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TEXTILE AND DYE INDUSTRY EFFLUENT, SLUDGE AND AMENDMENTS ON HEAVY METALS CHROMIUM, NICKEL, CADMIUM AND LEAD STATUS OF MAIZE CULTIVATED SOIL

M. PARAMESWARI

Department of Environmental Sciences, Tamil Nadu Agriculture University, Coimbatore, Tamil Nadu, India

ABSTRACT

To assess the impact of textile and dye industrial effluent on soil and crops, the Pot culture experiment carried out with maize crop to determine the effect of dye and textile factory effluent in combination with amendments (poultry manure, green leaf manure, bio compost, vermin compost) revealed that application of CETP sludge @ 5 t ha^{-1} + poultry manure @ 5 t ha^{-1} + NPK increased the soil organic carbon, available N, P, K, Ca, Mg and heavy metals like chromium in soil under treated effluent irrigation compared to river water irrigation. The total Cr content ranged from 0.50 to 13.25, 1.00 to 36.52 and 1.65 to 32.52 mg kg^{-1} at vegetative stage, flowering stage and at harvest stages, respectively under effluent irrigation. However, it did not produce any toxic effects to the crops. This showed that the treated effluent could be safely used for irrigation along with poultry manure @ 5 t ha^{-1} and NPK. However, continuous monitoring of the soil and ground water quality parameters are essential to suggest suitable remediation measures when treated textile and dye factory effluent is continuously use for irrigation

KEYWORDS: T- Treatment, N- Nitrogen, P- Phosphorus, K- Potassium, Cr- Chromium, GR Gypsum Recommendation, COH- Coimbatore Hybrid, Chromium- Cr, Cadmium-Cd, Nickel- Ni, Lead-Pb

INTRODUCTION

Textile dyeing industry is one of the major water consuming and high polluting industries in India. Effluent in higher concentrations affect the soil and causes heavy damage to crops growth conditions. Recent awareness and growing global concern for deterioration in the quality of environment has induced great interest in the identifying the various types of pollutants and the effect on living organisms (Ravi *et al*.,). The use of dyeing effluent for irrigation may be an alternate method for recycling if used rationally and in appropriate concentrations (Kumawat *et al*., 2001). The effluent and sludge generated from various industries are being dumped into the environment, causing various hazards on a long run. At the same time, these wastes contain essential nutrients. So utilization of such wastes for crop production can enhance the availability of nutrients and enrich soil organic matters that ultimately increase the growth of crops. (Parameswari, 2006) Butani Naresh *et al.,* 2013. The improper and indiscriminate disposal of industrial solids is posing a great challenge to India and other developing nations. They cause odor problem and are potential source of surface and ground water pollution. The sludge resulting from different industrial operations and wastewater treatment plants are managed through destructive methods: land filling and incineration (Ndegwa and Thompson, 2001). The textile and dye industrial sludge is reported to promote crop growth if added to the soil in quantities below the toxicity limits. Moreover, the land application of industrial sludge provides an effective and environmentally acceptable option of waste disposal to recycle valuable nutrients into the soil plant system (Parameswari, 2013). A pot culture experiment was conducted to assess the effect of effluent and sludge on soil quality and productivity of maize was carried out in the Department of Environmental Science, Tamil Nadu agricultural University, Coimbatore. The two different concentrations of effluent (1:1 dilution and un dilution) were taken for the pot culture experiment and compared with control (river water). Hybrid maize, (COH3) was used as the test crop. The treatment details are given below.

Experimental Details

Factor I: Irrigation Source

I_1 - River water (Control), I_2 – Diluted textile and dye effluent (1:1- Effluent and river water)

I_3 - Undiluted textile and dye effluent

Factor II: Treatments

T_1 - Control (NPK alone), T_2 - Textile and dye sludge @ 5 t ha^{-1} + NPK, T_3 - T_2 + FYM @ 12.5 t ha^{-1}, T_4 - T_2 + Poultry manure @ 5 t ha^{-1} , T_5 - T_2 + Green leaf manure @ 5 t ha^{-1} , T_6 - T_2 + Vermicompost 5 @ t ha^{-1} , T_7 - T_2 + Bio compost 5 @ t ha^{-1}

Fertilizer Dose: 135: 12.5: 50 NPK kg ha^{-1} respectively (100 per cent NPK)

Replication: Three, Crop: Maize (COH3), Design: FRBD

The experimental data were statistically scrutinized to find out the influence of various treatments on the soil properties and crop growth as suggested by Panes and Sukhatme (1955). The critical difference was worked out at five per cent (0.05) probability

The amendments and fertilizers were mixed thoroughly with seven kg soil as per the treatments given above and placed into plastic pots. Maize seeds were sown at five seeds per pot and thinned to three healthy seedlings per pot on 7th day after germination. Irrigation was given as per the treatments once in a week. The analytical procedures followed for the estimation of chemical constituent of the plant samples.

