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Heavy metal accumulation in cabbage and soil irrigated with different concentration of open dumping yard leachate in Bangalore

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Abstract
As world transforming with an advance science and technology, the generation of waste and standard of living are also increasing in a parallel way. The disposal of waste is becoming a menace due to its negative effect on environment if not managed scientifically, specially the leachates generated from landfills or dumping yard. The leachates generated in three seasons from open dumping yard, with different formulation (0, 10, 20, 30, 40, 50%) treated for cabbage resulted that increase in concentration will increase in heavy metal content of cabbage and soil, and in contrast the uptake was more till 20 percent of leachate application which resulted as increase in concentration will decrease in uptake due to trans factor of heavy metals.

Keywords: Heavy metals, open dumping yard, leachate

Introduction

World is swiftly transforming from an agriculture-based nation to an industrial and services-oriented. Industrialization is most important in uplifting the world's economy. On the other hand, it leads to serious problems relating to environmental pollution which consequently leads to an enormous quantity of solid/liquid wastes. A harmonious and balanced co-relation between humans and nature on the earth is vital for the existence of life and sustainable growth. With the advent of time, human beings directly or indirectly interfered with the natural environment for their need, comfort, and luxury. The solid waste problem is ubiquitous across the globe and is a serious issue in developing countries such as India. The waste generation rates are increasing and the characteristics are changing with an increase in a population explosion, industrial development, and living standards, particularly in growing cities such as Bengaluru. Leachate of municipal solid waste is a complex mixture of various pollutants such as organic compounds, inorganic salts, nutrients and heavy metals. The quality of leachate depends on various factors such as the composition of waste, biological and chemical processes occur during the degradation of waste, moisture content, rainfall and local climate. The leachate thus generated is considered as a major pollution threat to the surface and groundwater, soil, environment and human health. Bengaluru city generates about 5500-6500 metric tons of municipal solid waste every day out of which 75 per cent is disposed of in the landfills or dumping yard. The leachate discharged from these landfill or dumping yard will lead to serious environmental problems such as ground water, surface water pollution, soil pollution which in turn enters food chain. Farmers draw water directly from contaminated bore wells or from streams in Bengaluru rural areas at the vicinity of the dumping yard. Contaminated water irrigation may lead to the accumulation of heavy metals in agricultural soils and plants as noticed by (Sharma *et al.* 2007) [18]. The physical and chemical properties are also affected by the irrigation of this water (Azad *et al.*, 1986) [3]. Soil serves as both sink and source for heavy metals and monitoring the soil contamination levels provide a good indicator of environmental quality (Li *et al.*, 2009; Krishna and Govil, 2005) [10, 9]. The toxicity and mobility of heavy metals in soils not only depend on their total concentration but also on their specific chemical form and soil properties *viz.* pH, organic matter *etc.*, (Lu *et al.0*, 2003) [13]. The vegetables are being grown extensively in areas around the city which are contaminated with heavy metals and entering to food chain. The production and usage of heavy metals such as copper, cadmium and zinc have increased substantially over the years. The excess quantity of heavy metals disposed of the land can cause significant damage to the environment and human health as a result of their mobility, solubility and their ability to transfer in water or plants. The leachate from MSW landfills may leak into groundwater aquifers due to precipitation, spread into the adjacent river system by groundwater flow and pollute the surrounding environment. However, this process does not stop even after the landfill activities have stopped receiving solid waste. Hence, it is very essential to keep assessing and monitoring the surroundings of decommissioned landfill sites. In response to heavy metals, plants follow three different strategies: metal exclusion, metal indication and metal accumulation (Jan and Parray, 2016) [8]. Apart from plant defence mechanism, it is also necessary to ameliorate the soils contaminated with heavy metals.

