The Andhra Agric. J 65 (4): 859-863, 2018

Bioavailability of Heavy Metals on Textile Sludge Application to Soil

K Anand Kumar, P Prabhu Prasadini, G Ramachandra Rao and G Kishore Babu
Department of Environmental Sciences, APGC, ANGRAU, Lam, Guntur, A.P.

ABSTRACT

An incubation experiment was conducted with textile sludge obtained from NSL Textiles, Guntur district of Andhra Pradesh in the Department of Environmental Sciences, ANGRAU, Lam, Guntur. Study was carried out with 3 numbers of such sets, for sampling at 15, 30 and 45 days of incubation for estimation of heavy metals in soil. The sludge contained 37.6, 22.6, 4.5 and 106.6 ppm of Ni, Pb, Cd and Cr, respectively. The analysis of the incubation study data revealed that the variation among the treatments and among the incubation intervals was statistically significant. The interaction effect was found to be non-significant except in case of nickel. Over sludge treatments, the mean available Pb, Ni, Cd and Cr values were found to decrease from 15 to 45 days of incubation which might be due to formation of complexes with time of decomposition of sludge. The available Pb, Ni, Cr and Cd content in soils were significantly higher in all sludge treatments compared to control. The lead values were significantly higher by 0.28, 0.25 and 0.31 ppm with the application of untreated sludge @ 3, 5 and 10 t ha^{-1} respectively over control (2.74 ppm). The increase in Ni, Cd and Cr in soil with increased doses of sludge @ 3, 5 and 10 t ha^{-1} was also significant. Mean DTPA extractable heavy metals of the soil across the sludge treatments and incubation intervals followed the order: Pb (2.92 ppm) > Cr (0.725 ppm) > Ni (0.4 ppm) > Cd (0.062 ppm). Broadly, it was noticed that the untreated sludge applied treatments recorded the highest values of toxic heavy metals in soil followed by decomposed/treated sludge treatments.

Key words: *Bioavailability, Heavy metals, Textile sludge*

Textile industry being second largest sector in India after sugar industry is facing problems with its sludge disposal. The commonly adopted, safe disposal of sludge from textile industry as plants nutrient source requires research on bioavailability and concentration of toxic heavy metals.Textile industry is one of the most established industries in India and has a major share in the Indian economy, adding to about 14% of manufacturing value addition and 1/3rd of the India's gross export earnings. Textile industry is estimated to be generating around 6.23 million tonnes of hazardous waste annually. Out of this, 49.55% waste is recyclable, 6.67 % waste is incinerable and remaining 43.78% is disposable in secured landfills (Jeevanandam *et al.*, 2015). Textile industries consume large quantity of water for processing of raw materials into finished cloth, and produce extremely waste effluents. Textile wastewater consists of high concentration of pollutants, a complex composition, poor biodegradability and high level of dye. The main treatment methods for textile dyeing wastewater include physico-chemical processes (*e.g.,* coagulation/flocculation) and biodegradation (Gotvajn and Zagorc-Koncan, 2004). These processes produce huge quantity of sludge that must be disposed in an environmentally safe manner. The primary methods used to manage textile dyeing sludge are land application, incineration and landfill. On land application, the heavy metals transform in the soil or pollute underground water and/or will be absorbed by plants and eventually accumulating in the human body. Thus, it is very important to thoroughly understand heavy metals present in textile sludge before disposal. With this background, an attempt was made to study the effect of microbial consortium in the bioavailability of heavy metals on application of the textile sludge to soil.

