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Effect of Wastewater Irrigation on Growth and Yield of Rice Crop and Uptake and Accumulation of Nutrient and Heavy Metals in Soil

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Abstract Effect of irrigation with untreated and treated wastewater from Vidyaranyapuram sewage treatment plant station on growth and yield of rice as also in enrichment and bio accumulation of nutrients and metals in soil and rice plant in Vidyaranyapuram area in the South West of Mysore, Karnataka was selected. Treatments included untreated wastewater (UWW); treated wastewater (TWW) and ground water (GW) as control. Experimental was in randomized complete block design with 3 treatments with 3 replicates. Soil samples were collected from 0 - 60 cm depths were analyzed for pH, EC, nutrient and heavy metals contents. Plant height, tiller panicle length, number of tillers per plant, weight of 1000 seeds and yield/ plant were used as indicators. The wastewaters according to FAO system of water quality classification were found suitable for use in leaching and irrigating saline soils especially for short duration crops. Great changes in soil properties due to irrigation with UWW and TWW were observed. The growth and yield characters of rice crop were not improved by irrigation with UWW and TWW; however the high concentration of trace metals affected by lowering the growth and yield (number of grains/panicle, weight of 1000 seeds and yield/plant) attributing factors when irrigated by UWW and TWW as compared to GW control. These effects could be attributed to higher accumulation of micronutrients and macronutrients in soil and plant, when the mean values were highly significant as indicated by the present study.

Keywords: *wastewater, rice, growth and yield, nutrient, bio-accumulation factor*

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1. Introduction

The reuse of wastewater, in particular for irrigation, is an increasingly common practice, encouraged by governments and official entities worldwide. Irrigation with wastewater may have implications at two different levels: alter the physic-chemical properties and microbiological content of the soil and/or introduce and contribute to the accumulation of chemical and biological contaminants in soil. The first may affect soil productivity and fertility; the second may pose serious risks to the human and environmental health. The sustainable wastewater reuse in agriculture should prevent both types of effects, requiring a holistic and integrated risk assessment [1,2], did empirical study on profitability of rice cultivation in the East Calcutta Wetlands region in India. Plots using wastewater containing organic nutrients earn lower profits than those using groundwater. They also found that the profitability from using wastewater was negatively affected by the presence of heavy metals such as Lead and Mercury that are carried through untreated wastewater and get deposited in the soil. Of the two opposing effects of wastewater irrigation, the negative effect of heavy metal toxicity outweighs the positive effects of organic nutrients. [3,4], showed that wastewater increases soil salinity, organic carbon, N, K, Ca and Mg cations to a great extent. Soil is a biofilter that can reduce a large part of domestic wastewater pollutants, but the filtering increases EC, SAR, Na, Ca and Mg of soil. The results of [5,6] experiments showed that irrigation with wastewater significantly increased the macro elements (N, P and K) contents in corn forage by irrigation with wastewater. This increase could be related to the amount of nutritious (such as N, P and K) in wastewater. [7], observed that the soil physical (bulk density, particle density, total porosity, pore size distribution and aggregate stability) and hydraulic (water retention and infiltration) properties get significantly affected from wastewater irrigation to cauliflower and red cabbage plantings. Soil electrical conductivity and organic carbon content in wastewater irrigated soil were higher than in freshwater irrigated soil.

Wastewater application can result in a number of problems such as pathogenic infection and heavy metal accumulation in soil, underground water and crops to toxic levels [8]. Wastewater usage for irrigation has the benefits of conserving water and nutrients, reducing the pollution of rivers and canals, providing micronutrients, organic matter, all required nitrogen, and much of the required phosphorus and potassium for normal crop production [9]. CEC of investigated soil samples was high. High clay content results in high CEC of soil that holds more nutrients and loses few of them with rainfall [10]. Sand content of soil has influenced on bulk density than any other soil property. Clayey soils tend to have lower bulk densities and higher porosities than sandy soils [11]. [12], reported that, field application of all types of wastewater significantly increased soil cation exchange capacity (CEC). [13], found that Irrigation with wastewater leads to increasing accumulation of K, Na, Fe, Mn, Zn, Cu and B in the soil, compared to freshwater irrigated areas. [14], studied the effect of irrigation schedules of domestic wastewater on growth and yield of fodder sorghum. Continuous use of wastewater for irrigation tended to increase soil electrical conductivity (EC) and decreased soil pH. [15], revealed that, the wastewater does not cause pollution to soil and crops by accumulation of heavy metals (Cd, Cr, Cu, Zn), and the index for heavy metals content is far below the critical value of the national standard. The heavy metals were in the soil less than that taken away by the crops irrigated with wastewater. The output and input quantities have small effects on the heavy metals balance in the soil. [16], investigated the influence of irrigation with treated wastewater on soil chemical properties, olive tree yield and on virgin olive oil quality. Results showed that irrigation with treated wastewater increased soil pH, EC, OM, major elements (N, P, K, Na, Cl and Mg), salts and heavy metals such as Mn, Zn and Fe contents compared with well water irrigation. [17], evaluated the impact of treated wastewater irrigation on five native medicinal shrubs. Each species of shrub showed different selectivity to accumulate specific elements in their shoots, with high concentrations of N, P, K, Mn, Zn, Ni, Cu, Cd and Pb in forest site plants. Cd and Ni concentrations in shoot samples from both the planation and control sites were about 13 and 500 times above the permissible limits, respectively. [18], had discussed the feasibility of using low-cost filtered municipal wastewater for the irrigation of red amaranth. The accumulated levels of Fe, Mn, Cu, and Zn were within the safe limits; however, the concentration of Pb exceeded the safe limits.

