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IRRIGATION WATER QUALITY EFFECTS ON CO_2 EMISSIONS ALONG WITH CROP AND SOIL RESPONSES

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A field experiment was conducted to study the impact of three different water qualities on maize biological yield, soil properties and CO_2 emissions from cropped soil. The experiment was laid out at Agronomic Research Farm, University of Agriculture Faisalabad under Completely Randomized Design (CRD). Soil sample was collected at different depths for pH, EC, N, P, K and organic matter to observe the impact of different water qualities on soil and crop yield. Three different water qualities were applied for irrigation under conventional irrigation system of Pakistan. Three treatments as canal water (EC=0.25 dS m^{-1}), wastewater (EC=3.07 dS m^{-1}) and treated wastewater (EC=2.88 dS m^{-1}) were studied with three replications. Data regarding water qualities impact on soil, corn growth and chemical analysis of canal water, wastewater and treated wastewater along with measurement of CO_2 emissions were recorded by using standard procedures. The data was statistically analyzed by applying Fisher's analysis of variances technique. The results showed that wastewater irrigation significantly increased crop yield and growth as compared to two other water qualities. Wastewater irrigation also significantly enhanced the soil organic matter, nitrogen, phosphorus and potassium that are essential for good plant growth and proved good for soil as well. The results of the study also showed that wastewater irrigation application significantly increased the CO_2 emission with weekly increments and contributes towards global warming which ultimately affect the climate and cause climate change. Objective of research was to observe the impact of different water qualities on crop growth, soil, environment and CO_2 emission under conventional irrigation systems of Pakistan.

Keywords: canal water, climate change, CO_2 emission, irrigation water, Maize, treated wastewater, water qualities, wastewater.

INTRODUCTION

Pakistan falls in one of those countries that depend mainly on a single river system to fulfill the need of agricultural water demands. Huge quantity of irrigation water is lost due to traditional irrigation practices which could be saved by adopting water efficient techniques (Rizwan et al., 2018). Precipitation is the major source of water supply to the Indus River and its tributaries. According to study conducted by Rizwan *et al.* (2019) in the source region of Indus River, light precipitation had significantly decreasing trend while heavy precipitation had significantly increasing trends because of which droughts and flood will occur. Failure to accomplish regular distribution of rainwater, seasonal flood and reduction of glaciers are harmfully disturbing the accessibility of fresh water (Ranjan, 2012). As stated by UN organization a nation is under water shortage if it has below 1000m^3 per person water accessibility (Murtaza and Zia, 2012). Practice of recycling wastewater for agriculture has become popular because it is a valuable source for plants nutrients and soil organic matter but due to the presence of toxic chemicals and pathogens wastewater poses negative impacts on environment and human health (Abegunrin *et al.*, 2016). Fresh water scarcity resulted in inadequate irrigation requirements in current scenarios worldwide. In these conditions, the reclamation of sewage and blackish water becomes very important and effective (Shilpi *et al.*, 2018). Wastewater irrigation somewhat decrease the soil's capacity to hold nutrients.

Wastewater application for more than 10 years reduces the biomass productivity and plant vital nutrients as P, NO_3, N and K (Matheyarasu *et al,* 2016). Khan *et al.* (2013) proposed that contamination level was low in soil irrigated with tube well and high in soils irrigated with wastewater. Ayoub *et al.* (2016) analyzed that soil chemical properties (pH, EC, Ca, Na, P, K, Cu, Mn, Pb and B) in soil irrigated with reclaimed wastewater were significantly higher than in soil irrigated with fresh water. The duration of wastewater irrigation is very important to understand the accumulation of Pb and Cd in plants (Rusan *et al.*, 2007). Heavy metals absorption in plants produce in wastewater irrigated soils are greater than in plants grown in the soil that is not irrigated with wastewater (Khan *et al.*, 2008). Wang *et al.* (2007) stated that there was no significant effect on yield but yield was slightly higher in field irrigated with domestic wastewater. Heidarpour *et al.* (2007) studied that no significant effect on soil sodium, phosphorus and total nitrogen due to irrigation with wastewater. Wastewater increased organic matter in soil about 20-30%, increased in soil pH by 2-3 units, increased in cation exchange capacity of soil and built up of heavy metals (Qishlaqi *et al.*, 2008).

