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Effect of musi sewage water on soil properties of peri urban agriculture, Hyderabad, Telangana, India

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Abstract
To study the effect of Musi sewage water irrigation on Heavy metal contents in along the Musi River bed area in Rangareddy and Nalgonda districts of Telangana State in India.
The soils samples were collected at different locations along the Musi river bed just before sowing of the crops during *Kharif* 2012 and *Rabi* during 2012-13. These Soil samples were analysed for different parameters. The analysis of soil samples along the Musi river belt area indicated that all other parametersp HEC, CEC, OC, Available N, PK, DTPA Fe, Mn, Zn, Cu, Pb, Cd, Ni, Co and Cr in sewage water irrigated soils were more than in the Control soils. Further, it is observed that the values were more in *Rabi* season when compared to *Kharif* season. Available N, P_2O_5, K_2O, Fe, Mn, Zn, and Co contents were more than adequate level where as Pb, Cd, Ni and Cr contents were below the permissible limits.

Keywords: Musi sewage water on soil properties river bed area agriculture

1. Introduction
Hyderabad, being the most populous agglomeration in the world, generates daily huge amounts of solid, liquid and gaseous wastes from houses, industries, agriculture fields, automobiles *etc*. The generated wastes contain different type of pollutants in the form of detergents, pesticides, nitrates, fluoride and heavy metals (CPCB 2000) [16]. Surface runoff with these Organic and Inorganic pollutants through numerous drains ultimately ends up in Musi River and deteriorates the water quality. Due to the over-exploitation of the groundwater in adjoining areas of the Musi river basin pollutants also enter into the groundwater aquifers along with the river water. So the Musi River acts as a source of groundwater pollution. Further, Musi water is also being directly used for irrigation in some areas, so these pollutants added through irrigation water may pollute the field soil. Farmers of the peri-urban areas are also practicing intensive agriculture through imbalanced application of fertilizers and pesticides. The indiscriminate use of agro-chemicals like fertilizers and pesticides and/or irrigation with contaminated water can also pollute the soils of these irrigated areas. Hence the present study was undertaken.

Materials and Method
Peri urban area of Hyderabad (Peerzadiguda to Bacharam), Telangana, was selected as study area. Ten water samples were collected in three Replicas at ten selected locations at two times during *Kharif* (2013) and *Rabi* (2012-13) seasons from different surface sources of irrigation to the crops of these polluted areas as per Standard Procedure (APHA, 1985) [3]. Two Litre capacity stoppered Polythene bottles were used for collecting the sewage water samples and these bottles were washed with dil. Hcl and then rinsed with Distilled water. Details of the Standard methods used for analysis of samples are given in Table. 3.3. Separate glass bottles were used for sampling of sewage water samples for analysis of Heavy metals and these water samples were acidified with 1.5 ml HNO_3. The Electrical Conductivity (EC) of the water samples was by Conductivity Bridge Meter (Jackson 1973) [21].
The pH was also measured by pH Meter using glass electrode assembly (Jackson 1973) [21] and the sewage water samples analysed for TS, TDS, TSS, BOD, COD, HCO_3^{-1}, CO_3^{-2}, Acidity and Alkalinity as per the standard methods (APHA 1985) [3]. The pH, Salinity, Total solids, Total dissolved solids, Total suspended solids, Biological oxygen demand, Chemical oxygen demand, Carbonate, Bicarbonate, Acidity and Alkalinity at *Kharif* 2012

And *Rabi* 2012-13 seasons are given in the Table.1 and 2. The groundwater samples were also collected from the selected villages of the study area.

Ten locations at random along the Musi river belt area were selected and representative soil samples were collected from 10 farmers' fields. Five Surface (0-15 cm) soil samples were collected at random in each farmer field in different ten selected locations where the Musi river water is used as a source of irrigation for cultivation of crops and made them to composite sample representing each field.

Five surface Soil samples (0-15 cm) depth were collected at random from each selected field of ten locations before taking up the crop. These five samples collected at random made to composite sample represent each field, in the same way soil samples were also collected from uncontaminated agriculture fields where contaminated Musi river water was not used and normal water was used for irrigation, which served as Control. Samples were collected during both the seasons before taking up the crops.

Similarly Soil profile samples were taken up to 100 cm depth in all selected farmers' fields in ten locations at different depths of (0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm and 80-100 cm) following the Standard Methodology.

The Soil samples were collected in clean cloth bags and were dried under shade and pounded using wooden Pestle and Mortar and passed through a 2 mm Sieve. The processed soil samples were stored in Polythene bags after proper labelling and used for analysis of different parameters.