The objective of this investigation was to determine the effects of untreated and treated wastewater irrigation on growth and yield of rice as also on soil properties and the quantum of enrichment and bio accumulation of nutrients and metals in soil and rice crop irrigated with wastewater.

2. Materials and Methods

2.1. Study Sites

The study area is located in the suburban area in the South Western part of Mysore city, Karnataka, India, where sewage treatment plant of Mysore city is located. Locations were selected to get information understanding on the effect that typical wastewater creates on soil and rice crop in Mysore city. The present study also covers the physico-chemical characteristics of water samples collected from Vidyaranyapuram sewage treatment plant station. More than fifty percent of the sewage water handled by Mysore city is received by Vidyaranyapuram Sewage Treatment Plant. The total sewage generation of sewage treatment plant is 67.75 million liters per day. It is a biological treatment plant situated next to the solid waste disposal area at the foot of Chamundi Hills; the treated wastewater of Vidyaranyapuram sewage treatment plant (crosses the Dalvai Lake and reaches drinking water source that is the Kabini River. The treated sewage water is pumped out after sewage treatment to field channels for direct use as irrigation water; the farmers use also the untreated wastewater for irrigating various crops.

Field surveys were carried out in and around Mysore city, to collect soil, water and plant samples. Water samples collected from different sources included untreated wastewater, treated wastewater and ground water. The rice variety used for this trial crop was Jyothi, red rice. The experiment was conducted on sandy loam soil for UWW, loamy sand soil for TWW and sand soil for GW. Soil samples from 0-20, 20-40 and 40-60 cm depths and leaf samples of rice crop, grown on these fields and irrigated with various water types were collected. On the whole the samples of untreated wastewater, treated wastewater and ground water, along with soil and crops samples from the respective fields irrigated with these water sources were collected. The collected water samples were brought to the Soil Science laboratory of the university and filtered through Whitman filter paper no. 1. Immediately pH and EC of water samples were measured. Then water samples were acidified with few drops of l N nitric acid and stored in polythene bottles for further analyses. The collected soil samples were air dried, ground with wooden mortar and pestle, passed through 2 mm sieve and kept for further analyses. The collected plant samples were washed with distilled water and dried in oven at 60^oC till constant weight. These were ground in a micro grinding mill and stored. The soil and water samples were analyzed for physical and chemical properties while crop samples were analyzed for nutrients and heavy metals contents.

According to Soil and Plant Analysis Laboratory Manual of International Center for Agriculture Research in Dry Areas [19], common soil physical measurements were conducted, including particle size distribution, texture, porosity, bulk density and infiltration rate. The wastewater and ground water samples were analysed for such parameters pH, EC, nutrients and heavy metals contents as per standard, [20], methods. The soil samples were also analysed for the physico-chemical properties, nutrients content and heavy metals concentration. The concentrations of heavy metals in the soils were determined after digestion using the Hossner method [21]. The total concentrations of Fe, Mn, Cu, Zn, Cd, Ni, Pb, Co and Cr were determined by ICP-OES (Perkin Elmer, Model 8000 DV). Means for elements were calculated from triplicate samples. Water analysis was performed according to the standard methods [20]. The results of the water analyses are presented in Table 1. Dried plant samples were powdered using a pestle and mortar and sieved through muslin cloth and 0.5 g of the dried plant tissue was analyzed for: N, P, K, Ca, Mg, Na, Fe, Mn, Cu, Zn, Cd, Ni, Pb, Co and Cr. N concentration was determined after mineralization with sulphuric acid by "Kjeldahl method" [22], Na and K were by flame emission, P by colorimetric method [23] and Ca, Mg, Fe, Mn, Cu, Zn, Cd, Ni, Pb, Co and Cr concentrations by inductively coupled plasma optical emission spectrometry (ICP-OES, Perkin Elemer model 8000 DV).

