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PHYTO - ACCUMULATION OF Cu, Cd AND Pb IN MAIZE CROP GROWN UNDER DOMESTIC AND INDUSTRIAL WASTE WATER

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Abstract: A pot experiment was conducted to investigate the effect of sewage water and industrial effluent on germination, post germination growth and heavy metal accumulation in maize at the Agronomic Research Area of Faculty of Agriculture, Gomal University, Dera Ismail Khan, Khyber Paktunkhwa (KPK), Pakistan in 2013. Effluent and sewage water were applied in actual concentration and also diluted with tap water to different concentrations. Results showed that there was linear increase in growth parameters by the application of 100% tap water or at 100% industrial effluent and in some concentrations of sewage water. Maximum leaf area was recorded by applying 100% industrial effluent. Leaf area index was also maximum in treatments where 100% tap water, 100% industrial effluent and 25% tap water + 75% sewage were applied. Similarly, maximum fresh and dry plant weight was recorded in treatments where 100% tap water or 100% industrial effluent was applied either alone or in combination. Plant height and chlorophyll content were maximum in treatments where tap water + sewage water or tap water + industrial effluent was applied in different combinations. However, higher levels of heavy metals (copper, cadmium and lead) were accumulated in the soil by applying sewage water either alone or diluted with tap water in different concentrations. Therefore, it is concluded that although the sewage and effluent had elevated concentrations of some of the metals compared with tap water, the concentrations of such metals in these sources of irrigation water were, however, within the permissible limits for their use as irrigation water.

Keywords: Maize, Sewage water, Industrial effluent, Copper, Cadmium, Lead

1. INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop of Pakistan after wheat and rice. It is grown all over the world under a wide range of environmental conditions. Its grains are rich in vitamins A, C and E, carbohydrates, and essential minerals, and contain 9% protein. In Pakistan, maize is annually grown on an area of 947.2 thousand hectares with the total production of 3707 thousand tons. In KPK province, it is cultivated on 422.9 thousand hectares with the total production of 740.5 thousand tons.

Development of industrial sector in most parts of the country, including Dera Ismail Khan (Pakistan), there are increasing environmental concerns over a period of time. The establishment of sugar and textile industries in this part of the country is undoubtedly a major source of employment for the poor masses, however, the continuous and unrestricted distribution and moment of poisonous elements in soil-plant system discharged by these industries is quite alarming, which needs to be addressed accordingly.

The water collected through sewerage system in outskirts is mostly discharged to agricultural lands without treatment. There is an increased usage of sewage water for irrigation, particularly in the dry area where there is scarcity of natural water. Sewage water contains higher amounts of nutrients which increase crop yield substantially and reduce the need for fertilizer, and ultimately decrease overall cost of production. Khan et al., (2014) reported greater organic matter content and extractable P in the sewage water used for growing crops in the vicinity of Dera Ismail Khan district. Pollice et al., (2004) concluded that application of sewage water and industrial effluent as water and nutrient source for agricultural irrigation represents a low cost alternative and is applicable either in dry regions or in humid regions. The continuous use of sewage waste water can, however, lead to environmental problems such as soil sickness, soil and ground water contamination and phytotoxicity (Hicks & Hird, 2000). Polglase et al., (2001) is of the view that changes in sewage water application result in significant alterations of the genetic diversity of microorganisms in soil. Contamination of water by heavy metals through the discharge of industrial waste water is a worldwide environmental problem (Mataka et al., 2006). The elevated level of lead and other heavy metals, e.g. cadmium, chromium and mercury in the local water streams is a major concern to public health (Zhao & Zhang, 2006).

Keeping all this in view, the present research was initiated to decipher the potential use of the sewage and effluent (SE) as a source of irrigation water and also to evaluate their effect in different concentrations on growth parameters and heavy metals accumulation in maize.

2. MATERIALS AND METHODS

To study the impact of waste and industrial water on the heavy metal accumulation and growth of maize a pot experiment was carried out at Agronomic Research Area of Faculty of Agriculture, Gomal University, Dera Ismail Khan, KPK, in 2013. It was laid out in a completely randomized design with 4 replications. Different treatments including T_1 (100% Tap Water), T_2 (100% Sewage Water), T_3 (100% Industrial Effluent), T_4 (75% Tap Water + 25% Sewage Water), T_5 (75% Tap Water + 25% Industrial Effluent), T_6 (50% Tap Water + 50% Sewage Water), T_7 (50% Tap Water + 50% Industrial Effluent), T_8 (25% Tap Water +75% Sewage Water) and T_9 (25% Tap Water +75% Industrial Effluent). Urea, Diammonium Phosphate and Sulphate of potash fertilizers @120: 90: 70 NPK kg ha^{-1} were applied in each pot.