Heavy metals are essential micronutrients for plant metabolism but when in excess of these metals and other non-essential elements become extremely toxic (Williams *et al.*, 2000) [23]. Vegetables grown on heavy metal contaminated soil or applying heavy meatal contaminated water reduces yield due to inhibition of various metabolic processes and deteriorates quality of the produce. Use of contaminated water for irrigation leads to heavy metal accumulation in soil followed by bio magnification in the food chain and pose serious health hazards for human beings. Hence, the current research work was formulated to know the extent dumping yard or landfill pollution through leachate which causes heavy metal accumulation in cabbage and soil at different concentration in Bengaluru Karnataka, India.

Materials and Methods

The present study was carried out at Gundalahalli (13º31ˈ8.56ˈ N, 77 º37ˈ 20.35ˈ E), Doddaballapura Taluk, Bengaluru rural district, with an average rainfall of 880 mm and temperature of 29±2ºC. 25 to 30 per cent of waste generated from the whole Bangalore is dumped here and it is the second largest dumping site after Mavallipuram site. A pot culture experiment was conducted under greenhouse condition. Six treatments (0, 10, 20, 30, 40, 50%) with five replications and 5 litre of treatment water {*i.e*. Leachate volume: Water volume (Lv: Wv)} was applied every week in two splits per pot.

Leachate sampling

The leachate samples were collected from the leachate tank present in open dumping yard in three season *i.e.*, summer, winter and rainy season in a ten litre polythene can, leaving no airspace. Samples were stored in a dark condition at 4 ºC until it was applied to crop (APHA, 2012) [1]. The samples were acidified with a 5 per cent nitric acid to prevent the probability of heavy metal precipitation.

Plant sampling and processing

Edible part of cabbage crop was sampled. A total of 60 plant samples at maturity *i.e.*, at 90 Days after Planting (DAP) were collected during three season. The samples were washed with tap water, followed by washing with distilled water and then the samples were oven dried at 70 ºC for 72 hours, powdered and analyzed for the heavy metal content using microwave digestion and estimation using ICP-OES (Dospatliev *et al.*, 2012) [6]. Heavy metal uptake by crop was computed from their respective elemental concentration and expressed in $g ha^{-1}$ using following formula.

$$\text{Heavy metal uptake (g ha}^{-1}\text{)} = \frac{\text{Heavy metal content (mg kg}^{-1}\text{) X dry weight of crop (g pot}^{-1}\text{)}}{1000}$$

Soil sampling and processing

Ten gram of processed soil sample was taken in 50 mL centrifuge tubes to which 20 mL of extracting solution was poured into each sample. The extracting solution consisted of 0.005 M Diethylene Triamine Penta Acetic Acid (DTPA) + 0.001 M $CaCl_2.2H_2O$ + 0.1 N tri-ethanol amine buffered at pH 7.3 (Lindsay and Norwell, 1978) [11]. The samples were kept for mechanical shaking for 2 hours and later centrifuged at 3000 rpm for 3 minutes. The soil solution was filtered and analysed using ICP-OES (Plasma Quant 9100 series).