The analytical methods followed for all these studies are presented here under.

Table 1: Analysis Method of Textile and Dye Industry Solid Waste and Soil Sample

S. No.	Parameters	Methods Followed
Analysis of Textile and Dye Solid Waste		
1	pH and EC	Dye sludge and distilled water @ 1:10 and measured in pH meter and conductivity meter Falcon *et al.* (1987)
2	Preparation of triacid extract	Nitric acid: sulphuric acid: perchloric acid @ 9:2:1 ratio Biswas *et al.* (1977)
3	Preparation of diacid extract	Sulphuric acid and perchloric acid @ 5:2 ratio Biswas *et al.* (1977)
4	Total nitrogen	Diacid extract - semiautomatic Kjeldahl apparatus Bremner (1965)
5	Total phosphorus	Triacid extract - vanadomolybdate yellow colour method Jackson (1973)
6	Total potassium	Triacid extract - flame photometer Jackson (1973)
Analysis of soil sample		
1	pH	Soil: Water suspension of 1: 2.5 Jackson (1973)
2	Available N	Alkaline permanganate method Subbiah and Asija (1956)
3	Available P	Photoelectric colourimeter at 660 nm Olsen *et al.* (1954)
4	Available K	Neutral Normal Ammonium acetate extract (Flame photometer) Stanford and English (1948)
5	Heavy metals Chromium, Cadmium, Nickel and Lead	Atomic absorption spectrophotometer (AAS) Lindsay and Norvell (1978)

RESULTS AND DISCUSSIONS

This study was carried out to investigate the integrated management aspects of solid and liquid wastes, which are generated from textile and dye industry. The results obtained from the pot culture experiments are presented hereunder.

Characteristics of Textile and Dye Factory Effluent and River Water

The treated effluent used for the study had a pH of 8.38 with of dull blue colour and EC of 2.16 dS m^{-1}. The organic carbon content of the effluent was 0.60 per cent. The nitrogen, phosphorus and potassium contents of the effluent were 37.0, 24.0 and 16.8 mg L^{-1}, respectively. The calcium and magnesium contents of the effluent were 28.0 and 20.0 mg L^{-1}, respectively. The chloride, sulphate, carbonate, bicarbonate and sodium content of the effluent were 120.0, 42.0, 21.0, 85.0 and 150.0 mg L^{-1} respectively. Ramachandran (1994) reported that low concentrations of carbonate and bicarbonate compared to sulphate and chloride. Kothandaraman *et al.* (1976) reported a range from 300-570 mg L^{-1} for chloride and from 660-1600 mg L^{-1} for sulphate and very low content (less than 0.2 mg L^{-1}) of micronutrients and heavy metals. The river water had a pH of 6.95 and EC of 0.12 dS m^{-1}. The calcium content of the river water was 11.5 mg L^{-1} and sodium 6.5 mg L^{-1}.

Characteristics of the Initial Soil and Amendments

From the initial analysis, it was observed that the soil was low in available NPK status. The organic carbon content of the soil was low with appreciable quantities of exchangeable cations. Among the amendments, poultry manure was alkaline in nature with a pH of 8.50 with high NPK (1.33, 0.98 and 1.16 per cent, respectively) followed by bio compost. Among the materials, the organic carbon content was more or less same in all amendments except ETP sludge. The poultry manure, farmyard manure, green leaf manure and bio compost used as amendments in this study were analysed. Among the amendments, poultry manure was alkaline in nature with a pH of 8.50 along with high N, P and K (1.33, 0.98 and 1.16 per cent, respectively) followed by bio compost. Among the amendments, poultry manure had the highest Ca and Mg content of 1.18 and 0.56 per cent, respectively. The lowest Ca (0.31 per cent) and Mg (0.21 per cent) content were observed in green leaf manure.