The particle size was analysed by Bouyoucos Hydrometer method. The Electrical Conductivity (EC) of the soil samples was by Conductivity Bridge Meter (Jackson 1973) [21]. The pH was also measured by pH Meter using Glass Electrode assembly (Jackson 1973) [21] the soil samples analysed for Organic Carbon by Chromic Acid Wet digestion method (Walkley and Black), (Jackson (1973) [21]; Cation Exchange Capacity by Sodium Acetate method; Available Nitrogen by Alkaline Potassium Permanganate Method; Available Phosphorus by Olsen's Extractant (Sodium Bicarbonate) Method (Watanabe and Olsen, 1965) [44]; Available Potassium by NH_4OAc Method (Jackson,1973) [21]; Avail Micro nutrients and Heavy metals(Cd, Ni, Cr, Pb, Co) by DTPA Method (Lindsay and Norway, 1978) [23].

Results and discussion

All the soil samples were analyzed for Physico-Chemical properties (pH, EC and OC) and Chemical properties (Available N, P, K, Fe, Mn, Zn, Cu, Cd, Ni, Co, Pb and Cr)

Soil reaction (pH)

The pH values of the surface soil samples collected at different locations along the Musi river belt area before sowing of the crop ranged from 7.22 to 7.67 and 7.52 to 7.85 with the mean values of 7.49 and 7.70 during *Kharif* 2012 and *Rabi* 2012-13 seasons respectively.

All the soil samples collected along the Musi river belt area were Slightly Alkaline in reactions whereas soil samples collected at non polluted control plot at Annojiguda was Neutral in reaction. The pH value of the soil samples in control plot at Annojiguda was 7.10 and 7.19 during *Kharif* and *Rabi* seasons respectively. The highest pH value was recorded in the soil samples at Chowdaryguda (7.67) and the lowest was in the soil samples collected at Bacharam (7.22) during *Kharif* season where as the highest pH (7.85) at Peerzadiguda and lowest pH (7.82) at Bacharam were recorded during *Rabi* season (Table 4.4).

The pH values of the soil samples at different locations of Musi river irrigated area were found higher than in the control soil at Annojiguda where non polluted water was used for irrigation. Mohd Auyoub Bhat *et al.* (2011) [25], Ghosh *et al.* (2012) [20], Singh *et al.* (2012) [36] also observed the pH values of soil samples are Slightly to Moderate Alkaline in the fields irrigated with sewage and domestic waste water at different locations of the country.

Electrical conductivity (EC)

The Electrical conductivity (EC) values of the surface soils samples collected before sowing of the crop at different locations of Musi river area ranged from 0.62 to 1.70 and 1.15 to 2.10 dS m^{-1} with the mean values of 1.12 and 1.65 dS m^{-1} during *Kharif* 2012 and *Rabi* 2012-13 respectively and all the samples were non saline in nature.

The lowest Electrical conductivity values of 0.62 dS m^{-1} and 1.15 dS m^{-1} were observed at Gowrelli and Bacharam locations respectively during *Kharif* 2012 and *Rabi* 2012-13 seasons. Similarly, highest Electrical conductivity values of 1.70 and 2.10 dS m^{-1} were observed at Peerzadiguda during *Kharif* 2012 and *Rabi* 2012-13 seasons respectively (Table 4.4).

The Electrical conductivity (EC) values of 0.26 and 0.32 dS m^{-1} were recorded during *Kharif* and *Rabi* seasons respectively in Control plot at Annojiguda where normal non polluted water was used for irrigation.

The mean Electrical conductivity (EC) values of soil samples collected from different locations along the Musi river area were three times more during *Kharif* and about five times more during *Rabi* than the values recorded in Control plots where normal water was used for irrigation. Higher Electrical Conductivity values in soils irrigated with Musi sewage water might be due to the presence of more amounts of Salts, Sodium and Organic constituents in sewage water. These results are also in agreement with those reported earlier in sewage and industrial effluents irrigated soils by Sharma *et al.* (2000) [35], Prashani *et al.* (2001) [29], Rajanarendhar (2004) [30] and Venkata Sridhar (2006) [42]. The range of Electrical Conductivity values observed in this study are similar to the values observed by Usha Rani (2007) [41], Garg and totawat (2005) [19], Bhupal Raj *et al.* (2006) [9] and Vipin Kumar *et al.* (2010) [43] in their studies at different locations.

Cation exchange capacity (CEC)

The Cation Exchange Capacity (CEC) of the surface soils collected from different locations irrigated with Musi sewage water ranged from 17.87 to 19.48 c mol (p^+) kg^{-1} and 18.62 to 21.51 c mol (p^+) kg^{-1} with the average values of 18.48 and 20.17 c mol (p^+) kg^{-1} during *Kharif* and *Rabi* season respectively.

The highest *i.e* 19.48 c mol (p^+) kg^{-1} and lowest *i.e* 17.87 cmol (p^+) kg^{-1} Cation Exchange Capacity values were recorded at Parvathapuram and Chowdaryguda respectively during *Kharif* season. Similarly, the highest (21.51 cmol (p^+) kg^{-1}) and lowest (18.62 c mol (p^+) kg^{-1}) CEC values were recorded at Peerzadiguda and Bacharam locations respectively during *Rabi* 2012-13 season (Table 4.4).