The chemical characteristic of representative sewage water and industrial effluent samples are given in table 1. The data were recorded on days to germination, leaf area (cm^2), leaf area index, fresh plant weight (g), dry plant weight (g), plant height (cm), chlorophyll contents (μ g cm^2), copper determination (mg kg^{-1}), cadmium determination (mg kg^{-1}) and lead determination (mg kg^{-1}) as per the standard scientific procedures using Atomic Absorption Spectrophotometer (AAS) and analyzed statistically using the analysis of variance technique (Steel et al., 1997) and subsequently least significant difference (LSD) test was applied for comparing the treatment means through Statistix 9.0 computer software.

3. RESULTS AND DISCUSSION

3.1. Germination, plant height and chlorophyll content of maize crop

The data on days to germination of maize was non- significantly affected by the application of sewage water and industrial effluent (Table 2). All treatments took statistically similar number of days to germination. The sewage water and industrial effluent though contain certain toxic elements but their uses generally do not restrict germination and other initial plant growth stages. Ayasamy et al., (2008) recommended use of effluent that has no negative impact on seed germination and can effectively be used for irrigation. Selvi & Prajapati, (2008) studied the suitability of coal washery water for irrigation and noted 100% seed germination in all the treatments.

The plant height showed significant changed by the application of different types of water (Table 2). Among treatments, maximum plant height (51.75, 40.00 and 37.00 cm) was measured in T_8 (25% tap water + 75% sewage water), T_7 (50% tap water + 50% industrial effluent) and T_9 (25% tap water + 75% industrial effluent). Short stature plants were noted in T_6 (50% tap water + 50% sewage water). In this study, production of taller plant might be due to availability of sufficient amount of organic matter and nutrients through an increased concentration of effluent and sewage water application that contributed to overall vegetative growth and resulted in taller maize plants.

Table-1. Pre-application analysis of sewage water and industrial effluent.

Parameter	Sewage water composition	Industrial effluent composition	*Permissible value for Irrigation water
Copper content (mg L^{-1})	0.51	0.34	0.2
Cadmium content (mg L^{-1})	0.22	0.1	0.01
Lead content (mg L^{-1})	0.94	0.54	5.0

*Source: Ayers & Wetcot, (1976).

Table 2. Effect of sewage water and industrial effluent on days to germination of maize.

Treatment	Days to germination	Plant height (cm) 60 DAG	Chlorophyll content (µ g cm^2)
T_1= 100% Tap Water	5.50^{NS}	31.75 c	23.56 bc
T_2 = 100% Sewage Water	5.50	29.25 cd	22.56 bc
T_3 = 100% Industrial Effluent	6.00	29.75 cd	24.31 bc
T_4 = 75% Tap Water + 25% Sewage Water	5.75	27.75 cd	23.93 bc
T_5 = 75% Tap Water + 25% Industrial Effluent	5.25	27.50 cd	25.06 ab
T_6 = 50% Tap Water + 50% Sewage Water	5.75	27.25 d	27.50 a
T_7 = 50% Tap Water + 50% Industrial Effluent	4.75	40.00 b	24.12 bc
T_8 = 25% Tap Water + 75% Sewage Water	5.25	51.75 a	22.25 c
T_9 = 25% Tap Water + 75% Industrial Effluent	5.50	37.00 b	24.87 b
LSD		4.28	2.60

Means followed by different letter(s) in a column are statistically significant at 5% probability level
DAG= Days after Germination LSD= Least Significant Difference NS= Non- significant

Khan & Altaf, (2008) reported that wastewater significantly increased plant height, fresh and dry weight of leaves, leaf area as well as crop yield. Application of sewage water promotes better germination, root proliferation, and nutrient and water uptake by the crops and greater biomass production (Mohammad & Ayadi, 2004).

The chlorophyll content measured 60 days after germination (DAG) showed significant effect on maize plant (Table 2). The maximum chlorophyll content 27.50 and 25.06 µ g cm^2 was recorded in T_6 (50% tap water + 50% sewage water) and T_5 (75% tap water + 25% industrial effluent) respectively. Minimum chlorophyll content of 22.25 µ g cm^2 was noted in T_8 (25% tap water + 75% sewage water).

In this study, higher chlorophyll content in industrial effluent and sewage water treatments could be due to high nitrogen content in wastewater. Rattan et al., (2005) reported that sewage contains good amounts of useful major plant nutrients, such as N, P, K, and Ca, which are reflected in the build-up of these nutrients in the sewage-irrigated soils. Ramana & Singh, (2002) applied distillery effluents which resulted in increased leaf area, chlorophyll content, total dry weight and grain yield. Osaigbovo et al., (2006) also reported enhanced chlorophyll content in maize plant at low effluent concentration.