Initial Characteristics of the Sludge Used for Pot Culture Experiment

The sludge was alkaline in pH (8.50) and with EC of 4.53 dS m^{-1}. The sludge had small amount of total N and total P, but appreciable amount of total K. The sludge had very high amount of calcium (18.25 per cent) and magnesium (1.79 per cent). The sodium and sulphate contents of the sludge were 0.76 and 19.56 per cent, respectively. It had an appreciable amount of micronutrients and also microbial load.

Soil Characteristics as Influenced by Effluent Irrigation and Amendments

Soil Reaction

The soil reaction increased progressively till at the end of harvest stage. The pH varied significantly among the treatments at all the stages. At harvest stages, the highest mean pH (8.24) was recorded in T_2, which was followed by T_4 and T_3. The lowest mean was recorded in T_1 (7.91) at vegetative stage, which was on par with T_4. Treated undiluted effluent (I_3) irrigation significantly increased the soil pH over diluted effluent (1:1 ratio) and river water irrigation. Similar increase in soil pH due to effluent irrigation was reported by Vasconcelos and Cabrel (1993). The increase in soil pH due to amendment addition, in the present study corroborates with the findings of Olaniya *et al*. (1991). Soil pH increased with advancement of crop growth in the effluent irrigated treatments while under river water the change was not at a considerable level. Similar viewpoints were also expressed by Malathi (2001).

Electrical Conductivity (EC)

The soil EC ranged from 0.35 to 0.60 dS m^{-1}, 0.35 to 0.82 dS m^{-1} and 0.35 to 1.25 dS m^{-1} at vegetative, flowering and at harvest stages, respectively. Drastic increase in soil EC was observed up to flowering stage and the increase was marginal at harvest stage. Treated undiluted effluent irrigation significantly increased the soil EC over diluted effluent (1:1 ratio) and river water irrigation. Among the treatments, T_2 (sludge + NPK) registered higher mean soil EC during vegetative stage (0.52 dS m^{-1}), flowering stage (0.69 dS m^{-1}) and harvest stage (0.88 dS m^{-1}), followed by T_4, T_3 and T_6, which differed significantly among themselves. The higher EC in effluent receiving treatments might be due to salt accumulation because of continuous effluent irrigation. The increase in EC might be due to higher Ca and Mg content of sludge. These findings were in line with that of Hameed and Udayasoorian (1999). Significant interaction between irrigation and amendment was observed at all the stages of crop growth. The treatment combination I_3T_2 (effluent irrigation + CETP sludge) recorded the highest EC (1.25 dS m^{-1}) at harvest stage and the lowest value in I_1T_1 (0.35 dS m^{-1}) at vegetative stage. The results revealed that application of sludge alone without any amendments increased the EC value significantly. Similar observation in soil EC due to effluent irrigation has been noticed by Dhevagi *et al*. (2000).