2.2. Measuring Plant Growth and Yield

Observations on growth and yield of rice were taken randomly for five rice plants from each plot and every treatment. Plant height, tiller panicle length from the plot (cm), number of tillers per plant, weight of 1000 seeds (g) and yield/ plant (g) were recorded. Crop growth rate was worked out as proposed by [24].

2.3. Enrichment Factor (EF)

The EF was calculated according to the following equation [25]:

$$EF = C_T / C_B \quad (1)$$

Where, C_T is the concentration of the examined metal in the amended soil, C_B is the concentration of the background value of a given metal in the control soil. The enrichment factor is used to assess extent of soil contamination (enrichment), and it is interpreted as: EF < 2– depletion to minimal enrichment, EF 2 < 5 – Moderate enrichment, EF 5 < 20 – Significant enrichment, EF 20 < 40 – very high enrichment EF >40–extremely high enrichment [26,27].

2.4. Bio-accumulation Factor (BAF)

The BAF of Ca, Mg, Na, K, N, P, Fe, Mn, Cu, Zn, Cd, Ni, Pb, Co, and Cr and Pb in the plant samples were calculated as follows:

$$BAF = C_{plant} / C_{soil} \quad (2)$$

Where, C_{plant} is the concentration of the element in the plant, and C_{soil} is the concentration of same element in the soil on dry weight basis.

2.5. Statistical Analysis

The results of soil and crop analyses were subjected to analyses of variance (ANOVA) as applicable to a completely randomized block design. The statistical analysis was performed for each parameter, and the values compared as per Duncan's least significant difference test at $p < 0.05$. All statistical analyses were carried out using the SAS program, Version 9.1 [28]. Pearson's correlation coefficients between soil elements and elements in crops were calculated to evaluate the relation between these parameters in the soil and the crop. Correlation analyses were computed using the software package SPSS (version 19.0).

3. Results and Discussion

3.1. Water-quality Parameters

Regardless of the source of water (wastewater or groundwater) the quality of any water needs to be fit for irrigation. Parameters considered to assess wastewater quality included nutrients (N, P and K), salts (EC and TDS), cations and anions (HCO_3, CO_3, SO_4, Cl, Ca, Mg, Na, and K), trace elements (Fe, Mn, Cu, Zn, Cd, Pb, Ni, Pb, Co and Cr), and acidity/alkalinity (pH) [29]. The results of physico-chemical analysis of irrigation water (UWW, TWW and GW) were presented in Table 1. The values for BOD, COD and TSS are higher for UWW and TWW whereas lowest is for GW. According to FAO (1992) the tolerance limit of pH of water samples for irrigation should be 6.50-8.40. The electrical conductivity (EC) values of 1348, 1190 and 987µS/cm for UWW, TWW and GW, respectively indicated the salinity of the water [30]. Total of N, P and K level in UWW and GWW are higher than in GW which are considered essential nutrients for plant growth and soil fertility. All micro-nutrients and heavy metals concentrations in the wastewater and ground water are lower than the standard values prescribed for wastewater reuse as irrigation except Cd levels which are 4 times higher in the irrigation water than the recommended level of 0.01 mg/l as prescribed by [31].

3.2. Effect of Untreated and Treated Wastewaters and Groundwater Irrigation on Soil

3.2.1. Physical Parameters of Soil

Soil texture is an important characteristic that drives crop production and field management. The textural class of soil is determined by the percentage of sand, silt, and clay [32].The data on colour and soil texture of soils are presented in Table 2, GW irrigated rice crop grown soil is red sandy, while UWW and TWW irrigated soil were light gray loamy sand and sandy loam respectively. The soil colour may be due to the organic content of UWW and TWW. The results of the present study showed that there was similarity for soil texture of UWW was sandy loam and loamy sand while GW was sandy.

Table 1. Chemical characteristics of the irrigation waters

Parameters	UWW	TWW	GW
pH µS/cm	7.36	7.86	7.98
EC mgl^{-1}	1348	1190	987
DO mgl^{-1}	Nil	2.8	6.1
COD mgl^{-1}	820	259	52
BOD mgl^{-1}	597	66	13
TDS mgl^{-1}	582	531	498
Ca mgl^{-1}	50.24	51.90	47.20
Mg mgl^{-1}	33.98	40.10	49.57
Na mgl^{-1}	62	50	42
K mgl^{-1}	39	19	16
CO_3 mgl^{-1}	ND	ND	54
HCO_3 mgl^{-1}	240	402	516
Cl mgl^{-1}	104	159	15
N mgl^{-1}	66.31	50.10	0.79
P mgl^{-1}	5.11	2.91	0.061
SO_4 mgl^{-1}	27	24	56
Fe mgl^{-1}	2.66	2.19	0.086
Mn mgl^{-1}	0.155	0.073	0.058
Cu mgl^{-1}	0.06	0.05	0.05
Zn mgl^{-1}	0.138	0.261	0.283
Cd mgl^{-1}	0.051	0.038	0.040
Ni mgl^{-1}	0.074	0.039	0.035
Pb mgl^{-1}	0.055	0.049	0.050
Co mgl^{-1}	0.058	0.052	0.058
Cr mgl^{-1}	0.035	0.027	0.026

DO: Dissolved oxygen, COD: chemical oxygen demand, BOD: biological oxygen demand, TDS: total dissolved salts, ND: no detectable.