3.2. Leaf area and leaf area index of maize crop

The leaf area calculated at different stages (30, 45 and 60 DAG) of plant growth was significantly affected by sewage water and industrial effluent application (Table 3). After 30 DAG, the maximum leaf area (24.00 cm^2) was recorded in T_3 by the application of 100% industrial effluent. It was, however, statistically at par with T_1 (21.72 cm^2) where 100% tap water was applied. Minimum and statistically similar leaf area was noted in T_9 (25% tap water + 75% industrial effluent) and T_4 (75% tap water + 25% sewage water). After 45 DAG, the data showed maximum and statistically similar leaf area of 45.22 and 41.82 cm^2 in T_8 (25% tap water + 75% sewage water) and T_7 (50% tap water + 50% industrial effluent). Minimum leaf area (24.22 cm^2) was noted in T_6 (50% tap water + 50% sewage water). In this study, a parallel increase in leaf size was noted in every successive plant growth stages. At the final stage (60 DAG) of study, the maximum and statistically similar leaf area of 62.57 and 59.40 cm^2 was noted in T_1 (100% tap water) and T_3 (100% industrial effluent). It was followed by T_5 (75% tap water + 25% industrial effluent) with leaf area of 53.30 cm^2. Minimum leaf area (43.92 cm^2) was measured in T_6 (50% tap water + 50% sewage water) 60 DAG. Higher leaf area by the application of 100% industrial effluent showed that this can be used as water and nutrient source for agricultural irrigation (Pollice et al., 2004). Ramana & Singh (2002) also found that the application of distillery effluents resulted in increased leaf area and other growth characteristics. The increase in vegetative growth parameters suggested that applied treatments influenced the physiological processes, facilitated early leaf initiation, and resulted in a net increase in the number of leaves. The increase in the number of leaves might have facilitated the capture of more solar energy for metabolic use, fixed more CO_2, and produced greater photosynthates for growth (Myers et al., 1996). Application of sewage water alone or in combination with tap water did not increase leaf area considerably. Zhao & Zhang, (2006) reported that irrigation with the sewage sometime causes accumulation of nitrate and heavy metals in the crops and thereby restricts plant growth.

The leaf area index (LAI) was significantly affected by sewage water and industrial effluent application (30, 45 and 60 DAG) (Table 3). At the early stage the maximum LAI (3.60 and 3.50) was recorded in T_3 and T_1 by the application of 100% industrial effluent and in 100% tap water treatment, respectively. Minimum and statistically similar LAI was noted in T_6 (50% tap water + 50% sewage water), T_4 (75% tap water + 25% sewage water) and T_8 (25% tap water + 75% sewage water), respectively. The data further exhibited maximum and statistically similar LAI of 4.60 and 4.00 in T_1 (100% tap water) and T_7 (50% tap water + 50% industrial effluent) than other treatments including T_5 (75% tap water + 25% industrial effluent), T_2 (100% sewage water) and T_8 (25% tap water + 75% sewage water) 45 DAG. Minimum LAI was noted in T_3 (100% industrial effluent), T_6 (50% tap water + 50% sewage water), T_9 (25% tap water + 75% industrial effluent) and T_4 (75% tap water + 25% sewage water), respectively. Similarly, maximum and statistically similar LAI of 5.10 and 4.70 was noted in T_8 (25% tap water + 75% sewage water) and T_1 (100% tap water), followed by T_7 (50% tap water + 50% industrial effluent), T_9 (25% tap water + 75% industrial effluent) and T_4 (75% tap water + 25% sewage water) 60 DAG. Minimum LAI was recorded in T_5 (75% tap water + 25% industrial effluent) and T_6 (50% tap water + 50% sewage water), respectively. The higher LAI in treatments where 100% tap water, 100% industrial effluent and 25% tap water + 75% sewage water was applied could be due to absorption of clean water in plant vessels during growth and better nutrient availability through industrial effluent and sewage water. Mousavi et al., (2013) investigated the effect of primary-treated municipal wastewater (TMWW) on the LAI of maize in comparison to the clean irrigation water (control). Results showed that irrigation with TMWW had a significant positive impact on all characters compared with the control. The difference between results of these two studies could be the application of TMWW in Mousavi and coauthors' research in 2013 while in this study; sewage water and industrial effluent were applied in their actual concentrations without treatment.