The mean CEC values of 18.48 and 20.17 c mol (p^+) kg^{-1} during *Kharif* and *Rabi* seasons, were comparatively more than the CEC values recorded in control plot at Annojiguda was 15 and 17 c mol (p^+) kg^{-1} respectively. These high values of Cation Exchange Capacity in contaminated soil over

Control soils was mainly due to high clay and organic matter contents in soils.
Similar observations of increased Cation Exchange Capacity due to sewage and industrial effluents water was reported earlier by Rajanarendra (2004) [30] and Venkata Sridhar (2006) [42] at different locations of Andhra Pradesh.
The range of Cation Exchange Capacity values in soils observed in this study are similar to the range of values observed by Chandrashekar *et al.* (2005) [14], Sridhara Charya *et al.* (2008) [40], Vipin Kumar (2011) [43], Mohd Ayubbut *et al.* (2011) [20] and Ghosh (2012) [20].

Organic carbon (OC)
The results revealed that the Organic Carbon contents were higher in soils polluted with Musi sewage water than in Control (0.45 and 0.53 percent for *Kharif* and *Rabi*) and these values ranged from 1.17 to 1.84 per cent and 1.52 to 2.07 per cent with the mean values of 1.41 and 1.75 per cent respectively during *Kharif* 2012 and *Rabi* 2012-13 seasons (Table 4.4). The Organic Carbon (OC) content in the Musi sewage water irrigated soils was about three time more than its content in the control but where normal water was used for irrigation. The high OC content in sewage water irrigated soils was ascribed due to the addition of Organic matter through long term application of sewage water. Thus, sewage water application to soils is a Carbon building/ Sequestrating and Soil quality sustaining practice (Rattan *et al.* 2001) [31].
Similar observation was made earlier in their studies at different locations by Bhupal Raj *et al.* (2006) [9], Bhaise *et al.* (2007), Sridhara Charya *et al.* (2008) [40], Karche *et al.* (2011) [22], Jayadev and Puttaih (2012) [11], Mohd Ayubbut *et al.* (2011) Sing *et al.* (2012) [36] and Bincey (2014) [12].

Chemical characters
The analysed data with respect to chemical properties of sewage water irrigated soils along the Musi River is presented in Table 1

(A) Major nutrients
Available nitrogen
The Available Nitrogen contents in surface samples (0-15cm) collected at different location along the Musi river catchment belt area ranged from 280 to 368 kg ha^{-1} and 284 to 412 kg ha^{-1} with the mean values of 323 and 337 kg ha^{-1} respectively during *Kharif* 2012 and *Rabi* 2012-13 seasons.
The highest value (368 kg ha^{-1}) and lowest value (280 kg ha^{-1}) of soil Available N were observed in soils at Parvathapuram and Gourelli respectively during *Kharif* 2012 season. Similarly, highest (412 kg ha^{-1}) and lowest (284 kg ha^{-1}) Available Nitrogen values were observed in soils at Peerzadiguda and Gourelli respectively during *Rabi* 2012-13 seasons. The Available Nitrogen recorded in Musi sewage water irrigated soils during both the seasons was medium in status.
The higher content of Available Nitrogen in Musi sewage water irrigated soils might be due to continuous irrigation with the sewage water having higher amounts of Organic matter. The Available Nitrogen content in Musi sewage water irrigated soils was about two times more than that of its values in Control plot at Annojiguda during both the seasons.
The similar observations were made by Majti *et al.* (1962), Prashanthi and Jevan Rao (1989) [29], Achari *et al.* (1999) [42], Chanakya (2007) [13], Singh *et al.* (2009) [10] and Kharche *et al.* (2011) [22].

Available P_2O_5
The Available Phosphorus contents of soil samples collected at different selected locations during *Kharif* 2012 and *Rabi* 2012-13 ranged from 42.8 to 69.8 kg ha^{-1} and 48.72 to 74.54 kg ha^{-1} with the mean values of 57.2 and 62.4 kg ha^{-1} respectively.
The Available Phosphorus in the soil samples were under medium to higher category. Five out of total ten samples during *Kharif* and three out of ten samples, during *Rabi* were high in Available Phosphorus content. The mean Available Phosphorus contents during *Kharif* (57.2 kg ha^{-1}) and *Rabi* (62.4 kg ha^{-1}) were about three times more than the Available Phosphorus in control plot at Annojiguda where normal water was used for irrigation.
The increasing Available Phosphorus content in Musi sewage water irrigated soils compared to Control may be attributed to the fact that considerable amount of Phosphorus accumulates in sewage water due to organic matter, detergents and soap mixed water coming from wash room from urban localities and also due to addition of industrial effluents.
The similar observation of increasing Available Phosphorus due to sewage water irrigation was made earlier by, Azad *et al.* (1987) [6] at Ludhiana, Mythi *et al.* (1992) at Kolkata, Rajanaredhar (2004) [30] at Hyderabad, Dubhe *et al.* (2006) at Kurukshetra and Kharche *et al.* (2011) [22] at Rahuri.