Carbon dioxide ($CO_{2)}$ is produced through several processes like root respiration, rhizosphere respiration and decomposition of dead plant material. Soil respiration is linked to the root density so that the more root density causes more release of CO_2. Some of the carbon dioxide accumulated by photosynthesis and most of them was released into the air. Carbon dioxide released by the air is a greenhouse gas which cause warming of the earth surface or global warming. Schewe *et al.* (2014) performed a study by using global hydrological models (GHMs) and concluded that global warming of more than 2.7 degree centigrade, 15% of global population would face sever water shortage and the number of people also increased that would face water scarcity. The present research was conducted to investigate the effects of different qualities of irrigation water on maize growth, its biological yield, soil properties and CO_2 emission.

MATERIALS AND METHODS

The experiment was carried out at Agronomy Farm, University of Agriculture Faisalabad. The experimental area is located at 31.4288º North latitude to 73.0753º East longitude with altitude of about 184.4 m. The soil on which the experiment conducted was sandy loam. The base soil data is presented in Table 1. Keeping in view the objectives of the study Completely Randomized Design (CRD) was selected for experimental purpose and the duration of the trial was 50 days. Nine plots were selected for experiment each having area of 1m^2. Study layout along with its location is presented in Figure 1.

Three treatments with different water qualities namely canal water (EC=0.25 dS m^{-1}), wastewater (EC=3.07 dS m^{-1}) and treated wastewater (EC=2.88 dS m^{-1}) were studied at three levels with replicated nine times to observe the irrigation quality impact on crop biomass, soil and CO_2 emission in environment (Fig. 2). Wastewater was taken from the drain of industrial and domestic carrying wastewater passing near to the Agronomy Farm University of Agriculture Faisalabad, treated wastewater was taken from the stabilization ponds of Chokera treatment plant and canal water was taken from the water course of Agronomy Farm University of Agriculture Faisalabad. Maize hybrid DK-9108 was used with plant to plant distance 23 cm and row to row distance was also 23 cm. Total number of seeds planted in each plot were 25. Canal water was applied for 18 days after the sowing of crop given time to establish the crop germination and afterwards treatments were applied. Treatments were applied after 7 days according to the requirement of maize crop (Anjum *et al.*, 2014; Amin *et al.*, 2015).

Data regarding water qualities effects on soil (EC, pH, nitrogen, phosphorus, potassium, organic matter and sodium), chemical analysis of wastewater and treated wastewater (pH, EC, total dissolved solids, total suspended solids, ammonia, sulphate, fecal coliform and total organic carbon), impact of irrigation water qualities on corn growth (germination rate, plant height, dry matter weight and biological yield) and water qualities impact on CO_2 emission for six weeks were recorded by using standard procedures (back titration method). Data were statistically analyzed by applying Fisher's analysis of variances technique. All the data tables have been prepared for statistical analysis by using Statistics 10.0 software.