3.3. Plant fresh and dry weight of maize crop

Fresh plant weight was significantly affected by sewage water and industrial effluent application at 30, 45 and 60 days after germinations (Table 4). After 30 DAG, the higher fresh plant weight (30 and 24.57 g) was noted in T_3 (100% industrial effluent) and T_1 (100% tap water), while the least fresh plant weight was noted in T_2 (100% sewage water), T_6 (50% tap water + 50% sewage water) and T_4 (75% tap water + 25% sewage water), respectively. After 45 DAG, the maximum and statistically similar fresh plant weight (16.27 and 16.25 g) was recorded in T_1 (100% tap water) and T_7 (50% tap water + 50% industrial effluent). Minimum of 4.67 and 4.30 g fresh plant weight was recorded in T_6 (50% tap water + 50% sewage water) and T_2 (100% sewage water). After 60 DAG, the maximum and statistically similar fresh plant weight (20.67 and 18.40 g) was recorded in T_8 (25% tap water + 75% sewage water) and T_7 (50% tap water + 50% industrial effluent) and minimum (11.25 and 10.25 g) in T_6 (50% tap water + 50% sewage water) and T_5 (75% tap water + 25% industrial effluent). The maximum fresh plant weight was recorded in treatments where 100% tap water or 100% industrial effluent was applied either alone or in combination. This was possibly due to enrichment of nutrients in effluent or by the application of tap water that enhanced availability of nutrients through synthetic fertilizer application.

Table-3. Effect of sewage water and industrial effluent on leaf area (30, 45 and 60 days after germination) of maize.

Treatment	Leaf area (cm^2)			Leaf area index		
	Days after germination			Days after germination		
	30	**45**	**60**	**30**	**45**	**60**
T_1= 100% Tap Water	21.72 ab	35.57 bc	62.57 a	3.50 a	4.60 a	4.70 ab
T_2 = 100% Sewage Water	18.25 bc	31.02 cde	49.27 cd	2.20 bc	2.35 cd	2.90 cd
T_3 = 100% Industrial Effluent	24.00 a	29.37 cde	59.40 ab	3.60 a	1.87 d	2.72 bcd
T_4 = 75% Tap Water + 25% Sewage Water	17.12 c	28.97 cde	50.35 cd	2.17 d	1.72 d	3.00 cd
T_5 = 75% Tap Water + 25% Industrial Effluent	17.87 bc	28.20 de	53.30 bc	2.32 cd	3.77 bc	2.80 d
T_6 = 50% Tap Water + 50% Sewage Water	18.12 bc	24.22 e	43.92 d	2.25 d	1.80 d	2.75 d
T_7 = 50% Tap Water + 50% Industrial Effluent	18.12 bc	41.82 ab	51.62 c	3.05 cd	4.00 a	4.10 abc
T_8 = 25% Tap Water + 75% Sewage Water	18.62 bc	45.22 a	45.72 cd	2.15 d	2.25 cd	5.20 a
T_9 = 25% Tap Water + 75% Industrial Effluent	17.25 c	31.50 cd	49.72 cd	2.95 cd	1.75 d	3.50 bcd
$LSD_{0.05}$	3.98	7.09	7.62	1.70	2.20	1.25

Means followed by different letter(s) in a column are statistically significant at 5% probability level, NS= Non- significant

Table 4. Effect of sewage water and industrial effluent on fresh plant weight (30, 45 and 60 days after germination) of maize.

Treatment	Fresh plant weight (g)			Dry plant weight (g)		
	Days after germination			Days after germination		
	30	45	60	30	45	60
T_1= 100% Tap Water	24.75 b	16.27 a	16.67 abc	7.10 a	3.67 a	4.50 ab
T_2 = 100% Sewage Water	7.90 de	4.30 d	13.05 cde	3.27 bc	2.25 cd	3.20 cd
T_3 = 100% Industrial Effluent	30.00 a	6.12 cd	15.20 bcd	7.70 a	1.87 d	3.72 bcd
T_4 = 75% Tap Water + 25% Sewage Water	6.90 e	5.05 cd	12.85 cde	2.17 d	1.72 d	3.27 cd
T_5 = 75% Tap Water + 25% Industrial Effluent	8.17 de	7.42 c	10.25 e	2.32 cd	2.77 bc	2.80 d
T_6 = 50% Tap Water + 50% Sewage Water	6.92 e	4.67 d	11.25 de	2.05 d	1.80 d	2.75 d
T_7 = 50% Tap Water + 50% Industrial Effluent	10.42 d	16.25 a	18.40 ab	3.05 cd	3.80 a	4.22 abc
T_8 = 25% Tap Water + 75% Sewage Water	17.07 c	12.87 b	20.67 a	4.15 b	3.25 ab	5.27 a
T_9 = 25% Tap Water + 75% Industrial Effluent	10.15 de	6.62 cd	14.30 b-e	2.95 cd	1.75 d	3.70 bcd
$LSD_{0.05}$	3.43	2.64	4.42	1.09	0.70	1.80

Means followed by different letter(s) in a column are statistically significant at 5% probability level, LSD= Least Significant Difference

Ayasamy et al., (2008) reported that fresh and dry plant weight showed an increase by the application of industrial effluent. In general, fresh plant weight was negatively affected by sewage water application. This is because wastewater sometime reduces crop productivity due to nutritional imbalance and growth suppression due to toxic ions (Kijne et al., 1998).