Available potassium
The Available Potassium content of surface soil (0-15 cm) samples collected before sowing of the crop from different locations of Musi river catchment area ranged from 557 kg ha^{-1} at Bacharam to 688 kg ha^{-1} at Peerzadiguda with the mean values of 613 kg ha^{-1} during *Kharif* 2012 season. Similarly, it ranged from 580 kg ha^{-1} at Bacharam to 761 kg ha^{-1} at Peerzadiguda with the mean value of 673 kg ha^{-1} during *Rabi* 2012-13 seasons (Table 4.4).
All the collected soil samples along the Musi river belt area are categorized under high (>340 kg ha^{-1}). The Available Potassium content in Musi sewage water irrigated soils was comparatively more than in the Control (425 and 485 kg ha^{-1} for *Kharif* and *Rabi*) during both the seasons.
The higher amounts of Available Potassium in sewage water polluted soils over the Control soils are due to continuous use of Musi sewage water rich in Potassium as source irrigation in these soils. The high amount of available K_2O in soils irrigated with industrial effluents sewage water was also observed by Devaraj and Obulswamy (1995), Prashanthi and Jeevan Rao (1999) [29] and Bincey (2014) [12].
Similar observations were made by Azad *et al.* (1987) [6] and Khache *et al.* (2011) [22] during their studies at Ludhiyana, Kurukshetra and Rahore respectively.

(B) Micro nutrients
The data on DTPA Extracted available Micro nutrients in surface soil samples (0-15 cm) collected at different locations along the Musi River is presented Tab No 4.6

Iron (Fe)
The DTPA Extractable Iron content in surface soil sample collected at different selected locations along the Musi river belt area ranged from 14.37 to 22.57 mg kg^{-1} and 18.91 to 25.75 mg kg^{-1} with the mean values of 18.42 and 21.79 mg kg^{-1} during *Kharif* 2012 and *Rabi* 2012-13 seasons respectively. Where as in Control soils at Annojiguda the DTPA Extractable Iron was 7.5 and 6 mg kg^{-1} during *Kharif* 2012

and *Rabi* 2012-13 seasons respectively (Table.2).

The Available Iron contents in the Musi sewage water irrigated soils during *Kharif* 2012 and *Rabi* 202-13 seasons were about 2.5 and 3.5 times more respectively than that of in Control plot soils at Annojiguda where normal water was used for irrigation. Kharche *et al.* (2011) [22] also reported 1.55 times more DTPA Extractable Iron in sewage irrigated soil than in Control soil.

The mean Available Iron values recorded during *Rabi* (21.79 mg kg $^{-1}$) were more than *Kharif* (18.42 mg kg $^{-1}$). The Available Fe status of Musi sewage water irrigated soils was high compared to Control, which might be due to addition of Micro nutrients and also Organic matter though sewage water. (Rattan *et al.* 2005) [31-32] reported that sewage irrigation for long term resulted in significant buildup of DTPA Extractable Fe in soils compared to normal well water irrigated soils.

Bhupal Raj *et al.* (2006) [9], earlier also reported the higher DTPA Fe in polluted soil when compared to non-polluted soils in Telangana state.

The Available Iron values in all the soil samples during the both the seasons were two to three times more than the adequate level 7.5 mg kg $^{-1}$ as prescribed by Bhupal Raj *et al.* (2014) [11].

Similar range of higher Available iron values were observed by Saraswat *et al.* (2005) [34], Daleep kumar *et al.* (2011) [24], Malik (2011) [24] and Ajmal Khan *et al.* (2013) [1] in their studies at different locations.

Manganese (Mn)

The Available Mn in soil samples collected at different selected locations along the Musi river belt area ranged from 12.51 to 22.55 mg kg^{-1} and 16.25 to 25.32 mg kg^{-1} with the mean value of 17.43 and 21.35 mg kg^{-1} during *Kharif* 2012 and *Rabi* 2012-13 seasons respectively (Table 2). Mean DTPA Extractable Mn contents in the soil samples collected along the Musi river area during *Kharif* (17.43 mg kg^{-1}) and *Rabi* (21.35 mg kg^{-1}) were 3 and 3.5 times more during *Kharif* and *Rabi* seasons respectively than the value recorded in Control (5.62 and 5.87 mg kg^{-1}).

Bhupal raj *et al.* (2009) [10] also reported 7 times more of Available Mn in polluted than in non-polluted soils in Andhra Pradesh. These higher contents were probably due to relatively higher content of Fe in sewage water, addition of Organic matter through sewage water also regulate the availability of Micro nutrient by way of chelating them Singh and Singh (1994) [37], Bhupal Raj *et al.* (2006) [6] reported similar trends in Micro nutrients and Iron content in sewage irrigated soils of Ludhiyana, Varanasi and Hyderabad respectively. The mean values of Available Mn recorded in the Musi sewage water irrigated soils were four and five times more during *Kharif* and *Rabi* seasons respectively than the suggested adequate level of 4.00 mg kg^{-1} as prescribed by Bhupal Raj *et al.* (2014) [11].