Table 2. Physical parameters of soil samples of rice crop

Treatment	Particle Size distribution, %			Texture class	Colour	Bulk density (g/cm^3)	Calculation of porosity %	CEC Meq/100g
	Sand	Silt	Clay					
UWW	70.03	19.63	10.33	Sandy Loam	Light grey	1.56	41	16.38
TWW	82.22	12.3	5.47	Loamy sand	Light grey	1.68	37	13.17
GW	89.56	2.23	8.21	Sandy	Red	1.63	38	11.45

The rice soil had bulk density of 1.56 - 1.68 g/cm^3 and porosity of 38 - 41%. Sandy soils usually have high bulk density [33]. Sandy soils have higher bulk density, whereas clayey soils tend to have lower bulk densities and higher porosities [11]. [12], reported that, application of wastewater significantly increased soil cation exchange capacity (CEC). This is in consistent with our results shown in (Table 2) that the cation exchange capacity (CEC) was higher in the soil of rice with UWW and TWW as compared to control GW. The values of CEC soil were16.38, 13.17 and11.45 Meq/100g for UWW, TWW and GW, respectively in rice soil. The values of CEC soil decreased in the order; UWW > TWW> GW. CEC concentration of soils irrigated with wastewater is in the moderate range according to [34], guidelines as it recommends CEC values of 12 - 25 Meq/100g.

3.2.2. Nutrients and Heavy Metals in Soil

The results of the present study (Table 3) indicated that application of wastewater significantly allude in pH and EC. The pH value for UWW, TWW and GW irrigated soils were 6.73, 7.59 and 7.87 respectively and the EC of the same soils were 318, 246 and 204 µs/cm respectively, this is probably due to the high organic matter content of the irrigation water having high N levels that could be the result of a organic mixture with wastewater. These results were consistent with the finding [35,36]. The reason for decrease in soil pH may be decomposition of organic matter and production of organic acids in soils irrigated with wastewater. The result is similar to that of several researchers for EC as [7,14,37] who indicated that irrigation with wastewater led to increase in soil electrical conductivity compared to control. It is observed from the results that the total concentration of N, P and K were highly significantly increased in UWW and TWW soils as compared to control GW. This is due to the content in UWW, TWW and GW high concentrations of NPK, which are 0.29, 0.25 and 0.038% for N, 0.042, 0.038 and 0.008 for P and 0.043, 0.039 and 0.034 for K respectively, as shown in Table 2. As regards the concentrations of Ca and S there were significant differences observed on mean values for different sites like UWW, TWW and GW which were 0.56, 0.47 and 0.35% for Ca and 0.0038, 0.0032 and 0.0026% for soil, respectively, and there was increase did with due to wastewater irrigation, whereas Na and Cl concentration were not significantly different between different sites.

Treatments with UWW, and TWW increased concentrations of heavy metals like Mn, Cu, Cd, Ni, Pb and Cr in soil highly significantly compared to the control GW. Fe, Co and other heavy metals exhibited non-significant values in soils. Many investigations, including long and short term studies, showed that soil fertility increased as a consequence of irrigation with wastewater [38]. [5,6,17] they also reported that total N, P and K concentrations increased significantly in wastewater irrigation treatment compared to other treatments. Also similar results were noticed by [16], results showed that irrigation with treated wastewater increased soil pH, EC, OM, major elements (N, P, K, Na, Cl and Mg), salts and heavy metals such as Mn, Zn and Fe contents compared with well water.

Table 3. Effect of wastewater irrigation on nutrients and heavy metals content i soil

Parameter	UWW	TWW	GW
pH	6.73 c	7.59 b	7.87 a
EC µs/cm	318 a	246 b	204 c
Ca %	0.56 a	0.47 b	0.35 c
Mg %	0.24 b	0.22 b	0.29 a
Na %	0.046a	0.039 a	0.037a
K %	0.043 a	0.039 ab	0.034 b
Cl %	0.001a	0.001a	0.001a
N %	0.29 a	0.25 a	0.038 b
P %	0.042 a	0.038 b	0.008 c
S %	0.0038 a	0.0032 b	0.0026c
Fe mg/kg	55500a	49800a	42900a
Mn mg/kg	246 a	208 b	141c
Cu mg/kg	71a	48 b	32c
Zn mg/kg	193 b	214 b	263a
Cd mg/kg	9 a	7 b	6 c
Ni mg/kg	98 a	55 b	50 b
Pb mg/kg	67 a	36 b	23 b
Co mg/kg	34 a	30 a	20 a
Cr mg/kg	127 a	108 ab	92 b

Different letters in the same row indicate significant difference among means as determined by Duncan's multiple-range test ($p < 0.05$).

