Jr. of Industrial Pollution Control 23 (2)(2007) pp 351-356

CADMIUM AS A POLLUTANT IN ENVIRONMENT AND AGRICULTURE

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Key words : Cadmium pollution, Sewage sludge, City compost, Food chain.

ABSTRACT

Contamination of soil by heavy metals (Cd) is of widespread occurrence as a result of human agriculture and industrial activities. Cd induced reduction in the number of flowers and in vitro pollen germination but did not affect pollen viability. However it stimulated tube growth, decreased number of ovules/pistil (ovules were morphologically normal and receptive), inhibited number of pods, seeds, seed weight/ plant and 100 seed weight. Cd treatment did not affect starch content but increase protein content in physiologically mature seed. Significant yield reduction was obtained only in Alfisol and Ultisol amended with higher rate of Cd- enriched sewage sludge/city compost. The amount of cadmium in leachates remained more or less similar to the original values. The applied Cd remains in the top 10 cm soil (87-96%) and this resulted in lower recovery of heavy metals in the leachates (Cd 8.3%).

INTRODUCTION

The importance of Cadmium is that it is toxic and carcinogenic elements, which occur widely in the environment both from natural and anthropogenic sources, nearly ubiquitous in the environment, which is hazardious to human and ecosystem in excessive amount. Inputs are mainly from atmospheric deposition, application of biosolids, use of phosphates fertilizer, and from effluents from cadmium using and recycling industries.

Position in the periodic table

Cadmium (atomic number 48, atomic mass 112.40) has on outer electronic configuration of $4d^{10}5S^{2}$ and belongs to II B group of the periodic table. In soil the ionic form of cadmium, which is absorbed by the plants, are Cd^{+2} ion and Cd^{+4} ion. Plant easily absorbed Cd^{+2} ion as compared to Cd^{+4} ion because less energy is required for absorption of Cd^{+2} as compared to Cd^{+4}. Some other important properties are given below:

Colour	:	silver white metal
Atomic No.	:	48
Electronegative	:	112.4gmor^{-1}
Density	:	8.7 gm^{-1} at 20 °C
Melting point	:	321 °C
Boiling point	:	767°C
Wander walls Radius	:	0.154nm
Ionic Radius	:	0.097nm
Electronic shell	:	(Kr) $4d^{10} 5S^2$
Energy of first ionization	:	866kJmol^{-1}
Standard Potential	:	0.402V

Environmental cadmium in Food chain

Soil- plant transfer of Cd both soil and plant properties is considered. Fig. 1 shows that Soil supply parameters like soil-Cd concentration, partitioning of Cd between solid and solution phases affect the availability of Cd in soil, likewise soil characteristics eg. Soil acidity. Cd is most moveable in acid soil, presence of competing ions e.g. Clay type content and amount of organic matters, these matter helping in Cd-fixation. Similarly plant demand parameter, like presence of competing ions (Cd, H, Zn) in solution e.g. Deficiency of Zn in particular may lead to high Cd accumulation and soil fertility make Cd more available to plant and microorganism.

Bio-availability of Cd to soil microorganism is also depend on soil factor however less study has been done in the concern but soil factor like fertility is favorable to micro organism, Cd is found available to microorganism and after their death, Cd become available to plants.

Plant transfers the Cd towards wild animal, human. Direct injection of soil by human may also be significant exposure pathway in highly polluted soil eg. Geophagy by children.

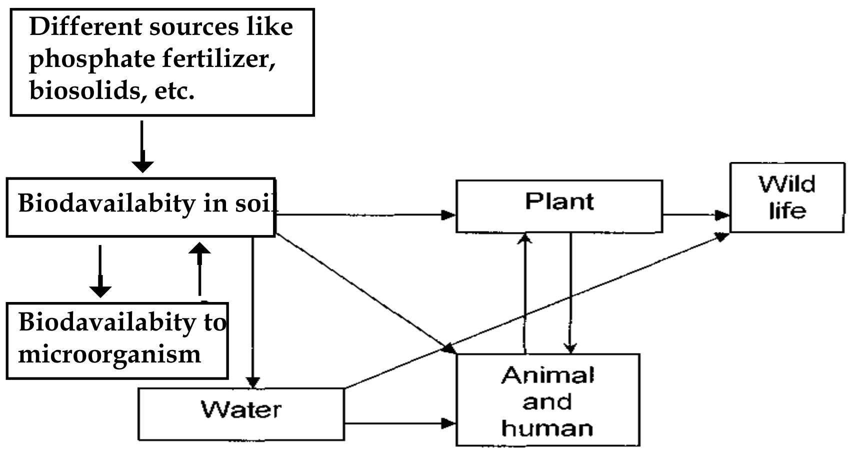

Fig.1 Movement of cadmium in food chain

Table 1

Forage yields of maize grown on four soils emended with Cd - enriched sewage sludge/city compost (Duration of plant growth: 30 days)