The dry plant weight was significantly affected by sewage water and industrial effluent application at three stages of maize plant. The highest dry weight of 7.70 and 7.10 g was recorded in T_3 (100% industrial effluent) and T_1 (100% tap water). While the lowest dry plant weight was noted in T_4 (75% tap water + 25% sewage water) and T_6 (50% tap water + 50% sewage water) at 30 DAG (Table 4). The data further indicated that maximum and statistically similar dry plant weight (3.80, 3.67 and 3.25 g) was recorded in T_7 (50% tap water + 50% industrial effluent), T_1 (100% tap water) and T_8 (25% tap water + 75% sewage water). Minimum dry plant weight was recorded in T_3 (100% industrial effluent), T_6 (50% tap water + 50% sewage water), T_9 (25% tap water + 75% industrial effluent) and T_4 (75% tap water + 25% sewage water) at 45 DAG. The data noted 60 DAG showed maximum dry plant weight (5.27, 4.50 and 4.22 g) in T_8 (25% tap water + 75% sewage water), T_1 (100% tap water) and T_7 (50% tap water + 50% industrial effluent) with the least dry plant weight (2.80 and 2.75 g) was recorded in T_5 (75% tap water + 25% industrial effluent) and T_6 (50% tap water + 50% sewage water). In certain cases, the diluted effluents enhanced the growth of the plants which might be due to the presence of phenolic compounds and enrichment of nutrients in wastewater. Khan & Altaf, (2008) reported that irrigation with wastewater, which contained sufficient quantities of N (21.02 mg L^{-1}), P (3.49 mg L^{-1}) and K (6.66 mg L^{-1}), significantly increased plant height, fresh and dry weight of leaves, leaf area as well as crop yield.

3.4. Concentration of heavy metals in the soil and plants

Post-harvesting effect of sewage water and industrial effluent on soil showed maximum copper contents (8.20 mg kg^{-1}) in T_7 (50% tap water + 50% industrial effluent) and minimum (0.21 mg kg^{-1}) in general soil sample (Fig. 1). Cadmium contents were higher (0.79 mg kg^{-1}) in T_2 (100% sewage water) and lower (0.01 mg kg^{-1}) in general soil sample. Similarly, higher lead contents (9.33 mg kg^{-1}) were found in T_3 (100% industrial effluent) and lower (0.56 mg kg^{-1}) in general soil sample.

3.4.1. Copper concentration (mg kg^{-1}) in plants

Copper content was significantly affected by effluent and sewage water application 30, 45 and 60 DAG (Fig. 2). The treatments showed the highest and statistically similar copper accumulation of 7.92 and 7.65 mg kg^{-1} in T_8 (25% tap water + 75% sewage water) and T_6 (50% tap water + 50% sewage water) at 30 DAGS, while the least copper uptake of 1.18 and 0.87 mg kg^{-1} was noted in T_1 (100% tap water) and T_2 (100% sewage water), respectively at 30 DAG.

After 45 days, the higher and statistically similar copper concentration (6.73 and 6.62 mg kg^{-1}) was found in T_6 (50% tap water + 50% sewage water) and T_5 (75% tap water + 25% industrial effluent). Less copper accumulation (2.41 and 2.22 mg kg^{-1}) was noted in T_9 (25% tap water + 75% industrial effluent) and T_1 (100% tap water), respectively. Similarly, at maximum days the copper concentration of 6.38, 6.24, 6.16 and 5.99 mg kg^{-1} was noted in T_2 (100% sewage water), T_6 (50% tap water + 50% sewage water), T_3 (100% industrial effluent) and T_7 (50% tap water + 50% industrial effluent) respectively.