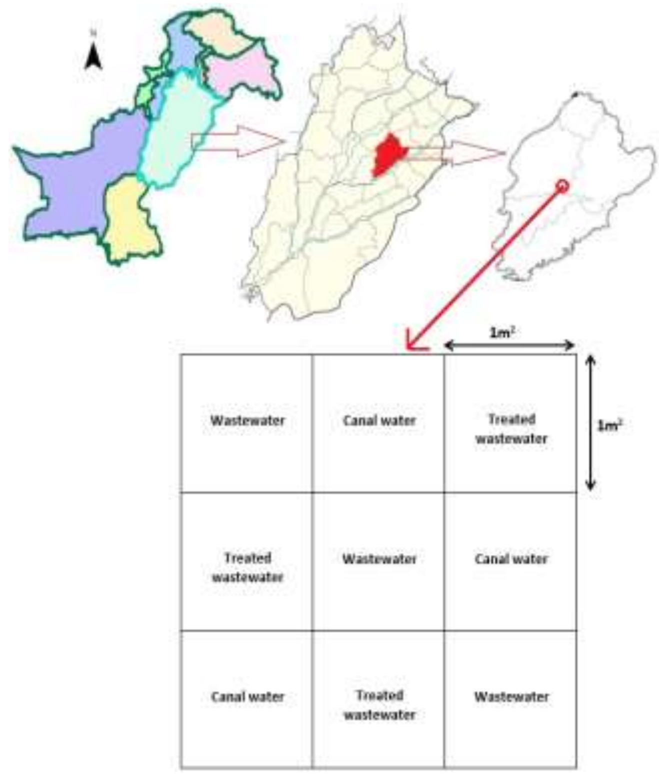

Figure 1. Study layout along with location.

Table 1. Base soil data of the experimental site.

Soil depth	Soil texture	pH	EC dS m^{-1}	Organic matter (%)
0-15	Sandy loam	8.0	0.97	0.74
15-30	Sandy loam	8.2	0.46	0.79

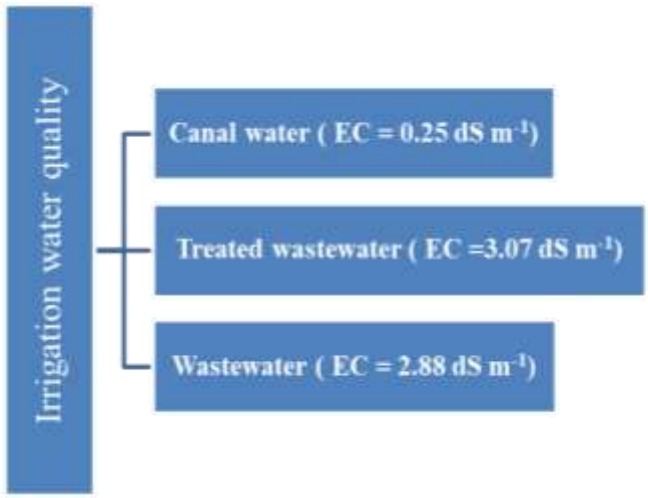

Figure 2. Irrigation water quality levels

RESULTS AND DISCUSSION

***Water qualities effects on soil*:** Soil samples were collected before sowing of crop to get the status of crop, it was observed during maturity of crop (30 DAS) and after the harvesting of crop (60 DAS) to investigate the water qualities impacts on soil chemical properties. Soil samples were collected from all the experimental plots and soil parameters were measured. Electrical Conductivity (EC) explains the presence of salinity. So, effect of irrigation water quality was tested and bottom-line was significantly proposed that the varying water qualities change electrical conductivity shown in Table 2. It was observed that by applying canal water soil EC decreased significantly in comparison to wastewater application. However, it showed non-significant changes with treated wastewater. Kiziloglu *et al.* (2008) reported that wastewater application increased soil salinity, organic matter, exchangeable Na, K, plant available phosphorus and microelements. Similar findings were observed previously by Bedbabis *et al.* (2014).

The pH analyses showed that wastewater slightly increased soil pH as compared to canal water and treated wastewater. Data regarding pH is shown in Table 2. Results are in line with Abegunrin *et al.* (2016) who explained that the use of wastewater irrigation increased the soil pH, Mg and K contents.

The data for nitrogen of soil was significantly different for wastewater and canal water that changed nitrogen of soil in different ways shown in Table 2. Nitrogen was more in wastewater plots (0.056%) as compared to canal water and treated wastewater. Similar result was founded by Bedbabis *et al.* (2014). Wastewater leads to significant increase in N, P, K, NA, EC, and organic matter reported by Galavi *et al.* (2010).