Results and Discussion

The heavy metal (Pb^{2+}, Cd^{2+}, Cr^{3+}, Co^{2+}, Ni^{2+} and Cu^{2+}) content in cabbage was found higher in treatment T_6 *i.e.* 50 per cent leachate and 50 per cent double distilled water and the transfer factor for heavy metals of cabbage was lower in the lower levels of leachate application and it was gradually increased with an application rate of leachates in all the three seasons and represented in Table 1, 2 and 3. Higher concentration of heavy metals in cabbage were mainly because of the higher affinity of plants to adsorb more heavy metals under higher concentration (Tiwari *et al*., 2008) [21]. In the present study, the lower level of leachate application resulted in translocation of less heavy metals to the shoot, which indicates that the plants adopted exclusion mechanism to overcome toxic effects of heavy metals, which is characteristic for the majority of plant species (Mapanda, 2005)[15]. With respect to the concentration of Mn^{2+}, Zn^{2+} and Fe^{2+} in cabbage grown during summer and rainy and Mn^{2+} and Fe^{2+} in winter season respectively was non-significant but numerically higher values were recorded in treatment T_6 which received 50 per cent leachate. Chang *et al.,* (2013) [4] revealed that among the heavy metals, Cd was more easily transferred from soil into leafy vegetables, with bio-concentration factor nearly 30-fold for Hg and 50 fold for Cr, Pb and As. The concentration of heavy metals (Pb^{2+}, Ni^{2+}, Co^{2+}, Zn^{2+} and Cu^{2+}) in plant tissue grown during the wet season was lesser than the dry season, it might be due to dilution effect during the wet season (Oluyemi *et al*., 2008) [16]. Madejon *et al*. (2003) [14] stated that the utilization of the landfill leachates with different dilutions for agricultural purposes is depending on the concentration of polluted heavy metal elements like Cd^{2+}, Co^{2+}, Cr^{3+}, Cu^{2+}, Ni^{2+}, Zn^{2+}, and Pb^{2+}. The results are in line with Simerjit (2012) [19], stated that the heavy metal concentration in summer and winter with reference to Pb, Cu, Co and Cd have revealed substantial variation (p<0.05), with less accumulation during winter and high during summers. No significant variation in the concentrations of Cr, Fe, Ni, Mn, Zn was noticed during summer and winter, but the seasonal outline for all the heavy metals was same *i.e.*, high values during summer and low values during the winter season. Dudal *et al.* (2005) [7] also stated that the mobility of heavy metals along with soluble organic matter might be affected in the winter season.

The contamination of heavy metals in vegetables at different leachate concentration in rainy season indicate that the concentrations were below the limit till 20 per cent of leachate application and for 30, 40 and 50 per cent, the heavy metal concentration was above the permissible limit recommended by WHO/FAO for Co, Mn and Zn. In vegetable especially in the rainy season because of dilution factor and overflow of pollutants and the inter-elemental correlation analysis showed a high positive correlation between the cabbage and soil heavy metals which suggest a common source of pollutants near landfill area. Accumulation of heavy metals in vegetables occur by various sources but soil and amount of rainfall or irrigation are considered the major one.

Table 1: Heavy metals content (mg kg^{-1}) in cabbage grown during summer using different formulation of leachate in pot culture experiment at harvest

	Pb	Cd	Cr	Co	Ni	Cu	Mn	Zn	Fe
Standards	0.3 * 0.2 #	0.1 * 0.3 #	2.3 #	0.05-0.1 *	1.5 *	40 *	50 #	60 *	425 *
T_1 (0%)	BDL	0.01 ^{e}	BDL	BDL	0.21 ^{f}	9.85 ^{d}	62.91	78.04	418.87
T_2 (10%)	0.02 ^{e}	0.09 ^{d}	0.06 ^{e}	0.09 ^{d}	0.47 ^{e}	16.78 ^{c}	64.95	83.11	441.76
T_3 (20%)	0.03 ^{d}	0.11 ^{d}	0.08 ^{d}	0.11 ^{d}	0.96 ^{d}	17.72 ^{bc}	66.19	84.58	444.97
T_4 (30%)	0.05 ^{c}	0.13 ^{c}	0.11 ^{c}	0.17 ^{c}	1.65 ^{c}	17.65 ^{bc}	66.84	85.46	446.23
T_5 (40%)	0.06 ^{b}	0.17 ^{b}	0.16 ^{b}	0.23 ^{b}	2.17 ^{b}	19.89 ^{ab}	68.17	86.35	448.78
T_6 (50%)	0.09 ^{a}	0.24 ^{a}	0.26 ^{a}	0.28 ^{a}	2.87 ^{a}	21.44 ^{a}	69.10	88.80	451.54
SEm±	0.002	0.007	0.007	0.008	0.080	0.839	3.163	3.163	21.066
C.D.(0.05)	0.008	0.020	0.020	0.024	0.233	2.448	NS	NS	NS
CV (%)	13.86	12.13	13.82	12.61	12.84	10.90	10.66	10.66	10.66