The relatively higher values of Available Mn in sewage water irrigated soils observed in their studies are similar to the observations made earlier at different location by singh and Karthikeyan (2003) [38], Saraswat *et al.* (2005) [34], Usha Rani (2007) [41], Chanakya (2007) [13], Malik *et al.* (2011) [24], Daleep Kumar *et al.* (2011) [24] and Ajmal Khan *et al.* (2013) [1].

Zinc (Zn)

The DTPA Extractable Zn in the soil samples collected at different locations along the Musi river belt area ranged from 1.57 to 1.97 mg kg^{-1} and 2.03 to 2.56 mg kg^{-1} with the mean values of 1.78 and 2.22 mg kg^{-1} respectively during *Kharif* and *Rabi* seasons (Table 2).

The mean Available Zn values in sewage water irrigated soil samples collected during *Kharif* and *Rabi* seasons were 2.5 and 2.8 times more respectively than the values recorded in Control soil (0.70 and 0.71 mg kg^{-1}) at Annajiguda where normal non polluted water was used for irrigation.

The mean DTPA-Zn values recorded in the soil samples were 1.2 and 1.5 times more in *Kharif* and *Rabi* season respectively when compared to adequate value of 1.5 mg kg^{-1} as suggested by Bhupal Raj *et al.* (2014) [11]. The higher content of Zn in these soils was probably due to addition of Organic matter to soil through sewage water and also due to slightly more Zn content in Musi sewage water used for irrigation.

Bhupal Raj *et al.* (2009) [10] reported 2.5 times more of DTPA Zn in polluted soils than in non-polluted soils, Ratan *et al.* (2005) [32], observed the buildup of DTPA-Zn in sewage irrigated soils due to continuous sewage water irrigation, Saraswat *et al.* (2005) [34] also reported similar observations.

Copper (Cu)

Available Copper values in the soils sample collected along the Musi river belt area at different selected location ranged from 3.17 to 7.66 mg kg^{-1} and 4.13 to 9.54 mg kg^{-1} with the mean values of 5.91 and 7.27 mg kg^{-1} respectively during *Kharif* and *Rabi* seasons. The relative lesser concentration during *Kharif* season might be due to dilution effect through rain water in monsoon period. These DTPA + Cu values in soils observed were 5.4 times more during *Kharif* season and 6.6 time more during *Rabi* season when compared to their respective value of 1.10 mg kg^{-1} in Control during *Kharif* and *Rabi* season (Table 2).

Ratan *et al.* (2005) [32] concluded that these sewage irrigation for 20 years resulted into significant buildup of DTPA – Cu (170%) in sewage irrigated soils over adjacent tube well water irrigated soils.

Similar to Zn, the relatively higher content of DTPA Copper in these soils might be due to addition of Organic matter through sewage water which regulates the availability of Micro nutrients.

Singh and Singh (1994) [37], Patel *et al.* (2004) [27] and Bhupal raj *et al.* (2006) [9] reported similar trends in Micro nutrient contents including Copper in the sewage irrigated soils of Varanasi, Anand and Hyderabad respectively.

(C) DTPA extractable heavy metals

Data on DTPA Extractable Heavy metals in soils collected at different location along the Musi river area is present in Table 4.6.

Lead (Pb)

The Lead (Pb) content in soils ranged from 5.47 to 6.74 mg kg^{-1} and 6.12 to 8.24 mg kg^{-1} with the mean values of 6.14 and 7.44 mg kg^{-1} in *Kharif* and *Rabi* seasons respectively, whereas as in Control (normal irrigation) these values were 4.20 and 4.40 mg kg^{-1} during *Kharif* 2012 and *Rabi* 2012-13 seasons respectively (Table 2).

The mean DTPA Pb value recorded in these sewage water irrigated soils during *Rabi* season was about 21% more than the value recorded during *Kharif* season. The less values of Pb in soils during *Kharif* season might be due to dilution due to rain water and run off.

Similarly, the mean Pb content in soils during *Kharif* and

Rabi seasons were more to an extent of 23.8 and 38.4 per cent than the values recorded in the control plots (4.2 and 4.4 mg kg^{-1}) respectively.

Patel *et al.* (2004) [27], Bhupal Raj *et al.* (2006) [9] and Mukund Brar *et al.* (2006) [26], also reported higher amounts of Pb in soils irrigated with sewage and effluent water compared to the normal irrigated soils during their studies at different locations.