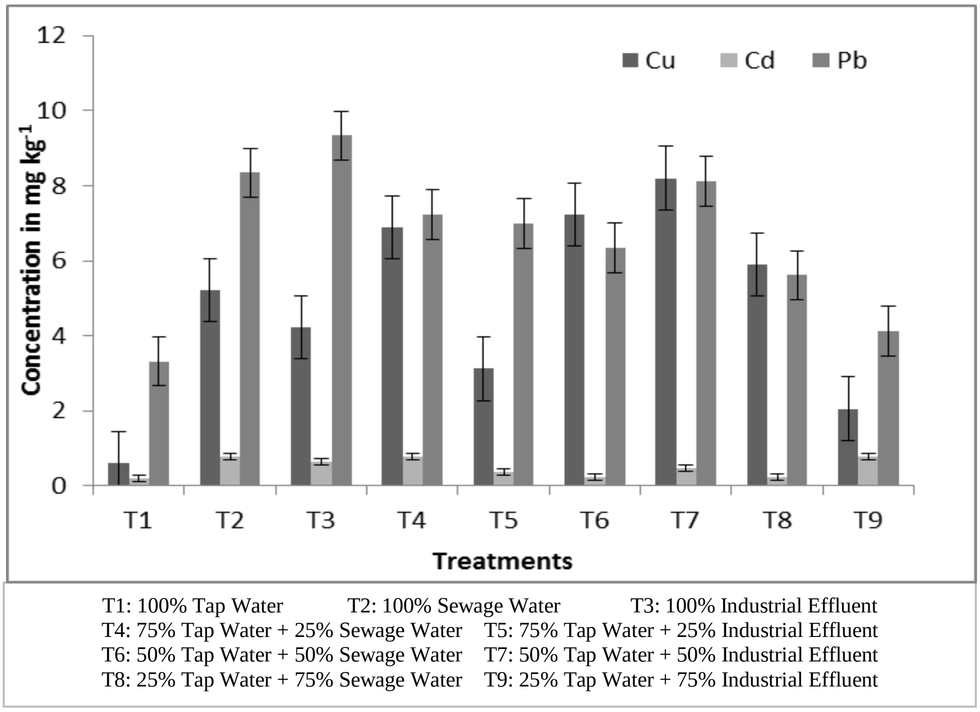


Figure 1. Effect of sewage water and industrial effluent on soil Cu, Cd and Pb concentration

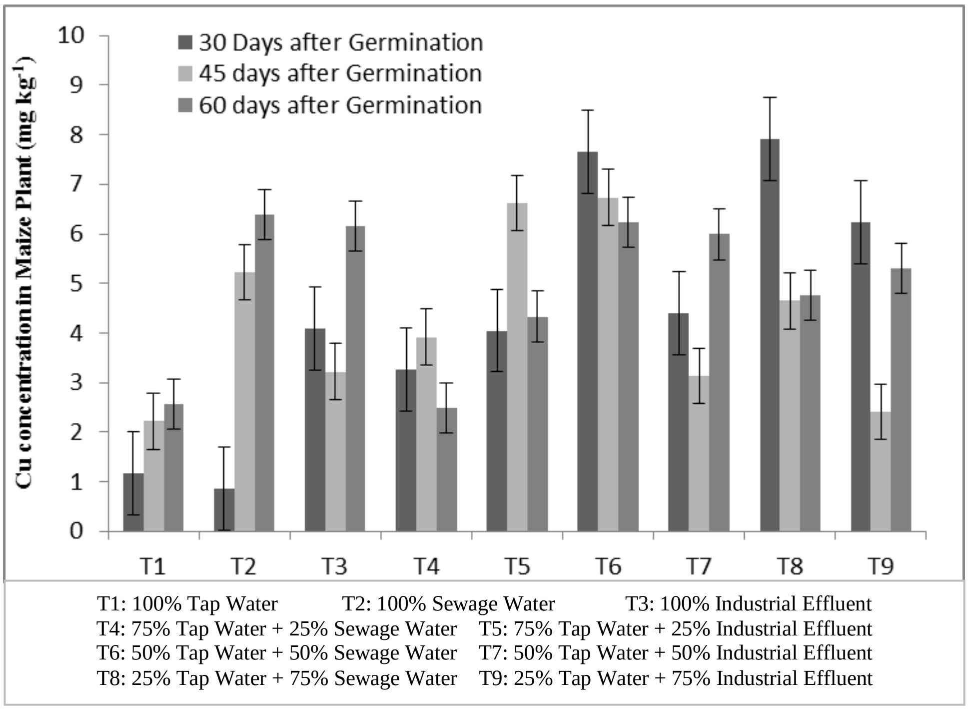


Figure 2. Post-harvesting effect of sewage water and industrial effluent on Cu concentration of maize plant