3.2.3. Elements Enrichment Factor (EF) in Rice Crop Soil

Data on nutrients concentration and estimated enrichment factors in soil of rice crop are presented in (Table 4). The enrichment factor of elements in soil of rice crop were in the order of N (7.63)> P (5.25)> Pb (2.91)> Ni (1.96)> Mn (1.74)> Co (1.70)> Ca (1.60)> Cd (1.50)> S (1.46)> Cr (1.38)> Fe (1.29)> K (1.26)> Na (1.24)> Cl (1.00)> Mg(0.83)> Zn (0.73) in the UWW irrigated soil. The values of N and P were in the enrichment category of significant enrichment, Cu and Pb in the enrichment category of moderate, while values of Ca, Na, K, Cl, S, Fe, Mn, Cd, Ni, Co and Cr were in the enrichment category of minimal enrichment and Mg and Zn indicate no enrichment. Whereas, the EF values of elements in soil irrigated with TWW was in the order N (6.58)> P (4.75)> Pb (1.57)> Cu and Co (1.50)> Mn(1.48)> Ca(1.34)> S (1.23) Cd and Cr (1.17)> Fe (1.16)> K (1.15)> Ni (1.10)> Na (1.05)> Cl (1.00)> Zn (0.81)> Mg (0.76). The enrichment categoryof UWW irrigated soil having were the EF values of N was in the enrichment category of significant enrichment, P in the enrichment category of moderate, while Ca, Na, K, Cl, S, Fe, Mn, Cu, Pb, Co, Cd, Ni and Cr values were in the minimal enrichment category and Mg and Zn indicate no enrichment.

Table 4. Nutrients concentrations and estimated enrichment factors for rice crop grown soil

Parameters	Soil of WW		Soil of TWW		Soil of GW
	Treatment	EF	Treatment	EF	(Control)
pH	6.73c	-	7.59b	-	7.87a
EC µs/cm	318a	-	246b	-	204c
Ca^{2+}%	0.56a	1.60	0.47b	1.34	0.35c
Mg^{2+}%	0.24b	0.83	0.22b	0.76	0.29a
Na^{+}%	0.046a	1.24	0.039a	1.05	0.037a
K^{+} %	0.043a	1.26	0.039ab	1.15	0.034b
Cl^{-}%	0.001a	1.00	0.00a	1.00	0.001a
N%	0.29a	7.63	0.25a	6.58	0.038b
P %	0.042a	5.25	0.038b	4.75	0.008c
S^{2-}%	0.0038a	1.46	0.0032b	1.23	0.0026c
$Fe^{2+,3}$ %	5.55a	1.29	4.98a	1.16	4.29a
Mn^{2+} mg/kg	246a	1.74	208b	1.48	141c
Cu^{2+} mg/kg	71a	2.22	48b	1.50	32c
Zn^{2+} mg/kg	193b	0.73	214b	0.81	263a
Cd^{2+}mg/kg	9a	1.50	7b	1.17	6c
Ni^{2+}mg/kg	98a	1.96	55b	1.10	50b
Pb^{2+}mg/kg	67a	2.91	36b	1.57	23b
Co^{2+}mg/kg	34a	1.70	30a	1.50	20a
Cr^{2+}mg/kg	127a	1.38	108ab	1.17	92b

3.3. Effect of Wastewater Irrigation on Mineral Content of Plant Tissues

Irrigation with wastewater generally led to changes in physico-chemical characteristics of soil and consequently heavy metal uptake by rice crop. Wastewater irrigation affected N, P, K, Ca, Mg and Na in tissues of rice crop (Table 5). The results show highly significant increase in the concentration of N, P and K in crop tissues grown with treatments UWW and TWW, as compared to GW. This is due to the samples high concentrations UWW and TWW of total N while GW contain low concentration of total N, P and K. A highly significant increase in Ca, Mg and Na concentration in UWW and TWW treatments as compared to the irrigated plant tissues GW was observed. The concentration of macro nutrients increased with increasing wastewater and were in the order UWW> TWW > GW in tissues of rice crop. This result is consistent with the study conducted by [5,6] where study showed that irrigation with wastewater significantly increased the macro elements (N, P and K) contents in corn forage by irrigation with wastewater. This increase could be related to the amount of sufficient nutrients elements present in wastewater.