The data for soil average phosphorus was significantly different for all the three water qualities that changed phosphorus of soil as shown in Table 2. Average value of phosphorus was high in soil irrigated with wastewater 6.73 ppm as compared to 4.9 ppm in soil irrigated with canal water. Similar results were founded by Bedbabis *et al.* (2014) and Galavi *et al.* (2010).The data for soil exchangeable potassium was significantly different for all the three water qualities that changed exchangeable potassium of soil at different levels as shown in Table 2. Irrigated soil with wastewater contains large amount of Potassium. Same results were founded by Abegunrin *et al.* (2016) and Bedbabis *et al.* (2014).

Organic matter is widely regarded as a vital component of soil fertility. The data for soil organic matter was significantly different for all the three water qualities that changed organic matter of soil at different levels as shown in Table 2. The highest organic matter was found in the soil irrigated with wastewater as 0.88% as compared to 0.75% obtained in soil irrigated with canal water. This implies that wastewater contains organic matter compounds which makes soil healthier. Same result was found by Abegunrin *et al.* (2016) and Bedbabis *et al.* (2014).

The data for soil exchangeable sodium was significantly different for wastewater and canal water changed exchangeable sodium of soil. Results showed that the amount of exchangeable sodium in soil irrigated with wastewater was 0.43 mmolc/100g as compared to 0.30 mmolc/100g recorded in the soil irrigated with canal water. Same result was found by (Abegunrin *et al.*, 2016 and Bedbabis *et al.*, 2014). Wastewater irrigation increased organic carbon, total phosphorus and potassium concentration, electrical conductivity, phenol concentration, pH, exchangeable sodium and salinization level reported by Zenjari and Nejmeddine (2001).

***Chemical analysis of wastewater and treated wastewater*:** Chemical analysis of wastewater treated wastewater and canal

Table 2. Statistical analysis of soil parameters.

Sr. No.	Treatments	EC	pH	Nitrogen (%)	Average phosphorus (ppm)	Exchangeable potassium (ppm)	Organic matter (%)	Exchangeable sodium (mmolc/100g)
1	Wastewater	0.30a	8.5a	0.056a	6.73a	180.67a	0.89a	0.43a
2	Treated wastewater	0.29ab	8.3b	0.053a	5.60b	176.33b	0.83b	0.37ab
3	Canal water	0.25b	8.1c	0.046b	4.90c	151.00c	0.76c	0.30c

Level with different letters are statistically significant at α=0.05

Table 3. Results of wastewater and treated wastewater parameters.

Parameters	Unit	Value for wastewater	Value for treated wastewater	NEQS for wastewater and treated wastewater
pH	--	7.30	7.93	6-10
EC	mS cm^{-1}	3.07	2.88	NG
TDS	mg L^{-1}	1790	1720	3500
TSS	mg L^{-1}	237	110	150
Ammonia	mg L^{-1}	0.24	<0.013	40
Sulphate	mg L^{-1}	172	135	600
Fecal coliform	--	Positive	Positive	NG
Total organic carbon	mg L^{-1}	390	88	NG

NG: Not Given, TDS: Total Dissolved Solids, TSS: Total Suspended Solids, NEQS: National Environment Quality Standard

water were performed prior to irrigation to find out the status irrigation water qualities. Samples were collected and then investigated for EC, pH, TDS, TSS etc. Results are given in Table 3. This research showed that parameters of wastewater like pH value 7.30 within the National Environment Quality Standard (NEQS) of 6-10, EC value 3.07 dSm^{-1}, TDS value 1790 mgL^{-1} within the range of NEQS as 3500 mgL^{-1}, TSS value 237 mgL^{-1}against NEQS of 150 mgL^{-1}, ammonia (NH_4-N) value 0.24 mgL^{-1} also with NEQS range as 40 mgL^{-1},Sulphate, fecal coliform and total organic carbon also remained within NEQS.