MATERIAL AND METHODS

An incubation experiment was conducted with textile sludge obtained from NSL Textiles, Guntur district of Andhra Pradesh in the Department of Environmental Sciences, ANGRAU. The treatments of the experiment included fine textured soil with conjoint application of the textile sludge with and without microbial consortium in plastic boxes maintained gravimetrically at maximum water holding capacity (49%) for 45 days of incubation period. The microbial consortia comprised of *Pseudomonas* spp., *Actinomycetes* spp., *Bacillus* spp., *Streptomyces* spp. and *Staphylococcus* spp.. The 10 combinations studied were : T_1- Soil alone (control), T_2 - Soil + sludge @ 3 t ha^{-1}, T_3 - Soil + sludge @ 5 t ha^{-1}, T_4 - Soil + sludge @ 10 t ha^{-1}, T_5 - Soil + sludge @ 3 t ha^{-1} + microbial consortium, T_6 -Soil + sludge @ 5 t ha^{-1} + microbial consortium, T_7 - Soil + sludge @ 10 t ha^{-1} + microbial consortium, T_8 - Soil + sludge decomposed with microbial consortium for 15 days @ 3 t ha^{-1}, T_9 - Soil + sludge decomposed with microbial consortium for 15 days @ 5 t ha^{-1} and T_{10} - Soil + sludge decomposed with microbial consortium for 15 days @ 10 t ha^{-1}. Sludge was applied to the set at three stages of decomposition each at three levels (3,5 & 10 t ha^{-1}) Viz., untreated sludge as in T_2 to T_4, treated sludge (sludge + decomposing microbial consortium) as in T_5 to T_7 and decomposed sludge (sludge incubated with decomposing microbial consortium for 15 days before application to the soil) as in T_8 to T_{10}. Study was carried out with 3 such sets, for sampling at 15 (I_{15}), 30 (I_{30}) and 45 (I_{45}) days of incubation for heavy metal analysis of soil. The sludge was analysed using standard procedures (Tandon, 2013) and found to contain 37.6, 22.6, 4.5 and 106.6 ppm of Ni, Pb, Cd and Cr, respectively. The Cr content was found to be higher than that prescribed in MSW Rules 1999, and all others were within the permissible limits as per MSW Rules 1999 and MoEF 2000. Soil samples collected over 45 days of incubation from all the treatments were analysed for toxic heavy metals namely Ni, Pb, Cd and Cr, using Atomic Absorption Spectrophotometer (Model Avanta GBC GF 3000 at NPCB, Vijayawada) (Lindsay and Norwell, 1978) and the data are presented and discussed below.

RESULTS AND DISCUSSION

The data showing the effect of application of the sludge on heavy metals content in soil over 45 days of incubation were statistically analysed and presented in the Table 1.

Heavy metals

Mean DTPA extractable heavy metals of the soil recorded across the sludge treatments and incubation intervals followed the order: Pb (2.92 ppm) > Cr (0.706 ppm) > Ni (0.4 ppm) > Cd (0.062 ppm).

DTPA extractable Pb

Perusal of the data indicated that there was a significant variation in lead values among the textile sludge treatments and the incubation intervals. But their interaction was found to be non-significant. The lead values were significantly higher by 0.28, 0.25 and 0.31 ppm with the application of untreated sludge @ 3, 5 and 10 t ha^{-1} respectively over that of recorded (2.74 ppm) in control. However, there was no significant difference among the untreated sludge doses. Higher DTPA – Pb might be due to the addition of Pb (22.55 ppm) to the soil through sludge. Gallardo *et al*. (1999) and Moral *et al*. (2002) also observed that sewage sludge treatment significantly increased DTPA-extractable metal contents in soil with respect to control.

Broadly, comparing the sludge treatments over incubation intervals, it was noticed that the untreated sludge applied treatments recorded higher values (av. 3.02 ppm) followed by decomposed (av. 2.92 ppm) and treated sludge (av. 2.87 ppm). Araujo and Monteiro (2005) also opined that composting decreases or eliminates the toxic heavy metals of textile sludge. Mahmood *et al*. (2013) also documented a reduction in heavy metal like Cu, Cd, Cr, Ni, Mn and Pb to the extent of 92.3, 89.46, 83.52, 80.7, 88.3 and 93.5 per cent, respectively through the inoculation of microbial consortium.

Incubation intervals across the sludge treatments showed significant negative influence on mean DTPA – Pb content of the soil which decreased from 2.98 to 2.81 ppm from 15 to 45 days of incubation. This might be due to formation of organo-metal complexes over time during decomposition of sludge. The clay-based soil used in this study had a relatively high adsorption capacity, which will limit bioavailability in the short term and long term. Results are in conformity with the findings of Palanivelu and Kumar (2001).