*WHO/FAO (Codex Alimentarius Commission. Joint FAO/WHO, 2007) and Indian standard Awashthi 2004 [2]. #European Union (EU), 2006.
Means within a column followed by the same letter are not significantly different at 5% level of significance.
BDL – Below Detectable Level; NS-Non-significant

Table 2: Heavy metals content (mg kg^{-1}) in cabbage grown during winter using different formulation of leachate in pot culture experiment at harvest

	Pb	Cd	Cr	Co	Ni	Cu	Mn	Zn	Fe
Standards	0.3 * 0.2 #	0.1 * 0.3 #	2.3 #	0.05-0.1 *	1.5 *	40 *	50 #	60 *	425 *
T_1 (0%)	BDL	0.06 ^{e}	BDL	BDL	0.11 ^{f}	8.91 ^{d}	56.61	63.18 ^{c}	388.87
T_2 (10%)	0.02 ^{d}	0.08 ^{d}	0.06 ^{d}	0.08 ^{d}	0.43 ^{e}	14.80 ^{c}	58.82	69.24 ^{bc}	400.01
T_3 (20%)	0.03 ^{d}	0.10 ^{c}	0.07 ^{d}	0.10 ^{d}	0.87 ^{d}	16.05 ^{bc}	59.94	76.58 ^{ab}	402.92
T_4 (30%)	0.05 ^{c}	0.12 ^{c}	0.10 ^{c}	0.15 ^{c}	1.49 ^{c}	16.88 ^{abc}	61.52	77.39 ^{ab}	404.06
T_5 (40%)	0.06 ^{b}	0.15 ^{b}	0.14 ^{b}	0.21 ^{b}	1.96 ^{b}	18.01 ^{ab}	61.79	78.19 ^{ab}	407.28
T_6 (50%)	0.08 ^{a}	0.21 ^{a}	0.23 ^{a}	0.25 ^{a}	2.70 ^{a}	18.51 ^{a}	63.57	81.26 ^{a}	408.87
SEm±	0.002	0.006	0.006	0.007	0.074	0.755	2.878	3.552	19.156
C.D (0.05)	0.007	0.019	0.018	0.022	0.216	2.204	NS	10.37	NS
CV (%)	14.81	12.23	13.47	12.49	13.13	10.88	10.66	10.69	10.66

Table 3: Heavy metals content (mg kg^{-1}) in cabbage grown during rainy using different formulation of leachate in pot culture experiment at harvest

	Pb	Cd	Cr	Co	Ni	Cu	Mn	Zn	Fe
Standards	0.3 * 0.2 #	0.1 * 0.3 #	2.3 #	0.05-0.1 *	1.5 *	40 *	50 #	60 *	425 *
T_1 (0%)	BDL	0.05 ^{e}	BDL	BDL	0.10 ^{e}	6.15 ^{d}	48.25	52.82	358.87
T_2 (10%)	0.02 ^{d}	0.08 ^{d}	0.05 ^{e}	0.08 ^{d}	0.40 ^{d}	10.53 ^{c}	55.01	61.59	374.12
T_3 (20%)	0.03 ^{c}	0.09 ^{cd}	0.07 ^{d}	0.09 ^{d}	0.81 ^{c}	11.26 ^{bc}	56.06	62.67	376.84
T_4 (30%)	0.04 ^{b}	0.11 ^{c}	0.09 ^{c}	0.14 ^{c}	1.40 ^{b}	11.84 ^{abc}	56.61	63.33	377.91
T_5 (40%)	0.05 ^{b}	0.14 ^{b}	0.14 ^{b}	0.20 ^{b}	1.84 ^{a}	12.63 ^{ab}	57.73	63.99	380.91
T_6 (50%)	0.08 ^{a}	0.20 ^{a}	0.22 ^{a}	0.24 ^{a}	1.93 ^{a}	12.98 ^{a}	58.52	65.06	382.40
SEm±	0.002	0.006	0.006	0.007	0.061	0.989	2.643	2.940	17.879
C.D (0.05)	0.007	0.019	0.017	0.020	0.178	1.548	NS	NS	NS
CV (%)	14.48	12.76	13.50	12.60	12.62	10.88	10.67	10.68	10.66