DTPA Extractable Heavy Metals

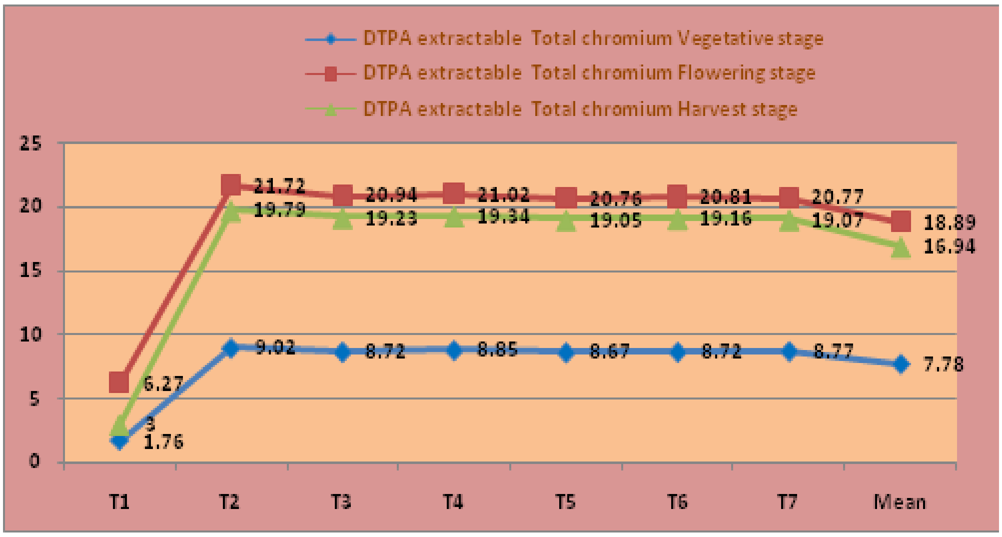
DTPA Total Chromium

The total Cr content ranged from 0.50 to 13.25, 1.00 to 36.52 and 1.65 to 32.52 mg kg^{-1} at vegetative stage, flowering stage and at harvest stages, respectively. In general, the Cr content increased up to flowering stage and declined at harvest stage. Continuous effluent irrigation increased the Cr content over river water irrigation at all stages of crop growth. Among the treatments, T_1 recorded the lowest value while the highest value of was in T_2 at all the stages. Significant interaction between irrigation and treatment was observed at all stages. The treatment combination I_3T_2 recorded the highest value of chromium while the lowest value in I_1T_1 at all stages.

Table 2: Effect of Effluent Irrigation and Amendments on Total Chromium Content of Soil under Maize (mg kg^{-1})

Treatments	DTPA Extractable Total Chromium					
	Vegetative Stage		Flowering Stage		Harvest Stage	
T_1	1.76		6.27		3.00	
T_2	9.02		21.72		19.79	
T_3	8.72		20.94		19.23	
T_4	8.85		21.02		19.34	
T_5	8.67		20.76		19.05	
T_6	8.72		20.81		19.16	
T_7	8.77		20.77		19.07	
Mean	**7.78**		**18.89**		**16.94**	
Interaction	**SEd**	**CD (0.05)**	**SEd**	**CD (0.05)**	**SEd**	**CD (0.05)**
I	0.03	0.05	0.07	0.13	0.06	0.12
T	0.04	0.08	0.10	0.20	0.09	0.19
I x T	0.07	0.14	0.17	0.35	0.16	0.32

The heavy metal content of the soil increased due to continuous effluent irrigation and the accumulation was more in surface soil than sub surface soil. It is in line with the findings of Jothimani (2002) and Parmeswari (2006). The polluted surface soil had higher amount of Cr, Cd, Ni and Pb than the unpolluted soil. The effluent irrigated post leachte column soil had higher amount of heavy metals. The clay soil (S_3) adsorbed large amount of Cr and strongly retained in the exchange sites. Similar observations have been reported by Sumathi (1999).



I_1 - Well water, I_2 - Treated textile dye effluent
T_1 – Control (NPK alone), T_2 – 50 %GR+NPK, T_3 – 100 %GR+NPK, T_4 –50%GR+PM+NPK,
T_5 – 100%GR+PM+NPK, T_6 –50%GR+ETP sludge +NPK, T_7 100% GR+ETP sludge + NPK,
T_8- 50%GR+FYM+NPK, T_9 -100 % GR+FYM+ NPK PM - Pressmud @ 5 t ha^{-1},
ETP sludge - Effluent Treatment Plant sludge @ 5 t ha^{-1}, FYM - Farmyard manure @ 12.5 t ha^{-1}

Figure 1: Effect of Effluent Irrigation and Amendments on Total Chromium Content of Soil under Maize (mg kg^{-1})