Treatment (g sludge/ compost kg ha^{-1} soil)	Soil sludge/compost Cd levels (ppm)	Dry matter yield (g pot^{-1}) Sewage sludge				Dry matter yield (g pot^{-}) City compost			
		Ultisol	Alfisol	Entisol	Vertisol	Ultisol	Alfisol	Entisol	Vertisol
0	0	0.81	1.14	1.18	1.09	0.79	0.83	0.84	0.87
25	7.5	0.88	1.04	1.27	0.95	0.59	0.92	1.09	1.26
50	15.0	0.90	0.58	1.10	1.25	0.67	0.88	1.10	0.71
100	30.0	0.40	0.29	1.17	1.40	0.72	0.55	0.95	0.83

Table 2

Dry weight (g pot^{-1}) of different forage species (tops) as influenced by cadmium

Cd applied (mg kg^{-1})	Alfalfa	Cowpea	Egyptian clover	Indian clover	Maize	Oats	Pearl millets	Teosinte
0	2.90	2.31	2.79	2.70	5.00	0.80	3.29	1.69
1	2.40	1.94	2.17	2.51	5.10	0.77	3.22	1.09
2.5	1.75	1.44	1.51	2.26	5.00	0.71	2.29	1.04
5	1.44	1.37	1.50	1.70	4.63	0.57	1.64	0.98
10	0.60	0.95	1.35	0.81	4.50	0.48	0.52	0.95
25	0.42	0.89	1.31	0.26	4.40	0.35	0.13	0.94
50	-	0.72	-	-	2.70	0.27	-	0.83
100	-	0.53	-	-	2.30	0.19	-	0.67
CD (P=0.05)	0.32	0.43	0.61	0.24	1.50	0.18	0.79	0.35

Table 3

Effect of Cadmium on sexual competence and yield components in mungbean genotypes

Characters	Genotypes/Cd Treatments (mM)								CD at 5% LS
	MH 85-111				MH98-6				
	Control	0.5	1.0	2.0	Control	0.5	1.0	2.0	
Pollen viability (%)	96.20	92.55	92.79	91.73	94.33	90.71	93.82	91.96	C=NS T=NS, CXT=NS
Pollen germination (%)	89.19	83.37	80.36	78.04	82.23	80.23	72.66	70.57	C=NS T=8.92, CXT=NS
Tube length (µm)	663.6	676.6	705.0	731.4	464.4	512.4	643.6	671.6	C=39.59 T=55.98,CXT=79.18
Style length (cm)	1.58	1.64	1.64	1.64	1.50	1.57	1.57	1.65	C=0.05 T=0.07,CXT=NS
Number of ovules/pistil	11.52	10.53	10.47	10.33	11.61	10.74	10.61	10.41	C=NS T=0.36, CXT=NS
Number of flowers/plant	17.62	14.73	12.58	9.87	16.80	15.37	13.87	9.50	C=NS T=2.92, CXT=NS
Number of pots/plant	12.93	9.75	8.25	6.37	12.37	10.97	9.75	6.56	C=NS T=1.63, CXT=NS
Number of seeds/pod	9.19	8.22	7.57	6.15	9.31	9.06	7.61	7.31	C=NS T=0.74, CXT=NS
Number of seeds/plant	118.6	86.1	64.1	40.9	115.0	98.0	74.6	49.0	C=NS T=15.09, CXT=NS
Seed weight/plant (g)	2.69	2.07	1.53	1.11	2.87	2.15	1.65	1.35	C=NS T=0.46, CXT=NS
Test weight of 100 seeds (g)	3.02	2.94	2.56	2.54	3.12	2.98	2.90	2.86	C=0.09 T=0.13, CXT=NS

C = Genotype T = Treatment

Direct and indirect sources of Cd into aquatic environment including atmospheric deposition erosion and other means of mobilization from soil, runoff, waste water effluents and P-fertilizer and manures contributes the Cd leaching from soil after deposition of Cd entry into water. The contribution from leaching from soil after deposition of Cd on the soil surface seems essential. This is true where ground water is close to the surface and/or where soil as in coarse -grained, shallow soils with low organic composition.