*WHO/FAO (Codex Alimentarius Commission. Joint FAO/WHO, 2007) and Indian standard Awashthi 2004 [2]. #European Union (EU), 2006.
Means within a column followed by the same letter are not significantly different at 5% level of significance. BDL – Below Detectable Level; NS-Non-significant

Heavy metal uptake

The heavy metal (Pb^{2+}, Cd^{2+}, Cr^{3+}, Co^{2+}, Ni^{2+} and Cu^{2+}) uptake was higher in treatment with the application of leachate concentration of 50% (T_6) in cabbage grown in summer, winter as well as in rainy season. Whereas, in contradictory the micronutrients (Co^{2+},Mn^{2+}, Zn^{2+} and Fe^{2+}) was found bit higher in treatment T_3 *i.e.* 20% leachate, than higher application of leachate concentration which is represented in table 4, 5 and 6. The heavy metal accumulation and translocation potential varied from metal to metal, plant to plant and season to season and did not follow any particular pattern. Genotypic effect, environmental effect and their interaction effect, highly affect heavy metal uptake in crop genotypes (Zeng *et al*., 2008; Cheng *et al*., 2006 and Liu *et al*., 2007) [24, 5, 12]. The continuous application of sewage water may lead to higher uptake of heavy metals but not the micronutrients, because of trans-factor and mobility of nutrients may vary Dudal *et al.*, (2005) [7].

Table 4: Effect of different leachate concentration collected in summer on uptake of heavy metals (g ha^{-1}) in cabbage

Lv: Wv	Pb	Cd	Cr	Co	Ni	Cu	Mn	Zn	Fe
T_1 (0%)	BDL	BDL	BDL	BDL	0.14 ^{e}	12.05 ^{d}	60.62 ^{c}	69.35 ^{c}	296.02 ^{b}
T_2 (10%)	0.02 ^{d}	0.08 ^{c}	0.05 ^{d}	0.08 ^{c}	0.41 ^{d}	18.24 ^{b}	80.65 ^{b}	90.30 ^{b}	383.98 ^{a}
T_3 (20%)	0.03 ^{c}	0.11 ^{b}	0.08 ^{c}	0.11 ^{b}	0.93 ^{c}	21.36 ^{a}	91.19 ^{a}	101.95 ^{a}	429.10 ^{a}
T_4 (30%)	0.03 ^{bc}	0.08 ^{c}	0.07 ^{c}	0.11 ^{b}	1.07 ^{c}	15.07 ^{c}	61.75 ^{c}	69.09 ^{c}	288.57 ^{b}
T_5 (40%)	0.04 ^{b}	0.11 ^{b}	0.10 ^{b}	0.14 ^{a}	1.36 ^{b}	15.58 ^{c}	61.04 ^{c}	67.66 ^{cd}	281.95 ^{bc}
T_6 (50%)	0.05 ^{a}	0.13 ^{a}	0.14 ^{a}	0.15 ^{a}	2.12 ^{a}	13.54 ^{cd}	52.29 ^{c}	58.14 ^{d}	239.21 ^{c}
SEm±	0.001	0.004	0.004	0.005	0.057	0.775	3.299	3.695	15.551
C.D. (0.05)	0.004	0.013	0.012	0.015	0.166	2.262	9.629	10.785	45.389
CV (%)	12.20	11.85	12.31	11.95	12.65	10.85	10.86	10.86	10.87

Table 5: Effect of different leachate concentration collected in winter on uptake of heavy metals (g ha^{-1}) in cabbage