The DTPA–Pb values recorded in all the soil samples along the Musi river catchment area were found to be lower than the permissible limits of 50 mg kg^{-1} and 250-500 mg kg^{-1} as suggested by FAO (1983) [18] and Awashi (2000) [4] respectively. The Musi sewage water used for irrigation also had the Pb values (0.03-0.482 mg L^{-1}) lower than the suggested permissible limits 5 mg L^{-1} as suggested by FAO (1985) [18]. Anith sing *et al.* (2010) [2] and Ratan *et al.* (2005) [32] observed 29.1 and 25% more Pb values respectively in soils irrigated with sewage water than in the normal water irrigated soils.

Similar observations of relatively higher amount of Lead in sewage water irrigated soils were made by Daleep Kumar *et al.* (2011) [24], Ajmal Khan *et al.* (2013) [1] and Sandip Singh *et al.* (2016) [33] at different locations.

Cadmium (Cd)

The DTPA Extractable Cd in Musi sewage water irrigated soils at different selected locations varied from 0.329 to 0.418 mg kg^{-1} and 0.429 to 0.518 mg kg^{-1} with the mean values of 0.376 and 0.472 mg kg^{-1} during *Kharif* and *Rabi* seasons respectively. It was observed that relatively higher amount of DTPA Cadmium was recorded in soil samples collected during *Rabi* season than that of *Kharif* season. The relatively lesser values in *Kharif* season might be due to effect of dilution and run off (Table 2).

The Mean Available Cadmium (Cd) values recorded in the soils during *Kharif* and *Rabi* seasons were more to an extent of 88 and 136 per cent respectively than the values recorded in Control soils (0.2 mg kg^{-1}) at Annajiguda where normal water used for irrigation. Bhupal Raj *et al.* (2006) [9] also reported similar range of Cadmium values in Musi sewage water irrigated soils in and around Hyderabad. Chahal *et al.* (2014) also observed Cadmium values ranging to 0.55 to 1.39 mg kg^{-1} in sewage water irrigated soils in Punjab.

The DTPA Cadmium values recorded in these soils under study were lower than the Critical levels of 3 mg kg^{-1} suggested by FAO (1983) [18], and Pescod *et al.* (1985) [28] and 3-6 mg kg^{-1} as suggested by Awasthi *et al.* (2000) [4].

The relatively more amount of Available Cadmium in these soils irrigated with sewage/effluent water than that of in Control were also observed in their earlier studies at different locations by Anith Sing *et al.* (2010) [2], Bhat *et al.* (2011) [8], Daleep Kumar *et al.* (2011) [24], Ajmal Khan *et al.* (2013) [1] and Sandip Sing *et al.* (2016) [33] at different locations.

Nickel (Ni)

The Available Ni in sewage irrigated soils at different locations ranged from 1.84 to 2.36 mg kg^{-1} and 2.09 to 3.11 mg kg^{-1} with the mean values of 2.12 and 2.66 mg kg^{-1} during *Kharif* and *Rabi* season respectively. It was observed that the mean the DTPA Extractable Ni values in Musi sewage water irrigated soils were more to an extent of 92 and 141 per cent respectively than the values recorded in control soils. Ratan *et al.* (2005) [32] and Bhupal raj *et al.* (2006) [9] reported 63% and 40% more DTPA–Ni in sewage irrigated soil over the normal irrigated soils (Table 2).

Kharche *et al.* (2011) [22] and Bhupal Raj *et al.* (2006) [9] reported higher DTPA – Ni values in sewage water irrigated soils to an extent 1.12 and 1.40 times more than in normal soils in Maharashtra and Telangana states respectively.

The Ni contents in all the Musi sewage water irrigated soils during both *Kharif* and *Rabi* season were quite lower than the safe critical of limits 50 mg kg^{-1} as suggested for soil by FAO (1983) [18] and Pescod *et al.* (1985) [28] and also critical level of 75 to 150 mg kg^{-1} as suggested by Awasthi *et al.* (2000) [4]. The Musi sewage water used for irrigating these soils also had Ni contents within the permissible limits.

The DTPA Ni values of the soil sample observed in this study are within the range of values recorded by Bhat *et al.* (2011) [8], Daleep kumar *et al.* (2011) [24] and Ajmal khan *et al.* (2013) [1].

Cobalt (Co)

The DTPA Extractable Cobalt contents in the Musi sewage water irrigated for different location varied from 0.357 to 0.415 as 0.447 to 0.514 mg kg^{-1} with the mean values of 0.386 and 0.483 mg kg^{-1} during *Kharif* 2012 and *Rabi* 2012-13 seasons respectively. The DTPA Extractable Cobalt recorded in soil sample of Control plot at Annajiguda were 0.20 and 0.140 mg kg^{-1} during *Kharif* and *Rabi* season (Table 2).

The mean Cobalt content in the Musi sewage water irrigated soils was about 2 times more than in the Control plot 0.20 and 0.24 mg kg^{-1} respectively, during *Kharif* and *Rabi* seasons. These mean Cobalt values recorded in soils during *Kharif* season was about 25% lower than that of in *Rabi* season might be due to dilution effect during rainy season.