DTPA extractable Ni

An examination of the data indicated that there was a significant variation in DTPA extractable Ni contents due to the treatments, incubation intervals and their interaction. Available nickel was higher in all sludge treatments (over 45 days of incubation) compared to control. This might be due to the release of nickel present in sludge (37.6 ppm). Gallardo *et al*. (1999) and Moral *et al*. (2002) also observed that sewage sludge treatment significantly increased DTPA-extractable metal contents in soil with respect to control. In any sludge treatment, the DTPA - Ni increased significantly with the level of sludge from 3 to 10 t ha^{-1}, with the corresponding ranges of 0.374 to 0.414 (av. 0.395), 0.392 to 0.418 (av. 0.404), and 0.408 to 0.424 (av. 0.417) ppm for untreated sludge, sludge with microbial consortium and sludge decomposed with microbial consortium, however, in case of the decomposed sludge, the levels 5 and 10 t ha^{-1} were at a par (0.419 and 0.424 ppm). Irrespective of the sludge treatment, graded levels of textile sludge application from 3, 5 and 10 t ha^{-1}, the mean DTPA extractable Ni was in the order of 0.391, 0.406 and 0.419 ppm. This could be due to the high Ni content of the textile sludge used in the study (37.6 ppm). Similar results of enhanced Ni contents with increased quantity of sewage sludge were also reported by Chitdeswari *et al*. (2002) and Jordao *et al*. (2006) for urban compost.

The average values (av.) calculated for incubation intervals revealed that there was a significant decrease from 0.414 to 0.385 ppm over the period of study, which could be due to the reason that Ni might have entered into several biochemical and chemical pathways resulting in fixation (clay – metal complexes and organo – metal complexes) and immobilization (in microbes) forming insoluble complexes over time.

Table 1: Effect of different sludge treatments on soil available Lead, Nickle, Cadmium and Chromium (ppm) over 45 days of incubation

Treatments	Lead				Nickle				Cadmium				Chromium			
	I_{15}	I_{30}	I_{45}	Mean	I_{15}	I_{30}	I_{45}	Mean	I_{15}	I_{30}	I_{45}	Mean	I_{15}	I_{30}	I_{45}	Mean
T_1	2.76	2.8	2.66	2.74	0.343	0.347	0.345	0.345	0.052	0.053	0.053	0.053	0.383	0.417	0.420	0.407
T_2	3.05	3.01	3.00	3.02	0.390	0.372	0.362	0.374	0.062	0.058	0.055	0.058	0.733	0.683	0.667	0.694
T_3	3.10	3.05	2.83	2.99	0.417	0.395	0.383	0.398	0.067	0.063	0.058	0.063	0.800	0.750	0.733	0.761
T_4	3.15	3.03	2.96	3.05	0.435	0.415	0.393	0.414	0.072	0.063	0.060	0.065	0.833	0.783	0.767	0.794
T_5	3.00	3.00	2.81	2.93	0.407	0.392	0.377	0.392	0.06	0.060	0.057	0.059	0.750	0.700	0.683	0.711
T_6	2.95	2.95	2.91	2.93	0.425	0.403	0.377	0.402	0.067	0.062	0.058	0.062	0.800	0.750	0.700	0.750
T_7	2.85	2.85	2.58	2.76	0.437	0.415	0.402	0.418	0.073	0.067	0.063	0.068	0.850	0.8	0.767	0.806
T_8	2.98	2.98	2.76	2.9	0.417	0.41	0.397	0.408	0.063	0.062	0.058	0.061	0.733	0.683	0.667	0.694
T_9	2.95	2.93	2.75	2.87	0.432	0.422	0.403	0.419	0.067	0.063	0.06	0.063	0.750	0.7	0.683	0.711
T_{10}	3.05	3.00	2.90	2.98	0.438	0.425	0.41	0.424	0.070	0.067	0.063	0.067	0.767	0.717	0.700	0.728
Mean	2.98	2.96	2.81		0.414	0.4	0.385		0.065	0.062	0.059		0.740	0.698	0.679	
Factors	*A	*B	*A×B		*A	*B	*A×B		*A	*B	*A×B		*A	*B	*A×B	
CD	0.157	0.09	*NS		0.008	0.005	0.014		0.003	0.002	*NS		0.05	0.027	*NS	
SE(m)	0.055	0.03	0.096		0.003	0.002	0.005		0.001	0.001	0.002		0.018	0.01	0.031	

***A-Treatments** *** B - Intervals** ***A×B - Treatments× Intervals** ***NS - Non-significant**

The treatments for incubation studies are furnished below.