Lv: Wv	Pb	Cd	Cr	Co	Ni	Cu	Mn	Zn	Fe
T_1 (0%)	BDL	0.04 ^{e}	BDL	BDL	0.07 ^{f}	10.09 ^{c}	51.57 ^{c}	59.19 ^{c}	247.99 ^{c}
T_2 (10%)	0.01 ^{d}	0.06 ^{d}	0.04 ^{d}	0.06 ^{c}	0.31 ^{e}	13.46 ^{b}	61.16 ^{b}	68.48 ^{b}	291.19 ^{b}
T_3 (20%)	0.02 ^{c}	0.08 ^{b}	0.06 ^{c}	0.08 ^{b}	0.74 ^{d}	17.05 ^{a}	72.80 ^{a}	81.39 ^{a}	342.56 ^{a}
T_4 (30%)	0.03 ^{bc}	0.07 ^{c}	0.06 ^{c}	0.09 ^{b}	0.90 ^{c}	12.74 ^{b}	52.20 ^{c}	58.40 ^{c}	243.93 ^{cd}
T_5 (40%)	0.03 ^{b}	0.09 ^{b}	0.08 ^{b}	0.12 ^{a}	1.13 ^{b}	12.92 ^{b}	50.63 ^{c}	56.12 ^{c}	233.84 ^{cd}
T_6 (50%)	0.04 ^{a}	0.11 ^{a}	0.12 ^{a}	0.13 ^{a}	1.55 ^{a}	11.79 ^{bc}	45.55 ^{c}	50.65 ^{c}	208.38 ^{d}
SEm±	0.001	0.004	0.003	0.004	0.044	0.628	2.686	3.010	12.624
C.D.(0.05)	0.004	0.011	0.010	0.013	0.129	1.833	7.838	8.785	36.847
CV (%)	12.33	11.14	12.46	12.05	12.59	10.79	10.79	10.79	10.80

Means within a column followed by the same letter are not significantly different at 5% level of significance.
BDL – Below Detectable Level

Table 6: Effect of different leachate concentration collected in rainy on uptake of heavy metals (g ha^{-1}) in cabbage

Lv: Wv	Pb	Cd	Cr	Co	Ni	Cu	Mn	Zn	Fe
T_1 (0%)	BDL	0.04 ^{d}	BDL	BDL	0.08 ^{e}	11.64 ^{e}	55.19 ^{d}	63.60 ^{d}	275.58 ^{c}
T_2 (10%)	0.02 ^{d}	0.08 ^{c}	0.05 ^{d}	0.08 ^{e}	0.40 ^{d}	17.81 ^{b}	79.76 ^{b}	89.30 ^{b}	379.73 ^{a}
T_3 (20%)	0.03 ^{c}	0.10 ^{b}	0.08 ^{c}	0.10 ^{d}	0.91 ^{c}	21.03 ^{a}	89.77 ^{a}	100.36 ^{a}	422.42 ^{a}
T_4 (30%)	0.04 ^{b}	0.09 ^{b}	0.08 ^{c}	0.12 ^{c}	1.21 ^{b}	17.02 ^{bc}	69.74 ^{c}	78.02 ^{c}	325.91 ^{b}
T_5 (40%)	0.04 ^{b}	0.10 ^{b}	0.10 ^{b}	0.14 ^{b}	1.32 ^{b}	15.13 ^{cd}	59.26 ^{d}	65.69 ^{d}	273.73 ^{c}
T_6 (50%)	0.05 ^{a}	0.13 ^{a}	0.15 ^{a}	0.16 ^{a}	1.58 ^{a}	14.34 ^{d}	55.42 ^{d}	61.61 ^{d}	253.49 ^{c}
SEm±	0.002	0.005	0.004	0.005	0.050	0.783	3.307	3.705	15.609
C.D.(0.05)	0.005	0.013	0.012	0.016	0.147	2.285	9.653	10.815	45.559
CV (%)	12.27	11.18	12.36	11.98	12.28	10.83	10.85	10.84	10.85

Means within a column followed by the same letter are not significantly different at 5% level of significance.
BDL – Below Detectable Level