The DTPA Cobalt values in all the soil sample during both the season were below the critical level of 2 mg kg^{-1} soil as suggested by Chapman (1975) and these observed values were just above 0.35 mg kg^{-1} as the sufficient level in soil as suggested by Mitch *et al.* (1964).

Patel *et al.* (2004) [27], Bhupal Raj *et al.* (2006) [9], Somshankar Das (2006) [39], Daleep Kumar *et al.* (2011) [24] and Malik *et al.* (2011) [24] also recorded similar range of Cobalt values in sewage irrigated soils during their studies earlier at different locations.

Chromium (Cr)

The mean contents of Available Chromium in Musi sewage water irrigated soil sample at different locations during *Kharif* and *Rabi* seasons were 0.045 to 0.057 mg kg^{-1} respectively. These values ranged from 0.035 to 0.065 mg kg^{-1} and 0.044 to 0.082 mg kg^{-1} respectively during *Kharif* and *Rabi* seasons (Table 2).

The relatively less concentrations of Chromium to an extent of 26% was observed during *Kharif* season when compared to *Rabi* season might be due to dilution effect during rainy season due to rain water and runoff water. The Available Chromium recorded in control soil was 0.002 mg kg^{-1} which is 28% less than the values recorded during *Kharif* and *Rabi* seasons.

The DTPA Chromium value in all the soil samples collected along with the Musi river area at all the selected locations were below the safe level of 2 mg kg^{-1} as suggested by Chapman (1975). Bhupal Raj *et al.* (2006) [9], Mohd Ayasbhai *et al.* (2011) [25], Ghosh *et al.* (2012) [20] and Balram Patel (2016) [7] also reported earlier that the DTPA Chromium values in sewage irrigated soils were below the permissible limit.

The DTPA Chromium values in the soils observed in this study are similar to the range of values observed by Singh and Karthikeyan (2003) [38] and Daleep kumar *et al.* (2011) [24] their studies earlier at different locations. The order of relative availability of DTPA Extractable Heavy metals in the sewage water irrigated soil in this present study was as Pb > Ni > Co > Cd > Cr.

All the Heavy metal concentrations in the soil samples were below the permissible limits of the EU standards (European Union, 2002), and Indian Standards (Awashi, 2000) [4]. Continuous removal of metals by food crops (vegetables and cereals) grown at these sewage water irrigated locations and Heavy metals leaching into deeper layers of the soils may be the reason for being their concentration below the permissible limit. Similar results were reported by Singh *et al.* (2010) [48], Tiwari *et al.* (2011) [46] and Nazir *et al.* (2015) [47] earlier in their studies at different locations.

But, the continuous irrigation with sewage water or effluents on long run to arable lands will go on increasing the concentrations of these heavy metals in the feeding zone of plant roots, which may not only become toxic to plant but also create problems in animals and human beings subsequently because of their entry into food chain.

Table 1: Physico-Chemical and Chemical characters of surface soil samples (0-15 cm) collected at ten different locations along the Musi river bed area during *Kharif* 2012 and *Rabi* 2012-13 (Mean of five samples)

S. No	Name of the village	pH	EC (dS m^{-1})	CEC (cmol (p^+) kg^{-1} soil)	OC (%)	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
Kharif (2012)								
1	Peerzadiguda	7.54	1.70	19.22	1.84	335	68.4	688
2	Parvathapuram	7.65	1.52	19.48	1.44	368	69.8	657
3	Kachwanisingaram	7.43	1.49	18.22	1.62	345	63.5	674
4	Prathapsingaram	7.66	1.20	17.87	1.47	347	66.6	644
5	Sadataliguda	7.43	1.10	18.65	1.27	327	59.7	591
6	Muthawaliguda	7.47	1.10	18.32	1.35	342	55.4	609
7	Korremula	7.28	0.92	18.38	1.22	294	55.6	583
8	Chowdaryguda	7.67	0.90	17.87	1.34	312	47.2	562
9	Gourelli	7.55	0.62	18.24	1.35	280	42.8	564
10	Bacahram	7.22	0.65	18.52	1.17	276	43.2	557
	Range	7.22-7.67	0.62-1.70	17.87-19.48	1.17-1.84	280-368	42.8-69.8	557-688
	Mean	*7.49*	*1.12*	*18.48*	*1.41*	*323*	*57.2*	*613*
	SD	0.16	0.36	0.53	0.20	32.97	10.15	49.19
	Control (Non polluted)	7.10	0.26	15	0.45	152	18.5	425
Rabi (2012-13)								
1	Peerzadiguda	7.85	2.10	21.51	2.07	412	74.5	761
2	Parvathapuram	7.75	1.92	21.12	1.81	359	73.6	752
3	Kachwanisingaram	7.82	1.89	20.74	1.90	362	68.7	719
4	Prathapsingaram	7.68	1.70	20.55	1.83	355	69.2	726
5	Sadataliguda	7.83	1.65	20.83	1.67	336	62.5	673
6	Muthawaliguda	7.66	1.85	19.93	1.73	334	63.6	658
7	Korremula	7.53	1.62	20.09	1.59	311	59.2	649
8	Chowdaryguda	7.67	1.50	19.52	1.67	322	53.5	593
9	Gourelli	7.66	1.15	18.82	1.73	284	50.7	618
10	Bacahram	7.52	1.15	18.62	1.52	290	48.7	580
	Range	7.52-7.85	1.15-2.10	18.62-21.51	1.52-2.07	284-412	48.7-74.5	580 - 761
	Mean	7.70	*1.65*	*20.17*	*1.75*	*337*	*62.4*	*673*
	SD	0.116	0.316	0.961	0.159	37.98	9.27	64.85
	Control (Non polluted)	7.19	0.32	17	0.53	164	19.3	485