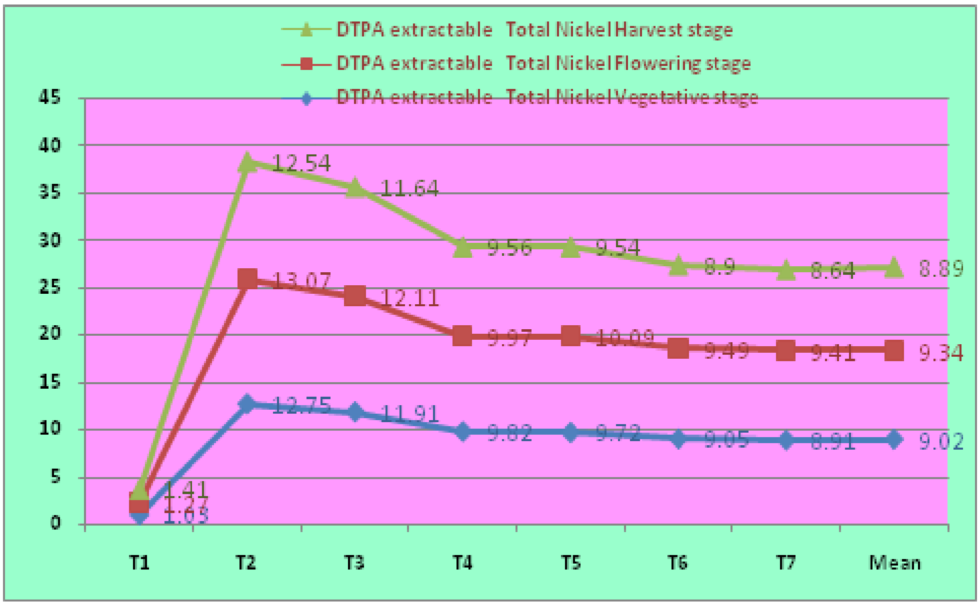
DTPA Total Nickel and Cadmium

The undiluted effluent irrigation increased the Ni and Cd content over diluted effluent @ 1:1 ratio and river water irrigation at all stages of crop growth. The Ni and Cd content in soil were reduced by the application of amendments after flowering stage. The content ranged from 0.08 to 20.25 mg kg^{-1}, 0.08 to 20.85 mg kg^{-1} and 0.72 to 20.15 mg kg^{-1} for nickel, 0.05 to 1.13 mg kg^{-1}, 0.08 to 1.15 mg kg^{-1} and 0.10 to 1.08 mg kg^{-1} for cadmium at vegetative, flowering and harvest stages, respectively. The highest mean Ni value was observed in T_2 (12.75 mg kg^{-1}) at vegetative stage and a similar trend was noticed at flowering and harvest stages also. In general the Ni content increased up to flowering stage and then decreased at harvest stage.

The interaction between irrigation and treatment was found to be significant. The treatment combinations I_3T_2 recorded the highest value of Ni and the lowest value in I_1T_1. This findings corroborate with gypsum application was found to increase the availability of micronutrients in the soil (Palanisami, 1989). Effluent irrigation plus 20 t ha^{-1} gypsum recorded maximum germination percentage, shoot length, dry weight of sugar cane settling, and increase in content and uptake of N, P, K, Mn and Zn and also the Fe and Cu (Oblisami and Palanisami, 1991). The exchangeable chromium decreased towards the harvesting stage of crop growth. Textile and dye industrial CETP sludge was identified as an effective nutrients source for groundnut crop (Thavamani, 2000).

Table 3: Effect of Effluent Irrigation and Amendments on Total Nickel Content of Soil under Maize (mg kg^{-1})

Treatments	DTPA Extractable Total Nickel					
	Vegetative Stage		Flowering Stage		Harvest Stage	
T_1	1.03		1.27		1.41	
T_2	12.75		13.07		12.54	
T_3	11.91		12.11		11.64	
T_4	9.82		9.97		9.56	
T_5	9.72		10.09		9.54	
T_6	9.05		9.49		8.90	
T_7	8.91		9.41		8.64	
Mean	**9.02**		**9.34**		**8.89**	
Interaction	**SEd**	**CD (0.05)**	**SEd**	**CD (0.05)**	**SEd**	**CD (0.05)**
I	0.03	0.07	0.03	0.07	0.03	0.07
T	0.05	0.10	0.05	0.11	0.05	0.01
I x T	0.09	0.17	0.09	0.18	0.09	0.17



I_1 - Well water, I_2 - Treated textile dye effluent
T_1 – Control (NPK alone), T_2 – 50 %GR+NPK, T_3 – 100 %GR+NPK, T_4 –50%GR+PM+NPK,
T_5 – 100%GR+PM+NPK, T_6 –50%GR+ETP sludge +NPK, T_7 100% GR+ETP sludge + NPK,
T_8- 50%GR+FYM+NPK, T_9 -100 % GR+FYM+ NPK PM - Pressmud @ 5 t ha^{-1},
ETP sludge - Effluent Treatment Plant sludge @ 5 t ha^{-1}, FYM - Farmyard manure @ 12.5 t ha^{-1}