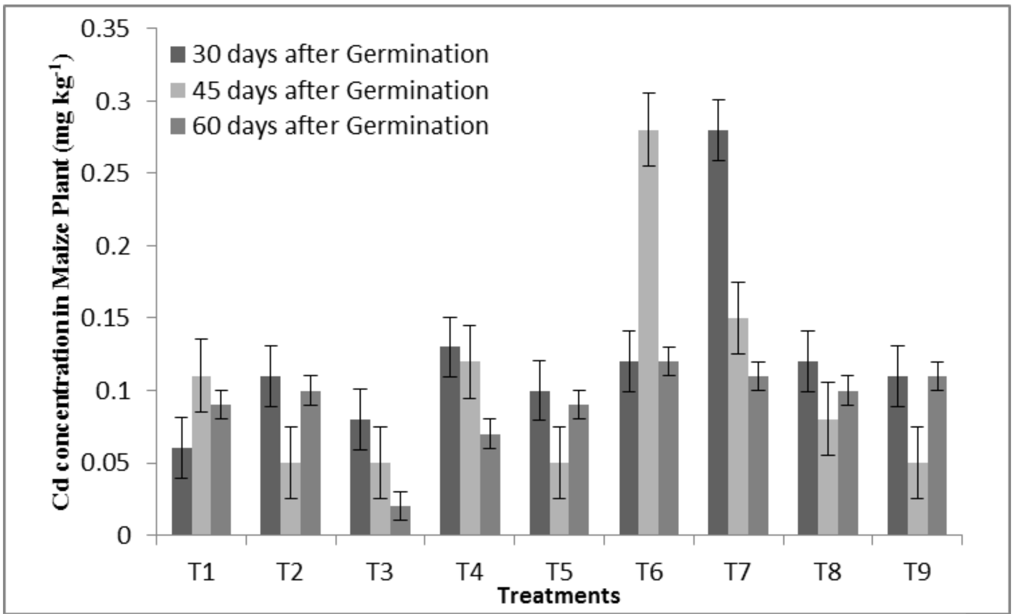
Lowest but statistically similar copper concentration (2.56 and 2.48 mg kg^{-1}) was found in T_1 (100% tap water) and T_4 (75% tap water + 25% sewage water). Li, (2012) also stated that the contents of total Zn, Cu, and Cd in the soils and plant increased linearly with sewage sludge application rates. The presence of higher copper concentration in T_6 also had negative impacts on the leaf area, leaf area index, fresh and dry plant weight in this study. Copper is toxic to a number of plants at 0.1 to 1.0 mg L^{-1} in nutrient solutions.

3.4.2. Cadmium concentration (mg kg^{-1})

The cadmium concentration measured in the plant samples after 30 DAG was 0.28 mg kg^{-1} noted in T_7 (50% tap water + 50% industrial effluent) which was non-significantly different from rest of all other treatments including T_1 (100% tap water) which had minimum of 0.06 mg kg^{-1} cadmium level (Fig.3). It is further revealed from the data that maximum cadmium concentration of 0.28 mg kg^{-1} was noted in T_6 (50% tap water + 50% sewage water) than other treatments included in the study. The difference among treatments was, however, non-significant statistically 45 DAG. Similarly, higher level of cadmium level (0.12 mg kg^{-1}) was recorded in T_6 (50% tap water + 50% sewage water). Minimum cadmium level of 0.07 and 0.02 mg kg^{-1} was found in T_4 (75% tap water + 25% sewage water) and T_3 (100% industrial effluent) 60 DAG. Singh & Agrawal, (2010) also found that uptake and translocation ratio of heavy metals were higher in plants grown at wastewater irrigated site. Manganese showed maximum uptake followed by zinc, copper, lead, nickel, chromium and cadmium. Similarly, Kruse & Barrett, (1985) concluded that wastewater irrigation leads to transport of heavy metals to soils and may cause crop contamination. Some of these heavy metals may bio-accumulate in the soil while others, e.g. cadmium and copper may be redistributed by soil fauna. Cadmium has been found toxic to beans, beets and turnips at concentrations as low as 0.1 mg L^{-1} in nutrient solutions.