This research showed that pH value 7.93 within the National Environment Quality Standard (NEQS) of 6-10,EC value 2.88dSm^{-1}, TDS value 1720 mgL^{-1} within NEQS range of 3500 mgL^{-1},TSS value 110 mgL^{-1} within NEQS value of 150 mgL^{-1}, ammonia (NH_4-N) value <0.013 mgL^{-1} also within NEQS range as 40 mgL^{-1}. Sulphate, fecal coliform and total organic carbon also remained within NEQS (Table 3).The analysis was conducted in the standard way for wastewater and treated wastewater testing.

***Impact of irrigation water qualities on corn growth parameters*:** Germination rate for corn seedlings was observed on daily basis until 100% germination was obtained. After 1st week the 75% plants were germinated and after 2nd week germination rate was 100%. Generally, the emergence count was 11-12 plants per square meter (Table 4).

Table 4. Mean germination rate of corn for various treatments.

Water quality	Total emergence count m^{-2}			Average
Canal water	11	11	11	11
Treated wastewater	12	12	13	11
Wastewater	10	11	12	12

The results of irrigation water quality on plant height were statistically significant shown in Table 5. Use of wastewater increased the plant height as compared to canal water and treated wastewater. The maximum plant height 152 cm was obtained in plots irrigated with wastewater as compared with other two treatments. The plots that were irrigated with treated wastewater also showed increase in plant height as compared to plots irrigated with canal water. Similar result was found by the Tavassoli *et al.* (2010).

Mean comparison showed that the use of wastewater in comparison with canal water irrigation increased the dry matter weight (44000 kg ha^{-1}) because of the presence of enough amounts of nutritious elements in wastewater shown in Table 5. The plots that were irrigated with treated wastewater also showed increase in dry matter weight of plants as compared to the plants irrigated with canal water. Tavassoli *et al.* (2010) reported that wastewater improves the yield and plant dry matter weight as compared the irrigation with canal water. Similar results were found by Barbera *et al.* (2013).

Effects of irrigation water quality on biological yield were statistically analyzed in Table 5. Mean comparison showed that the use of wastewater in compassion with canal water irrigation increased the biological yield (76000 kg ha^{-1}). The increase of biological yield of corn could be related to the amount of enough nutritious elements in wastewater as N, P and K. In present study the positive impacts of wastewater and treated wastewater on crop growth were investigated. Similar result was found by Tavassoli *et al.* (2010). Barbera *et al.* (2013) also proposed that wastewater increase crop yield, growth and dry matter weight of crop.

Biological yield and plant dry matter of maize against different irrigation quality levels are presented in Figure 3.

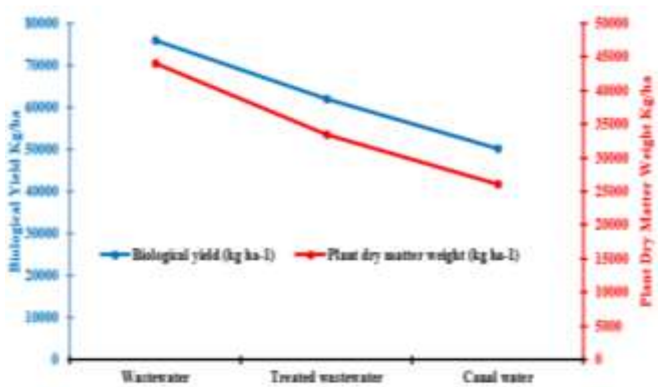

Figure 3. Crop yield against Irrigation water quality levels.

Table 5. Crop responses under different water qualities.

Sr. No.	Treatments	Plant height (cm)	Plant dry matter weight (kg ha^{-1})	Biological yield (kg ha^{-1})
1	Wastewater	152.33 a	44000 a	76000 a
2	Treated wastewater	141.00 b	33330 b	62000 b
3	Canal water	131.33 c	26000 c	50000 c

Level with different letters are statistically significant at α=0.05

Table 6. Water qualities impacts on CO_2emissions.