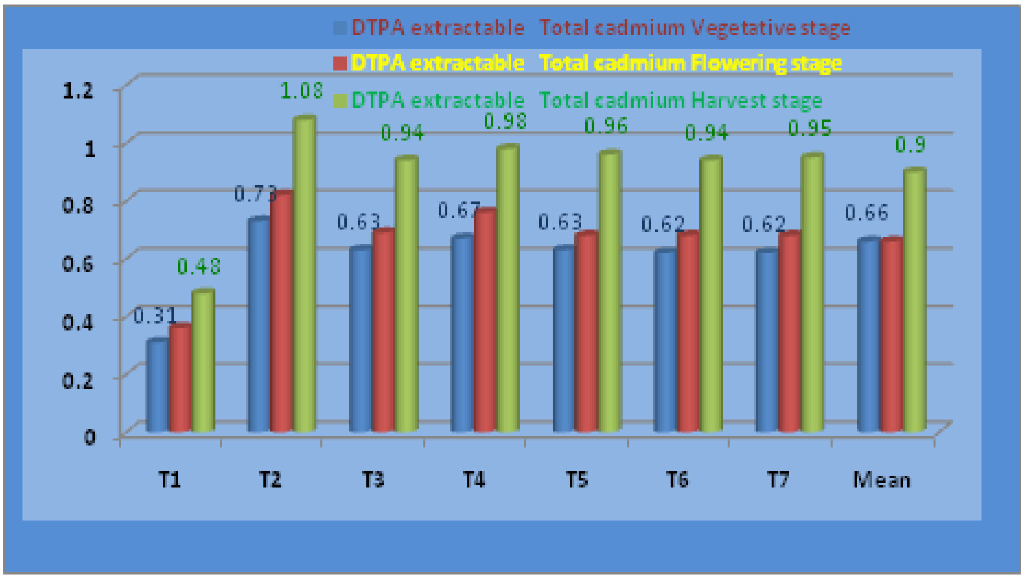
Figure 2: Effect of Effluent Irrigation and Amendments on Total Nickel Content of Soil under Maize (mg kg^{-1})

Table 4: Effect of Effluent Irrigation and Amendments on Total Cadmium Content of Soil under Maize (mg kg^{-1})

Treatments	DTPA Extractable Total Cadmium		
	Vegetative Stage	Flowering Stage	Harvest Stage
T_1	0.31	0.36	0.48
T_2	0.73	0.82	1.08
T_3	0.63	0.69	0.94
T_4	0.67	0.76	0.98
T_5	0.63	0.68	0.96
T_6	0.62	0.68	0.94
T_7	0.62	0.68	0.95
Mean	**0.66**	**0.66**	**0.90**

Table 4: Contd.,

Interaction	SEd	CD (0.05)	SEd	CD (0.05)	SEd	CD (0.05)
I	0.001	0.01	0.002	0.004	0.002	0.004
T	0.003	0.01	0.003	0.006	0.003	0.006
I x T	0.005	0.01	0.005	0.011	0.005	0.010



I_1 - Well water, I_2 - Treated textile dye effluent
T_1 – Control (NPK alone), T_2 – 50 %GR+NPK, T_3 – 100 %GR+NPK, T_4 –50%GR+PM+NPK,
T_5 – 100%GR+PM+NPK, T_6 –50%GR+ETP sludge +NPK, T_7 100% GR+ETP sludge + NPK,
T_8- 50%GR+FYM+NPK, T_9 -100 % GR+FYM+ NPK PM - Pressmud @ 5 t ha^{-1},
ETP sludge - Effluent Treatment Plant sludge @ 5 t ha^{-1}, FYM - Farmyard manure @ 12.5 t ha^{-1}

Figure 3: Effect of Effluent Irrigation and Amendments on Total Cadmium Content of Soil under Maize (mg kg^{-1})