Heavy metal content in soil

Effect of different leachate concentration on DTPA extractable heavy metal content (mg kg^{-1}) of soil after harvest of cabbage grown in post summer, winter and the rainy season is represented in Table 7, Table 8 and Table 9, respectively. Application of different leachate concentration increased the DTPA extractable Pb^{2+}, Cd^{2+}, Cr^{3+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Mn^{2+}, Zn^{2+} and Fe^{2+} content of the post-harvest soil as compared to initial concentration and permissible limit in all the treatments except T_1 (0% leachate concentration) which increased in minute amount than initial soil concentration. In the present study, the heavy metal concentration in soils was in the range lower than the Indian permissible limits (Awashthi, 2004) [2]. As soil is the universal mother of all life forms, contaminated soil can alter the nutritional value of food and fodder crops. Using of sewage effluent irrigation may considerably enhance the availability of various heavy metal to plants (Rattan *et al.*, 2002; Singh and Singh, 1996) [17, 20]. Vandanaparth *et al.* (2011) [22] revealed that the soil treated with leachate as a flood irrigation and soil present in the vicinity of dumpsite are noticeably polluted by metals with their concentrations beyond threshold values.

Table 7: DTPA extractable heavy metal content (mg kg^{-1}) of soil after harvest of cabbage grown during summer

	Pb	Cd	Cr	Co	Ni	Cu	Mn	Zn	Fe
Initial	0.2	0.09	0.06	0.02	0.15	0.9	17.13	1.31	21.84
Standards	10-70 #	0.07-1.1 #	65 ©	10 ©	75-150 *	6-60 #	437 ©	50-100 ©	150 ©
T_1 (0%)	0.04 ^{e}	0.03 ^{e}	0.01 ^{f}	BDL	0.12 ^{d}	0.20 ^{d}	12.51 ^{d}	1.18	18.35 ^{c}
T_2 (10%)	0.78 ^{d}	0.53 ^{d}	0.06 ^{e}	0.03 ^{e}	0.18 ^{c}	1.34 ^{c}	17.31 ^{c}	1.21	22.41 ^{b}
T_3 (20%)	1.31 ^{c}	0.74 ^{c}	0.08 ^{d}	0.05 ^{d}	0.21 ^{c}	1.49 ^{c}	17.85 ^{bc}	1.23	24.89 ^{ab}
T_4 (30%)	1.59 ^{b}	1.17 ^{b}	0.11 ^{c}	0.08 ^{c}	0.24 ^{b}	1.78 ^{b}	19.16 ^{abc}	1.25	25.31 ^{ab}
T_5 (40%)	1.65 ^{ab}	1.24 ^{b}	0.15 ^{b}	0.12 ^{b}	0.29 ^{a}	2.07 ^{a}	20.30 ^{ab}	1.28	26.42 ^{a}

T_6 (50%)	1.78^{a}	1.38^{a}	0.23^{a}	0.14^{a}	0.31^{a}	2.18^{a}	21.65^{a}	1.33	27.17^{a}
SE m±	0.064	0.046	0.006	0.004	0.011	0.078	0.87	0.06	1.16
C.D.(0.05)	0.185	0.133	0.019	0.013	0.031	0.230	2.55	NS	3.38
CV (%)	11.88	12.04	13.48	13.99	10.72	11.68	10.78	10.62	10.73

Table 8: DTPA extractable heavy metal content (mg kg^{-1}) of soil after harvest of cabbage grown during winter