Sr. No.	Treatments	CO_2 emission in 1st week	CO_2emission in 2nd week	CO_2 emission in 3rd week	CO_2 emission in 4th week	CO_2 emission in 5th week	CO_2 emission in 6th week
1	Wastewater	195.00 a	298.00 a	259.00 a	220.67 a	300.00 a	300.00 a
2	Treated wastewater	150.00 a	252.33 b	209.00 b	220.67 b	245.00 b	228.00 b
3	Canal water	98.667 b	197.00 c	143.00 c	117.00 c	191.33 c	158.00 c

Level with different letters are statistically significant at α=0.05

Water qualities impacts CO_2: To investigate the different water qualities contribution in the changing climate and carbon dioxide emissions were measured in canal water irrigated plots, wastewater irrigated plots and treated wastewater irrigated plots by using back titration method. The effect of irrigation water quality tested highly significant suggested that the varying water qualities produce different carbon dioxide emission (Table 6).

CO_2 emission observed for 1st week after irrigation was significantly different for all the three water qualities. The CO_2 emissions were 98.667 mg kg^{-1} from soil irrigated with canal water as compared to wastewater and treated wastewater (Table 6). The maximum 195 mg kg^{-1} value of CO_2 emission was determined in wastewater.

CO_2 emission for 2nd week after irrigation was significantly different for different water qualities. Maximum value of CO_2 was measured in wastewater plots 252.33 mg kg^{-1}. Lowest value of CO_2 measured in plots irrigated with canal water 197.00 mg kg^{-1} and this indicated the less production of CO_2 emission and less warming of climate. Rise in CO_2 emission observed in treated wastewater as compared to plots irrigated with canal water. More CO_2 emission towards climate change was in wastewater and treated wastewater rather than emission from the plots irrigated with canal water.

The values recorded for CO_2 emission for 3rd week after irrigation was also significantly different for different water qualities. The average values of the treatments showed that extreme value of $CO_2$was observed in wastewater 209 mg $kg^{-1}$and minimum was recorded in plots irrigated with canal water 143 mg kg^{-1}.This exposed the smaller production of CO_2 emissions and lesser warming of climate (Table 6).

The value of CO_2 emission for 4th week after irrigation was also statistically significant for different water qualities. Highest value of CO_2 was recorded in wastewater 220mg $kg^{-1}$and smallest in plots irrigated with canal water 117 mg kg^{-1}. This showed the minor emissions of CO_2 and slight warming of climate. Boast in CO_2 emission was in plots of wastewater irrigated as compares to plots of canal water.

In 5th week maximum value was observed in wastewater plots 254 mg $kg^{-1}$and lowest in canal water 191.3 mg kg^{-1} and this specified the little production of CO_2 emissions and lower warming of climate as shown in Table 6. More CO_2 emission observed in wastewater and treated wastewater as compared to plots irrigated with canal water.

The data of CO_2 emission for 6th week also showed the same trend as in 1stto 5th week regarding CO_2 emission. Maximum value of CO_2 in this week for wastewater plots was 228 mg kg^{-1}while lowest in plots of canal water 158 mg kg^{-1}. This directed the less production of CO_2 emission and less warming of climate. Similar results were found by EL-Fadel and Massoud (2001).

Conclusion**:** It is concluded that wastewater has a high nutritive value that improves plant growth, reduce fertilizer application and increase productivity of poorly fertile soils. Wastewater irrigation affects the physical as well as chemical properties of the soil, yield and the mineral content in the plant. Wastewater can be used as an alternative water resource in water scarcity and it is also an organic fertilizer due to the presence of organic carbon, excess nitrogen, potassium and phosphorus which reduce mineral fertilization cost. Wastewater cannot be used for long duration due to its bad impact on climate and the presence of heavy metals which may affect the human health. More plant height, dry matter weight and biological yield were observed in wastewater then in treated wastewater and minimum in canal water. The wastewater irrigation increases the emission of CO_2 from soil as compared to canal water and treated wastewater. Canal water has less value of emission of CO_2 gas when compared to all the other water qualities. Treated wastewater irrigation can be used for agricultural practices in long run because it does enhance the plant yield and soil nutrients.

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