- T_1 - Soil alone (control)
- T_2 - Soil + sludge @ 3 t ha^{-1}
- T_3 - Soil + sludge @ 5 t ha^{-1}
- T_4 - Soil + sludge @ 10 t ha^{-1}
- T_5 - Soil + sludge @ 3 t ha^{-1} + microbial consortium
- T_6 - Soil +sludge@ 5 t ha^{-1} + microbial consortium
- T_7 - Soil + sludge @ 10 t ha^{-1}+ microbial consortium
- T_8 - Soil + sludge@ 3 t ha^{-1} incubated with microbial consortium for15 days
- T_9 - Soil + sludge @ 5 t ha^{-1} incubated with microbial consortium for 15 days
- T_{10} - Soil + sludge @ 10 t ha^{-1} incubated with microbial consortium for 15 days Microbial consortium was applied @ 2litres per acre.

DTPA extractable Cd

Variation in the DTPA extractable Cd contents in soil was significant among the textile sludge treatments and incubation intervals but the interaction was not significant. A perusal of the data indicated that the sludge treatments differed significantly in mean DTPA - Cd contents ranging from 0.053 ppm in the control to 0.068 ppm when 10 t ha^{-1} of textile sludge was applied in conjunction with microbial consortium, however, it was on par with the same level of untreated sludge (0.065 ppm) and decomposed sludge (0.067 ppm). Graded levels of sludge application from 3 to 10 t ha^{-1} across incubation intervals increased the DTPA - Cd from 0.058 to 0.065, 0.059 to 0.0.068, 0.061 to 0.067 ppm respectively for untreated, treated and decomposed sludge treatments. The buffering capacity of the soil might degrade the pollutants very effectively at lower doses of textile sludge addition due to formation of complexes over time. Similar results were obtained by Chakravarthy (2008) using industrial sludge. Chang *et al*. (1997) also reported that the cadmium concentration in soils increased with increasing sewage sludge application due to 10-year land application of sewage sludge.

Incubation intervals across the sludge treatments showed a significant reduction in mean DTPA extractable Cd contents from 0.065 ppm at I_{15} to 0.062 ppm at I_{30} and 0.059 ppm at I_{45}, resulting in a net depletion of 9.2 per cent.

Broadly, comparing the sludge treatments over incubation intervals, it was noticed that rather than the treatment, the quantity of textile sludge applied showed considerable increase in DTPA extractable Cd contents of the soil.

DTPA extractable Cr

The statistical analysis of data indicated that there was a significant variation in DTPA extractable chromium values among the treatments and among the incubation intervals. But their interaction was found non-significant.

Mean over incubation period of 45 days, DTPA extractable chromium was more in all sludge applied treatments compared to control. This might be due to high concentration of chromium (106.6 ppm) present in sludge. Gallardo *et al*. (1999) and Moral *et al*. (2002) also observed that sewage sludge treatment significantly increased DTPA-extractable metal contents in soil with respect to control. On an average irrespective of the treatment across the incubation intervals, the results revealed that DTPA extractable Cr was in the order of 0.70, 0.741 and 0.776 ppm respectively with 3, 5 and 10 t ha^{-1}, resulting in a corresponding build up of 72.0, 82.1 and 90.1 per cent against control.

The mean DTPA extractable chromium values were found to decrease significantly from 15 to 45 days. The decrease was from 0.740 to 0.698 ppm which further decreased to 0.679 ppm from I_{15} to I_{30} and I_{45} gradually. The reason might be that chromium forms anionic species chromates and forms precipitates with cations such as Ca and becomes insoluble (Adriano, 2001) or might be leached to the ground water due to anion repulsion with soil clays.

