that application of wastewater increased the concentration of these metals in soil. Similarly, according to Li *et al.* (2017) application of wastewater increased the cadmium and fluorine concentration in soil through wheat crop.

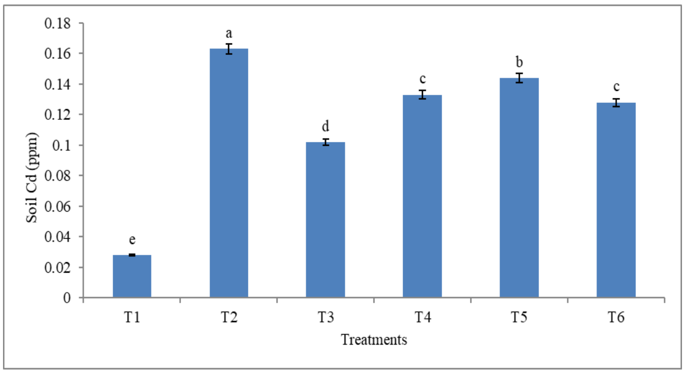

Figure 3: *Hazardous impact of industrial wastewater utilization on Cd content (ppm) in soil. T_1 = 100% CW (canal water) irrigation; T_2 = 100% WW (wastewater) irrigation; T_3 = CW 75% + WW 25%; T_4 = CW 50% + WW 50%; T_5 = CW 25% + WW 75% and T_6 = Cyclic/alternate use of CW and WW.*

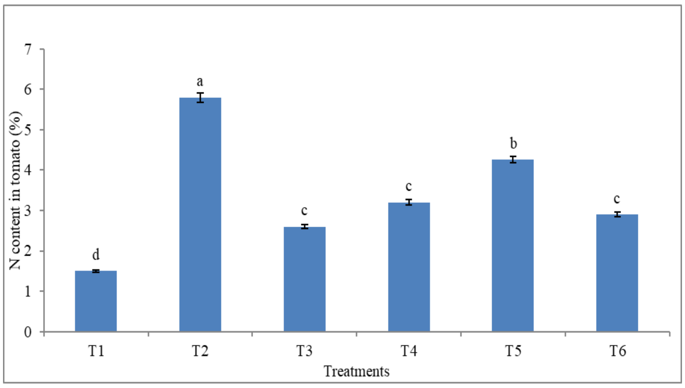

Figure 4: *Hazardous impact of industrial wastewater utilization on N content (%) in tomato plant. T_1 = 100% CW (canal water) irrigation; T_2 = 100% WW (wastewater) irrigation; T_3 = CW 75% + WW 25%; T_4 = CW 50% + WW 50%; T_5 = CW 25% + WW 75% and T_6 = Cyclic/alternate use of CW and WW.*

Concentration of nitrogen (%) in tomato

Nitrogen concentration of the tomato plants was considerably increased due to the application of wastewater along with canal water at various levels (Figure 4). The maximum nitrogen concentration (5.8 %) was obtained from the T_2 (100% wastewater). The minimum nitrogen concentration (1.5 %) was obtained from control treatment (T_1 = 100 % canal water). Similar results were reported by Bashir *et al.*

(2014). They claimed that plant growth may improve by using wastewater because of its highly nutritive value. In fact, the received results showed that the tomato plants irrigated with wastewater had essential improvement with respect to other plants that irrigated with canal water. According to Chaoua *et al.* (2019) the obtained results showed that the growth and yield of tomato crop were highly increased as a result of industrial wastewater. Wastewater application frequently reduces the fertilizer's application requirements because it has a large amount of plant nutrients such as organic matter (N, P and K) and micronutrients.

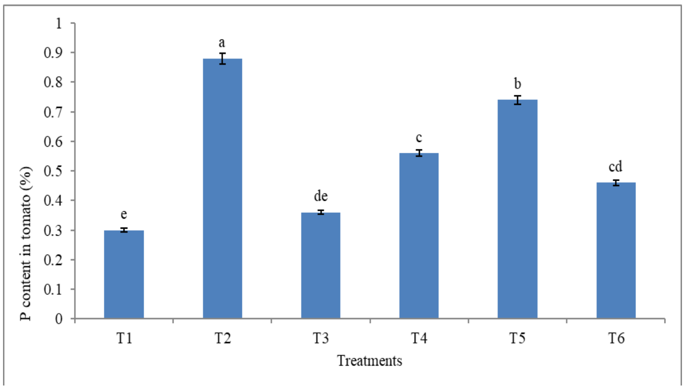

Figure 5: *Hazardous impact of industrial wastewater utilization on P content (%) in tomato plant. T_1 = 100% CW (canal water) irrigation; T_2 = 100% WW (wastewater) irrigation; T_3 = CW 75% + WW 25%; T_4 = CW 50% + WW 50%; T_5 = CW 25% + WW 75% and T_6 = Cyclic/alternate use of CW and WW.*