	Pb	**Cd**	**Cr**	**Co**	**Ni**	**Cu**	**Mn**	**Zn**	**Fe**
Initial	0.2	0.09	0.06	0.02	0.15	0.9	17.13	1.31	21.84
Standards	10-70 #	0.07-1.1 #	65 ©	10 ©	75-150 *	6-60 #	437 ©	50-100 ©	150 ©
T_1 (0%)	0.03^{e}	0.05^{d}	0.02^{de}	BDL	0.12^{b}	0.10^{d}	12.51^{d}	1.18^{cd}	18.35^{c}
T_2 (10%)	0.61^{d}	0.48^{c}	0.01^{e}	BDL	0.010^{d}	0.94^{c}	17.16^{c}	0.97^{e}	23.51^{b}
T_3 (20%)	0.98^{c}	0.56^{c}	0.03^{d}	0.022^{d}	0.020^{d}	1.02^{c}	17.54^{bc}	1.02^{de}	24.24^{ab}
T_4 (30%)	1.01^{c}	0.91^{b}	0.08^{c}	0.056^{c}	0.086^{c}	1.26^{b}	18.94^{abc}	1.26^{bc}	24.98^{ab}
T_5 (40%)	1.58^{b}	1.04^{a}	0.13^{b}	0.068^{b}	0.124^{b}	1.37^{b}	19.91^{ab}	1.41^{ab}	25.37^{ab}
T_6 (50%)	1.94^{a}	1.12^{a}	0.21^{a}	0.080^{a}	0.148^{a}	1.58^{a}	20.99^{a}	1.56 a	26.93^{a}
SEm±	0.057	0.037	0.005	0.002	0.005	0.078	0.860	0.060	1.146
C.D.(0.05)	0.167	0.109	0.015	0.008	0.014	0.159	2.510	0.174	3.345
CV (%)	12.51	12.06	14.67	16.08	12.34	11.69	10.78	10.80	10.72

*Indian standard (Awashthi 2004) [2] and European Union (2006); #FAO/WHO, codex general standard for contaminants and toxins in foods, 2001; ©World Health Organization, 2007.

Means within a column followed by the same letter are not significantly different at 5% level of significance.

BDL – Below Detectable Level

Table 9: DTPA extractable heavy metal content (mg kg^{-1}) of soil after harvest of cabbage grown during rainy season

	Pb	**Cd**	**Cr**	**Co**	**Ni**	**Cu**	**Mn**	**Zn**	**Fe**
Intial	0.2	0.09	0.06	0.02	0.15	0.9	17.13	1.31	21.84
Standards	10-70 #	0.07-1.1 #	65 ©	10 ©	75-150 *	6-60 #	437 ©	50-100 ©	150 ©
T_1 (0%)	0.01^{e}	BDL	BDL	BDL	BDL	BDL	7.89^{c}	0.066^{e}	20.34^{c}
T_2 (10%)	0.02^{d}	BDL	BDL	BDL	BDL	BDL	11.26^{b}	0.090^{e}	22.31^{bc}
T_3 (20%)	0.08^{c}	BDL	BDL	BDL	BDL	0.47^{d}	11.94^{b}	0.128^{d}	23.48^{abc}
T_4 (30%)	0.09^{c}	0.21^{c}	BDL	BDL	0.056^{c}	0.69^{c}	12.80^{b}	0.176^{c}	24.15^{ab}
T_5 (40%)	0.12^{b}	0.26^{b}	BDL	BDL	0.090^{b}	0.98^{b}	14.76^{a}	0.224^{b}	25.10^{ab}
T_6 (50%)	0.15^{a}	0.29^{a}	BDL	BDL	0.124^{a}	1.08^{a}	15.98 a	0.340^{a}	25.98^{a}
SEm±	0.004	0.009	-	-	0.003	0.033	0.566	0.009	1.126
C.D.(0.05)	0.013	0.025	-	-	0.009	0.098	1.654	0.028	3.287
CV (%)	12.98	15.29	-	-	15.97	13.94	10.19	12.68	10.69

*Indian standard (Awashthi 2004) [2] and European Union (2006); #FAO/WHO, codex general standard for contaminants and toxins in foods, 2001; ©World Health Organization, 2007.

Means within a column followed by the same letter are not significantly different at 5% level of significance.

BDL – Below Detectable Level

Conclusion

From the present study, it can be concluded that the leachate generated from the landfill or open dumping yard has negative impact and if it is used continuously will lead to bio accumulation of heavy metals in cabbage and metals enter in to food chain. Higher the application of leachate concentration higher the content of heavy metals but the potentiality of cabbage has shown that 20 per cent has maximum uptake and continuous application of leachate to soil was exceeded the limits.

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