Table 5. Effect of wastewater irrigation on chemical content of rice crop

Parameter	UWW	TWW	GW
Ca %	0.81a	0.58b	0.39c
Mg %	0.62a	0.46b	0.30c
Na %	0.26a	0.22a	0.094b
K %	3.12a	2.70b	2.25c
N %	4.53a	4.41a	2.96b
P %	0.38a	0.33b	0.28c
Fe mg/kg	342a	259b	195c
Mn mg/kg	182a	118b	86b
Cu mg/kg	54a	27b	14c
Zn mg/kg	56c	87b	119a
Cd mg/kg	7a	6ab	3b
Ni mg/kg	20a	18a	16a
Pb mg/kg	29a	20ab	13b
Co mg/kg	18a	12ab	10b
Cr mg/kg	30a	28a	18a

Different letters in the same row indicate significant difference among means as determined by Duncan's multiple-range test ($p < 0.05$).

The heavy metals concentrations in rice collected from sampling UWW, TWW and GW sites are given in Table 4. Heavy metal accumulation was significantly higher ($P < 0.05$) in leaves of rice irrigated with UWW, TWW and GW at all locations except the contents of Zn, Ni and Cr. The overall values of heavy metals as per [39,40,41,42,43], in the current study are above the recommended levels. In tissues of rice except Mn was in sufficient range and Pb was in optimum range for wastewater treatment according to [39].

3.3.1. Bioaccumulation Factor (BAF) for Heavy Metals in Rice Crop

Bioaccumulation factors are shown in Table 6. It was calculated for heavy metals transfer from soil to tissue of rice crop. The Bioaccumulation factors for heavy metals in soil irrigated with UWW were in the descending order of Cd (0.78)> Cu (0.76)> Mn (0.74)> Co (0.53)> Pb (0.43)> Zn (0.29)> Cr (0.24)> Ni (0.20)> Fe (0.006), for TWW the elements were Cd (0.86)> Mn (0.57)> Cu and Pb (0.56)> Zn (0.41)> Co (0.40)> Ni (0.33)> Cr (0.23)> Fe (0.005), whereas for the control GW, it was in the order of Mn (0.61)> Pb (0.57)> Co and Cd (0.50)> Zn (0.45)> Cu (0.44)> Ni (0.32)> Cr (0.20)> Fe (0.005). There was no significant difference in BAF values among the UWW, TWW and GW. Relatively high BAF values were found with UWW grown rice crop, whereas the lowest BAF value was found for control (GW). The results indicate that heavy metals bioavailability was low with UWW, TWW and control (GW) grown rice crop.

Table 6. Bioaccumulation factors for heavy metals in rice crop

Parameters	UWW	TWW	GW
Fe^{2+} mg/kg	0.006	0.005	0.005
Mn^{2+} mg/kg	0.74	0.57	0.61
Cu^{2+} mg/kg	0.76	0.56	0.44
Zn^{2+} mg/kg	0.29	0.41	0.45
Cd^{2+} mg/kg	0.78	0.86	0.50
Ni^{2+} mg/kg	0.20	0.33	0.32
Pb^{2+} mg/kg	0.43	0.56	0.57
Co^{2+} mg/kg	0.53	0.40	0.50
Cr^{2+} mg/kg	0.24	0.23	0.20