Concentration of phosphorus (%) in tomato

P concentration of the tomato plants was considerably increased due to the application of wastewater along with canal water at various levels (Figure 5). The maximum phosphorus concentration (0.88 %) was obtained from the T_2 (100% wastewater). The minimum phosphorus concentration (0.3 %) was obtained from control treatment (T_1= 100 % canal water). Cristina *et al.* (2020) also reported same findings about the sludge application of wastewater to soil increased the level of potassium, phosphorus and the organic matter in soil and resulted to bumper plant growth of the tomato plant. Similarly, Meena *et al.* (2016) arranged the field trial to irrigate the pearl millet crop with municipal wastewater and result showed that the application of municipal wastewater decreased the soil salinity, and increase the microbial activity, phosphorus, and potassium concentration of the pearl millet crop.

Potassium (%) of tomato plant

Figure 6 indicated that the concentration of potassium of the tomato plants was considerably increased due to the application of wastewater along with canal water at various levels. The highest K concentration (2.4 %) was obtained from the T_2 (100% wastewater). The lowest K concentration (1.8 %) was obtained from control treatment (T_1= 100 % canal water). Similar findings were reported by Howell *et al.* (2018). They claimed that plant growth may be improved by using wastewater because of its highly nutritive value. The concentration of potassium and the sodium were increased with application of winery wastewater application with result to increase soil EC and pH. According to Meena *et al.* (2016) the treatment of wastewater enhances the level of potassium, phosphorus and organic matter positively with the application of wastewater along the other side the nutritious level of the wheat and mustard crop were significantly improved.

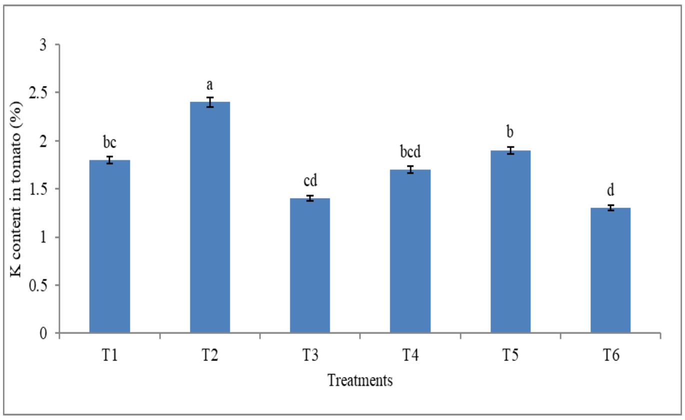

Figure 6: *Hazardous impact of industrial wastewater utilization on K content (%) in tomato plant. T_1 = 100% CW (canal water) irrigation; T_2 = 100% WW (wastewater) irrigation; T_3 = CW 75% + WW 25%; T_4 = CW 50% + WW 50%; T_5 = CW 25% + WW 75% and T_6 = Cyclic/alternate use of CW and WW.*

Conclusions and Recommendations

Findings of present research implied that irrigation with wastewater significantly improved the growth and nutrient acquisition of tomato plants. Highest values for N, P and K content of tomatoes were recorded when 100% wastewater was applied as a source of irrigation. Similarly, soil quality parameters like EC, pH, organic matter, P, K concentration and heavy metal was found maximum in pots receiving pure wastewater (T_2). However, it is the cyclic use of wastewater with canal water that can safely be used for getting good quality tomatoes and to mitigate hazardous impact of heavy metals contained in wastewater.

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Novelty Statement

Cyclic use of waste with canal water can safely be practiced for growing good quality tomatoes and to mitigate hazardous impact of heavy metals contained in wastewater.

Author's Contribution

Rehman Shabbir: Conducted the research trial
Ghulam Sarwar: Supervised the trail
Noor-us-Sabah: Statistical analysis
Mukkram Ali Tahir: Co-supervision of the trial
Muhammad Luqman: Proof reading and final editing
Muhammad Fahad Ullah: Technical assistance at every step for write up
Muhammad Zeeshan Manzoor: Helped in all field and Lab. work
Imran Shehzad: Helped in all field and Lab work.

Conflict of interest
The authors have declared no conflict of interest.

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