Control - Non polluted water at Annojiguda

Table 2: Available Micronutrients and Heavy Metals contents of surface soil samples (0-15 cm) collected at ten different locations along the Musi river belt during *Kharif* 2012 and *Rabi* 2012-13 (Mean of five samples)

S. No	Name of the village	Micronutrients (mg kg^{-1})				Heavy Metals (mg kg^{-1})				
		Fe	Mn	Zn	Cu	Pb	Cd	Ni	Co	Cr
Kharif (2012)										
1	Peerzadiguda	22.57	22.25	1.83	6.57	6.62	0.418	2.27	0.411	0.051
2	Parvathapuram	21.27	19.33	1.63	7.38	6.74	0.408	2.36	0.395	0.065
3	Kachwanisingaram	21.72	20.54	1.87	7.33	6.64	0.414	2.28	0.415	0.047
4	Prathapsingaram	20.89	19.6	1.84	7.27	6.24	0.372	2.2	0.357	0.052
5	Sadataliguda	16.14	18.44	1.97	7.66	6.22	0.388	2.19	0.391	0.044
6	Muthawaliguda	18.47	20.32	1.93	5.27	5.97	0.352	2.21	0.383	0.037
7	Korremula	15.54	13.44	1.75	3.17	6.25	0.367	1.91	0.387	0.044
8	Chowdaryguda	16.12	15.27	1.73	4.18	5.65	0.364	2.03	0.371	0.035
9	Gourelli	17.15	12.64	1.69	4.72	5.57	0.329	1.91	0.377	0.042
10	Bacahram	14.37	12.51	1.57	5.55	5.47	0.352	1.84	0.368	0.036
	Range	14.37-22.57	12.51-22.25	1.57-1.97	3.17-7.66	5.47-6.74	0.329-0.418	1.84-2.36	0.357-0.415	0.035-0.065

	Mean	18.42	17.43	1.78	5.91	6.14	0.376	2.12	0.386	0.045
	SD	2.97	3.63	0.131	1.56	0.461	0.030	0.183	0.018	0.009
	Control (Non polluted)	7.5	5.62	0.70	1.10	4.2	0.2	1.1	0.20	0.002
Rabi (2012-13)										
1	Peerzadiguda	25.75	25.32	2.56	9.54	7.48	0.518	3.11	0.496	0.058
2	Parvathapuram	22.52	24.41	2.44	8.25	8.24	0.472	3.08	0.487	0.082
3	Kachwanisingaram	23.64	23.11	2.23	8.66	7.72	0.483	2.88	0.514	0.055
4	Prathapsingaram	22.77	23.33	2.29	9.05	7.70	0.467	2.74	0.491	0.065
5	Sadataliguda	20.77	24.22	2.25	7.89	8.11	0.515	2.83	0.504	0.057
6	Muthawaliguda	21.52	22.75	2.17	6.75	7.53	0.457	2.67	0.462	0.047
7	Korremula	19.78	18.52	2.04	7.21	7.22	0.472	2.49	0.483	0.057
8	Chowdaryguda	20.77	19.24	2.03	5.21	7.11	0.455	2.23	0.478	0.044
9	Gourelli	21.52	16.37	2.11	6.05	7.14	0.429	2.45	0.447	0.054
10	Bacahram	18.91	16.25	2.04	4.13	6.12	0.453	2.09	0.462	0.047
	Range	18.91-25.75	16.25-25.32	2.03-2.56	4.13-9.54	6.12-8.24	0.429-0.518	2.09-3.11	0.447-0.514	0.044-0.082
	Mean	21.79	21.35	2.22	7.27	7.44	0.472	2.66	0.483	0.057
	SD	1.98	3.43	0.178	1.75	0.599	0.028	0.341	0.021	0.011
	Control (Non polluted)	6.0	5.87	0.77	1.10	4.4	0.2	1.1	0.24	0.002

Control **-** Non polluted water at Annojiguda

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