3.5. Effect of Wastewater on Growth and Yield Characters of Rice

The mean values for plant height of rice plant irrigated with UWW, TWW and GW are presented in Figure 1 and Figure 2. Plant height was significantly affected by irrigation with wastewater, the height of plant were 66.4, 59.11 and 57.16 cm for UWW, TWW and GW respectively. The effects of wastewater irrigation on number of tillers/plant of rice plant were recorded and the mean values are presented in Figure 1. Maximum number of tillers/plant (15.48) was produced by UWW, followed TWW (13.97) and minimum by GW (12.21). Tiller panicle length of rice irrigated with UWW, TWW and GW increased significantly (Figure 1). Maximum tiller panicle length (22.54 cm) was in UWW, followed TWW (20.25 cm) and minimum in GW (18.76 cm). Wastewater treatment (UWW and TWW) did not significantly increase the number of grains/panicle as compared to GW control. The order of increase in grains/panicle was GW> TWW>UWW (Figure 2). The data regarding the weight of 1000 seeds of rice are shown in Figure 2. Irrigation with untreated and treated wastewater did not increase weight of 1000 grain weight and the increases for TWW and UWW were 24, 21.6 and 20.5 g respectively. The mean yield/plant (Figure 2) was also influenced by different treatments. Maximum yield/plant of 20.17 and 18.32 g were recorded in GW and TWW, respectively, whereas, untreated wastewater (UWW) recorded minimum yield/plant of 17.13 g. From these results, it could be concluded that the growth and yield characters of rice crop were not improved as a result of irrigation with untreated and treated wastewater; the high concentration of trace metals affected ultimately by lowering the growth and yield attributing factors. These effects could be attributed to higher accumulation of micronutrients and macronutrients in soil and plant, when the mean values were highly significant as indicated by the present study. Many investigations, including long and short term studies for growth and yield parameters of rice crop irrigated with wastewater were reported by [44], showed that the change in the total irrigated area by wastewater was marginal over the decade, whereas the built-up area within the watershed boundaries doubled and there was a distinct shift in cropping patterns of paddy rice. [45], indicated positive impact on most growth and yield variables and grain and biomass yields of wheat with wastewater treatment, which positively contributed to plant height, number of spikes/square metre, spike length, number of spikelets, grain in the spike, and 1000-grain weight, but not to the number of grains in the spike. [46], summarized that, the adverse effect of excessive salts in the wastewater was responsible for the reduction in dry biomass as observed in rice. [47], discussed that, the industrial wastewater effect leads to decrease in various growth parameters such as seedling growth of the root and shoot of rice and wheat crop plants compared with control. [48], studied the effects of wastewater and well water irrigation and amongst the crops, wheat recorded highest grain yield, which was found better than gram, whereas highest straw yield was recorded in gram, which was found better than wheat. [37,49]. They are studied the agronomical characteristics like shoot length, root length, number of flowers, pods, dry weight of *V. mungo* which recorded higher values with distillery wastewater low and moderate effluent concentration and decreased with the increase in effluent concentration from 50% to100% as compared to bore well water (control).

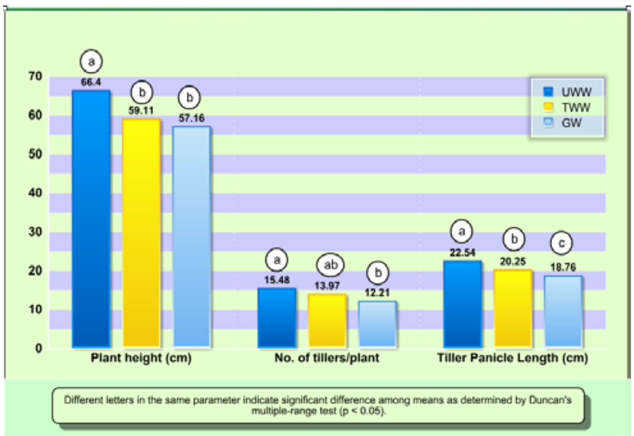

Figure 1. Plant height, number of tillers per plant and tiller panicle length of rice irrigated with untreated, treated wastewater, and groundwater

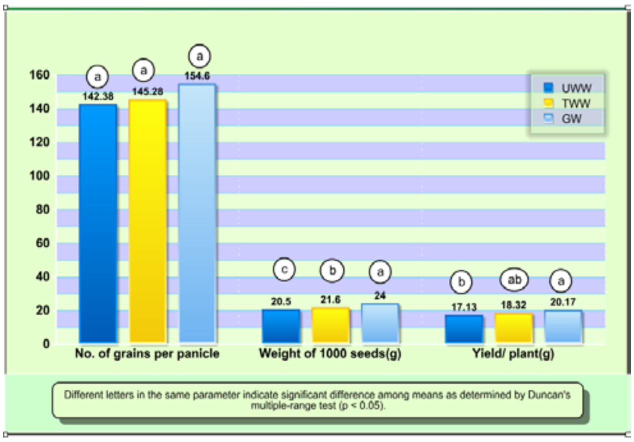

Figure 2. Number of grains per panicle, weight of 1000 seeds and Yield/ plant of rice irrigated with untreated, treated wastewater and groundwater