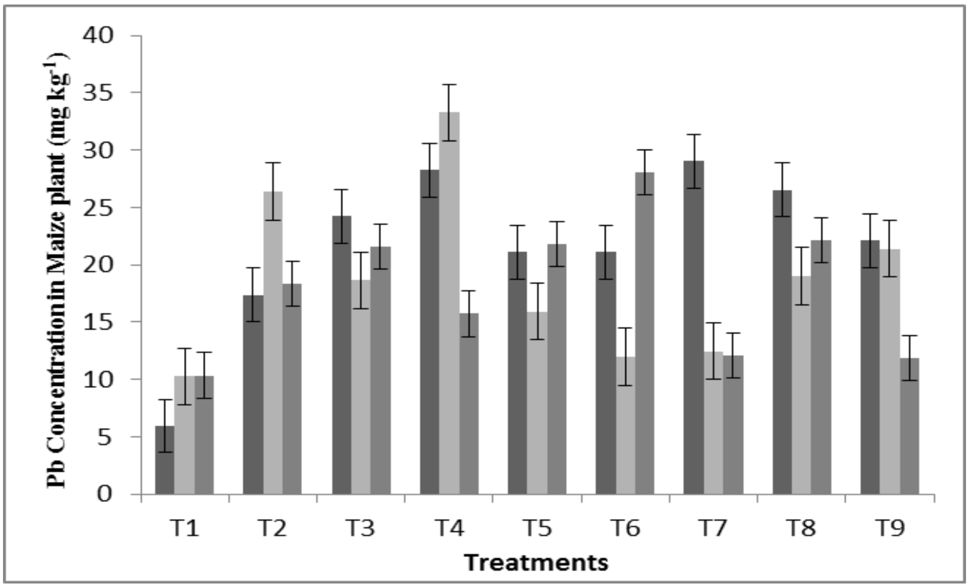
3.4.3. Lead concentration (mg kg^{-1})

A significant effect of sewage water and industrial effluent application was noted on lead concentration in maize plant 30, 45 and 60 DAG (Fig. 4). The result at 30 DAG showed higher but statistically similar lead concentration of 29.04 and 28.27 mg kg^{-1} in T_7 (50% tap water + 50% industrial effluent) and T_4 (75% tap water + 25% sewage water), while T_1 (100% tap water) had minimum level of lead (5.94 mg kg^{-1}) 30 DAG. The data taken 45 DAG showed that T_4 (75% tap water + 25% sewage water) had maximum (33.29 mg kg^{-1}) lead concentration. Minimum and statistically similar lead content of 12.46, 11.97 and 10.26 mg kg^{-1} was found in T_7 (50% tap water + 50% industrial effluent), T_6 (50% tap water + 50% sewage water) and T_1 (100% tap water), respectively. The data further revealed maximum lead accumulation of 28.04 mg kg^{-1} in T_6 (50% tap water + 50% sewage water), followed by T_8 (25% tap water + 75% sewage water), T_5 (75% tap water + 25% industrial effluent) and T_3 (100% industrial effluent). Minimum lead concentration of 10.33 mg kg^{-1} was fond in T_1 (100% tap water) 60 DAG. In the present research, maximum lead accumulation was noted in treatments where sewage water was applied along with tap water in different concentrations. It was probably due to high toxic metal level present in sewage water. Barriquelo et al., (2003) treated soil twice with sewage sludge. The soil, containing sewage sludge, presented a higher concentration of lead.



T1: 100% Tap Water T2: 100% Sewage Water T3: 100% Industrial Effluent
T4: 75% Tap Water + 25% Sewage Water T5: 75% Tap Water + 25% Industrial Effluent
T6: 50% Tap Water + 50% Sewage Water T7: 50% Tap Water + 50% Industrial Effluent
T8: 25% Tap Water + 75% Sewage Water T9: 25% Tap Water + 75% Industrial Effluent

Figure 3. Post-harvesting effect of sewage water and industrial effluent on Cd concentration of maize plant



T1: 100% Tap Water T2: 100% Sewage Water T3: 100% Industrial Effluent
T4: 75% Tap Water + 25% Sewage Water T5: 75% Tap Water + 25% Industrial Effluent
T6: 50% Tap Water + 50% Sewage Water T7: 50% Tap Water + 50% Industrial Effluent
T8: 25% Tap Water + 75% Sewage Water T9: 25% Tap Water + 75% Industrial Effluent

Figure 4. Post-harvesting effect of sewage water and industrial effluent on Pb concentration of maize plant

4. CONCLUSION

The tap water and effluent was shown to have a favorable effect on seed germination, seedling growth and heavy metal parameters. The most important advantage in the application of effluent waste water is that it can avoid environmental problems of discarding it into adjacent water bodies. Thus considerable quantities of fresh water can be saved for human consumption. Although the sewage and effluent had elevated concentrations of some of the metals compared to the tap water, the concentrations of such metals in these sources of irrigation water were, however, within the permissible limits for their use as irrigation water. The study suggests that if the crops are supplied with inadequate amount of essential plant food nutrients, wastewater irrigation will act as a supplemental source of fertilizer thus increases crop yields. On the other hand, if plant food nutrients applied through wastewater irrigation result in over supply of nutrients, yields may negatively be affected. From this study, it can be concluded that sewage effluent, in addition to being a source of irrigation water, is a potential source of plant nutrients, and that effluent application can result in an increase in micro- and macro-nutrients in soils.

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