Total Lead

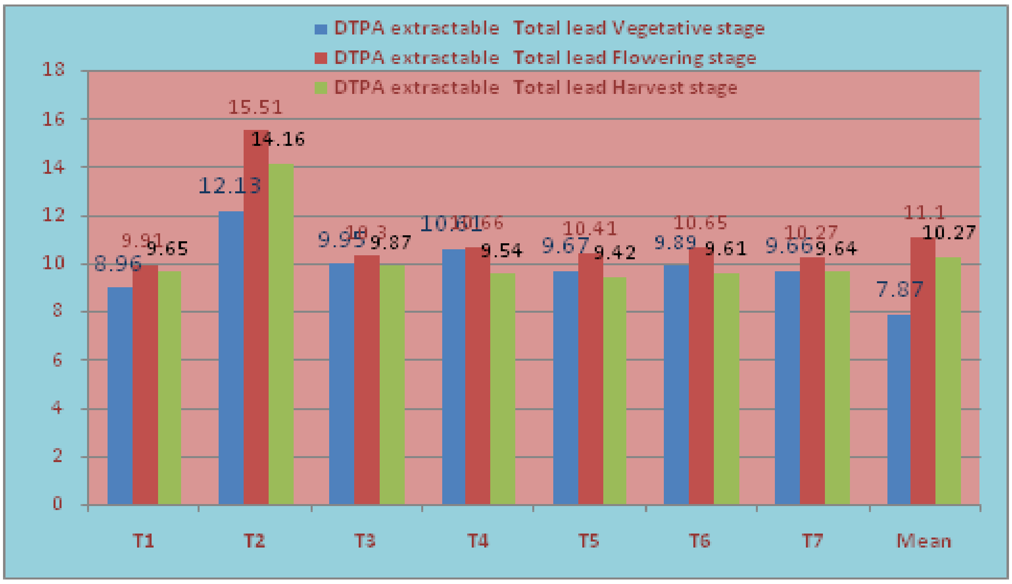
The total lead content of soil ranged from 1.25 to 5.85, 12.25 to 17.25 and 13.38 to 15.85 mg kg^{-1} in control, diluted effluent @1:1 ratio and undiluted effluent irrigation at vegetative stage, respectively. Amendments application significantly reduced the Pb accumulation in soil as compared to CETP sludge application (T_2). Among the amendments, green leaf manure (T_5) performed better followed by bio compost (T_7). The total lead content increased with advancement of crop growth at all the stages. The interaction effect was significant and treatment combination I_3T_2 recorded the highest total lead content at all stages.

Table 5: Effect of Effluent Irrigation and Amendments on Total Lead Content of Soil under Maize (mg kg^{-1})

Treatments	DTPA Extractable Total Lead		
	Vegetative Stage	Flowering Stage	Harvest Stage
T_1	8.96	9.91	9.65
T_2	12.13	15.51	14.16
T_3	9.95	10.30	9.87
T_4	10.61	10.66	9.54
T_5	9.67	10.41	9.42
T_6	9.89	10.65	9.61
T_7	9.66	10.27	9.64
Mean	**7.87**	**11.10**	**10.27**

Table 5: Contd.,

Interaction	SEd	CD (0.05)	SEd	CD (0.05)	SEd	CD (0.05)
I	0.03	0.06	0.03	0.07	0.03	0.06
T	0.05	0.10	0.05	0.10	0.05	0.09
I x T	0.08	0.16	0.09	0.18	0.08	0.16



I_1 - Well water, I_2 - Treated textile dye effluent
T_1 – Control (NPK alone), T_2 – 50 %GR+NPK, T_3 – 100 %GR+NPK, T_4 –50%GR+PM+NPK,
T_5 – 100%GR+PM+NPK, T_6 –50%GR+ETP sludge +NPK, T_7 100% GR+ETP sludge + NPK,
T_8- 50%GR+FYM+NPK, T_9 -100 % GR+FYM+ NPK PM - Pressmud @ 5 t ha^{-1},
ETP sludge - Effluent Treatment Plant sludge @ 5 t ha^{-1}, FYM - Farmyard manure @ 12.5 t ha^{-1}

Figure 4: Effect of Effluent Irrigation and Amendments on Total Lead Content of Soil under Maize (mg kg^{-1})

CONCLUSIONS

In this study the soil pH and EC was increased under undiluted effluent irrigation along with amendments, when compared to diluted effluent irrigation. Addition of amendments had a strong influence in enhancing the soil quality parameters *viz.,* Organic carbon, available. The total Chromium content ranged from 0.50 to 13.25, 1.00 to 36.52 and 1.65 to 32.52 mg kg^{-1} at vegetative stage, flowering stage and at harvest stages, respectively under effluent irrigation. However, it did not produce any toxic effects to the crops. The yield attributes and grain yield of maize was higher in effluent irrigated soil amended with CETP sludge @ 5 t ha^{-1} + poultry manure @ 5 t ha^{-1} + NPK. The continuous monitoring of the soil and ground water quality parameters are essential to suggest suitable remediation measures when treated textile and dye factory effluent is continuously use for irrigation

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