3.7. Pearson's Correlation between Elements in Soil and Rice Crop

The relationship among different elements content in soil and rice crop were analyzed by Pearson's correlation coefficient determined by statistical methods and results are presented in Table 7. The correlation among 15 elements parameters like, Ca, Mg, Na, K, N, P, Fe, Mn, Cu, Zn, Cd, Ni, Pb, Co and Cr of UWW, TWW and GW were studied (Table 7); thirty seven combinations of 15 elements were obtained. Ca has positive correlation with Ca, Mg, Na, K, N, P, Fe, Mn, Cu, Zn, Pb and Co at P=0.01 and Cd and Cr at P=0.05 levels of significance. Mg has negative correlation with Na, K and N at P=0.05 levels of significant. Na is positive significant correlation with K, Zn and Pb at P=0.01 and with Fe, Cu and Cr at P=0.05 level of significance. K was positive correlated with P, Fe, Mn and Cu at P=0.01 and with N, Zn, Ni, Pb and Co at P=0.05 level of significance. N has indicated positive correlation significant with P, Fe, Mn, Cu and Pb at P=0.01 and with Cd and Co at P=0.05 in levels of significant. P shows positive correlation with Fe, Mn, Cu and Zn at P=0.01 and with Cd, Pb, Co and Cr at P=0.05 level of significance. Besides these all other relations also showed significant relationship among heavy metals. Whereas, Fe has positive correlation significance with Mn, Cu, Zn and Pb at P=0.01 and Cd, Ni, Co and Cr at P=0.05 levels of significance. Mn showed positive correlation significance with Cu, Zn and Pb at P=0.01 and Cd, Ni and Co at P=0.05 level of significance. Cu has positive correlation significant with Zn, Pb and Co at P=0.01 and Ni and Cr at P=0.05 level of significance. Cd has positive correlation with Pb and Cr at P=0.05 level of significance. Cu has positive correlation with Zn, Ni, and Pb at P=0.01 and Cr at P=0.05 levels of significance. Ni shows positive correlation with Co at P=0.01 and Pb at P=0.05 levels of significance. Pb has shows positive correlation Co and Cr at P=0.05 level of significance. From the above results, it can be seen that, the relationship among the elements Ca, Na, Mg, K, N , P and the heavy metals were significant at P=0.01 and P=0.05 levels, between the soil and the rice crop. These results were in conformity with the finding of (38) [37], who reported that characteristics viz., EC, pH, Cl, Na, K, Ca, Mg, Fe, TKN, PO_4, SO_4, Cd, Cr, Cu, Mn and Zn of the soil. Similar observations were reported by [49], who found positive correlation significance (P<0.01) effect on soil characteristics like Na, K, Ca, Mg, Fe, N, P, Cd, Cr, Cu, Mn and Zn. Similar trend in the positive correlation of elements such as Mg, Na, K, N and P was observed by [50].

Table 7. Pearson correlation coefficient between soil nutrient and nutrient content of rice plant

	Ca	Mg	Na	K	N	P	Fe	Mn	Cu	Zn	Cd	Ni	Pb	Co	Cr
Ca	0.960**														
Mg	0.952**	-0.665													
Na	0.961**	-0.769*	0.508												
K	0.965**	-0.677*	0.833**	0.786*											
N	0.865**	-0.747*	0.649	0.685*	0.869**										
P	0.972**	-0.642	0.622	0.869**	0.925**	0.887**									
Fe	0.928**	-0.636	0.720*	0.839**	0.867**	0.832**	0.863**								
Mn	0.929**	-0.460	0.571	0.922**	0.823**	0.805**	0.824**	0.895**							
Cu	0.956**	-0.494	0.726*	0.861**	0.835**	0.820**	0.897**	0.919**	0.957**						
Zn	0.930**	-0.628	0.899**	0.702*	0.840**	0.857**	0.976**	0.909**	0.953**	0.954**					
Cd	0.763*	-0.372	0.434	0.592	0.676*	0.780*	0.739*	0.676*	0.774*	0.544	0.430				
Ni	0.657	-0.498	0.605	0.744*	0.608	0.623	0.706*	0.716*	0.664	0.631	0.549	0.597			
Pb	0.877**	-0.654	0.855**	0.709*	0.817**	0.786*	0.898**	0.884**	0.871**	0.949**	0.726*	0.726*	0.923**		
Co	0.851**	-0.263	0.504	0.710*	0.699*	0.710*	0.737*	0.748*	0.862**	0.773*	0.362	0.899**	0.733*	0.735*	
Cr	0.670*	-0.428	0.730*	0.250	0.584	0.702*	0.776*	0.566	0.740*	0.614	0.790*	0.314	0.684*	0.249	0.732*

**. Correlation is higher significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

4. Conclusion

The results of this study has shown the effects of irrigation with untreated and treated wastewater (UWW and TWW) on growth and yield of rice crop, on soil properties and the effect on enrichment and bio accumulation of nutrients and metals in soil and rice crop. Growth and yield characters of rice crop were not improved as a result of irrigation with untreated and treated wastewater; the high concentration of trace metals in wastewater affected ultimately by lowering the growth and yield (number of grains/panicle, weight of 1000 seeds and yield/plant) when irrigated by untreated wastewater and treated wastewater as compared to ground water control. The effects could be attributed to higher accumulation of micronutrients and macronutrients in soil and plant, when the mean values were highly significant as indicated by the present study as compared to ground water (GW). Bio-accumulation factor values were high with untreated wastewater grown rice crop, whereas lowest Bio-accumulation factor values were found for control ground water site. The Pearson's correlation coefficient shows that the relationship among the elements Ca, Na, Mg, K, N , P and the heavy metals are significant P= 0.01 and P= 0.05 levels between soil and rice crop.

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