Plant uptake of Cadmium

Cadmium concentration in normal plants ranged from 0.1 -2.4 ppm (Alloway 1990), but at higher concentration it has been shown to affect plant growth and dry matter yield adversely (Bingham *et al.* 1976). Green house pot culture experiments were conducted to evaluate the uptake of cadmium by maize crop from increasing level of Cd- enriched sewage -sludge and city compost amended Ultisol, Alfisol, Entisol, and Vertisol. In general, significant yield reduc-

Table 4

Effect of Cadmium on starch and protein content (mg/g) of physiologically mature mungbean seeds

Cd treatment (mM)	Starch MH85 - 111	Starch MH 98 - 6	Protein MH85 - 111	Protein MH 98 - 6
Control	400.8	341.1	233.9	247.9
0.5	418.7	338.8	271.3	249.1
1.0	340.2	433.8	277.4	291.8
2.0	344.4	457.3	358.8	3 2 6 . 8
Mean	376.0	392.7	285.3	278.7

CD at 5% LS, C (Genotype) = NS, C (Genotype) = NS, T (Treatment) = NS
T (Treatment) = 29.61. CXT =91.8, CXT =NS

Table 5

Effect of rhizospheric cadmium on its portioning in roots, stem, leaf, pod wall and seeds (µg g^{-1} dry wt.) in mungbean genotypes. Values in parentheses indicated percent distribution in each component.

Plant part	Genotypes/Cd Treatments (mM)								CD at 5%LS
	MH 85-111				MH 98 - 6				
	Control	0.5	1.0	2.0	Control	0.5	1.0	2.0	
Root	2.0	45.0	99.4	130.9	2.05	27.5	74.7	89.6	C=5.58 T=7.89 CXT=11.10
Stem	1.70	27.5	40.0	100.0	1.90	12.5	12.5	25.0	C=7.39 T=10.45 CXT=10.45
Leaf	1.82	20.0	22.5	47.5	1.84	15.0	20.0	30.0	C=2.04 T=2.88 CXT=4.08
Pod wall	1.45	17.5	17.5	20.0	1.55	10.0	10.0	10.0	C=2.04 T=2.88 CXT=4.08
Seed	1.25	12.5	12.5	15.0	1.25	15.0	15.0	15.0	C=NS T=2.88 CXT=NS
Total	8.22	122.5	191.9	313.2	8.59	80.0	132.2	169.6	

tion of maize shoots was obtained only in Ultisol, and Alfisol amended with higher rates of Cd- enriched sewage-sludge/city compost. Results further suggest that care has to be taken while amending soil (acid soil in particular) with sewage- sludge and city compost containing high amount of Cd (Table 1).

Cd induced numbers of flowers and in vitro pollen germination but did not affect pollen viability. However, it stimulated tube growth although did not affect pistil length, it decreased number of ovules/pistil. Ovules were morphologically normal and receptive. Cadmium inhibited number of pods, seeds and seed weight. Cd treatment did not affect starch content but increase protein content in physiologically mature seeds. Accumulation of Cd^{2+} was maximum in the roots and least in the seeds (Table 3).

Eight forage species belonging to the leguminocae and graminae families were grown in pots in a coarse textured soil treated with different quantities of Cd concentration tested i.e. 1 and 2.5 mg Cd kg^{-1} soil, most species exhibited significant reduction in plant growth, measured as dry matter yields. Forage species belonging to the Graminae family (Table 2).

For plant species like soybean and wheat, Cd toxicity was observed at 25 % yield reduction have been reported for spinach, soybean, curelycress, lettuce, corn, carrot and turnip at Cd addition level of 4, 5, 8,13, 18, 20 and 28 mg kg^{-1} soil, respectively (Bingham *et al*. 1975).

CONCLUSION

Cadmium is a toxic and carcinogenic metal, nearly ubiquitous in the environment, which is hazardous to human and ecosystems in excessive amounts. Inputs are mainly from atmospheric depositions, application of bio-solids, use of phosphates fertilizer, and effluents from cadmium using and recycling industries. Cd induced reduction in the number of flowers and in vitro pollen germination, it stimulated tube growth, decreased number of ovules/pistil (ovules were morphologically normal and receptive), inhibited number of pods, seeds, seed weight/ plant and 100 seed weight, Cd treatment increase protein content in physiologically mature seed. Significant yield reduction was obtained only in Alfisol and ultisol amended with higher rate of Cd- enriched sewage sludge/city compost.

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