Over the sludge treatments and incubation intervals, it was noticed that the treated sludge applied treatments recorded higher values than untreated and decomposed sludge applied treatments. This could be due to the reason that when pre decomposed sludge is applied the chromates may be lost due to anionic repulsions with clays and humates.

CONCLUSION

From this study it was found that the DTPA extractable heavy metals of the soil across the sludge treatments and incubation intervals followed the order: Pb (2.92 ppm) > Cr (0.706 ppm) > Ni (0.4 ppm) > Cd (0.062 ppm). Availability of Pb, Ni, Cd and Cr was found to decline over 45 days of incubation and Ni, Cd and Cr increased with increasing doses of textile sludge. The level of sludge application, across all the treatments did not have much influence on soil Pb content. Broadly, comparing the sludge types over incubation intervals, it was noticed that the untreated sludge applied treatments recorded the highest values of toxic heavy metals in soil followed by that of decomposed/treated sludge treatments; giving a lead to consider treatment of sludge with microbial consortium as a strategy for its use in agriculture without environmental risk.

LITERATURE CITED

Adriano D C 2001 Trace elements in terrestrial environments: Biogeochemistry, bioavailability and risks of metals, 2nd edition. *Springer*. New York.

Araujo A S F and Monteiro R T R 2005 Plant bioassays to assess toxicity of textile sludge compost. *Scientia Agricola (Piracicaba, Braz.)*, 62(3):286-290

Chakravarthy D M 2008 Utilization of industrial sludge for agriculture. *M.Sc Thesis*. Acharya N.G. Ranga Agricultural University, Hyderabad.

Chang A C, Hyun H and Page A L 1997 Cadmium uptake for Swiss chard grown on composted sewage sludge treated field plots: plateau or time bomb. *Journal of Environmental Quality*, 26: 11-19

Chitdeswari T, Savithri P and Mahinai Raja S 2002 Effect of sewage biosolids compost on biomass yield of amaranthus and heavy metal availability.

Journal of the Indian Society of Soil Science, 50(4): 480-484

Gallardo L F, Azcon M, Quesada J L and Polo A 1999 Phytoavailability and extractability of copper and zinc in calcareous soil amended with composted urban waste. Journal *of environmental science and health bulletin*, 34: 1049-1064

Gotvajn A Z and Zagorc-Koncan J 2004 Characterization of textile wastewater: its environmental impact and biotreatability. *Chemical and Biochemical Engineering* Quarterly, 18:309–315

Jeevanandam S, Ravikumar K, Ashutosh Das and Mukesh Goel 2015 Comprehensive study on textile dyeing sludge as a substitute for cement in cement-mortar. *International Journal of Technology,* 5(2): 219-224

Jordao C P, Nascents C C, Cecem P, Fentes R L F and Pereira J L 2006 Heavy metal availability in soil amended with composted urban solid wastes. *Environmental Monitoring and Assessment*, 112 (1/3): 309-326

Lindsay W L and Norwell W A 1978 Development of DTPA soil tests for zinc, iron, manganese and copper. *Soil Science Society of America Journal*, 42: 421-428

Mahmood R, Sharif F, Ali S and Hayyat M U 2013 Bioremediation of textile effluent by indigenous bacterial consortia and its effects on *Zea mays* L. CV C1415. *The Journal of Animal & Plant Sciences*, 23(4):1193-1199

Ministry of Environment and Forests 2000 Notification 25th September, S.O. 908(E), New Delhi.

Moral R, Cortes A, Gomez I and Matix-Beneyto J 2002 Assessing changes in Cd phytoavailability to tomato in amended calcareous soils. *Bioresoure technology,* 85: 63-68

Municipal Solid Wastes (Management and Handling) Rules 1999 Rules 6(1) and (3), 7(1), *S.O.908 (E)*, New Delhi.

Palanivelu K and Kumar R 2001 Characterization and leachability studies in textile effluent treatment plant sludge. *Environment Pollution Control Journal*, 5(1): 38-40

Tandon H L S 2013 Methods of analysis of soils, plants, waters, fertilisers & organic manures. *Fertiliser Development and Consultation Organisation*, New Delhi.

Received on 23.11.2017 and revised on 16.03.2018