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Heavy metal accumulation of urban domestic rubbish compost in turfgrass by EDTA chelating

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Abstract: Seven kinds of heavy metal accumulation of rubbish compost in turfgrass by EDTA chelating were investigated. With EDTA application, heavy metal accumulation by two species of turfgrass was increased significantly. The enrichment coefficients of *Lolium perenne* L(L) and *Festuca arundinacea* L(F) to Cr reached 9.45 and 6.15 respectively. In the range of EDTA dosages given, heavy metal accumulation in turfgrass increased with increasing EDTA level. There were significant differences in remediation of different metals by applying EDTA. L had high ability to accumulate Cr, Cd, Ni and Zn, showing better remediation to heavy metals of rubbish compost. In contrast, F showed high ability to accumulate Cr, Ni, Cu and Zn. Low EDTA level increased aboveground net primary production (ANP) of turfgrass, but EDTA would considerably inhibit it when EDTA was higher than 20 mmol/kg. The results demonstrated that the optimum dosage of EDTA for remediating heavy metals in rubbish compost by turfgrass was between 10 mmol/kg and 20 mmol/kg.

Keywords: domestic rubbish compost; EDTA; turfgrass; heavy metal; accumulation

Introduction

With rapid urbanization and the improvement of living standard of city dwellers, annual output of urban domestic rubbish increases fast. Rubbish pollution has become a hot and difficult environmental issue, and rubbish resource utilization has received increasing attention throughout the world(Li, 2004; Paul, 2000). In China, rubbish has been stockpiled more than 60 hundred million tons over the years, with lower than 5% resource utilization (Dong, 2000). Compost is an important way for rubbish resource utilization (Duo, 2000). In the past 20 years, rubbish compost for agriculture was prevalent. However, heavy metal contamination has become serious in recent years, and their toxic effects have been drawn general attention (Webber, 1984; Chander, 2002). Heavy metal pollutants are stable in the environment, highly toxic to biological organisms(Chen, 2003; Zhang, 2002; Chander, 2001). It is recognized that rubbish compost contains considerable amounts of heavy metals. They can be accumulated in crops, enter food chain finally and pose direct threat or potential hazard to human health(Baranowski, 2002). Now rubbish compost enterprises are abandoned one after another. Most rubbish compost is left unused. Rubbish compost medium is a complex-polluted system with multiple heavy metals present. Therefore, study on remediation of heavy metals in rubbish compost has especially important significance.

EDTA has high capacity to chelate metals. In the remediation of heavy metal polluted soil, adding EDTA can elevate metal solubility and mobility in soil, increase uptake and accumulation in plants, and enhance the effectiveness of phytoremediation and shorten remediation period. Turfgrass has especially ecological significance in alleviating pollution and protecting environment. It is perennial plant, and has characteristics of high regeneration capacity and fast growth. It could be mowed many times in one year and produce large amounts of aboveground biomass much more than that of hyperaccumulators. Mowing could remove the biomass, like an "extraction pump", gradually extract heavy metals from medium. So compared with other plants, turfgrass could effectively remediate heavy metals in compost medium. The objective of this study was to investigate the effects of EDTA on extraction of heavy metals in rubbish compost by turfgrass. It could provide a scientific basis for remediation of heavy metal contaminated sites by turfgrass.

1 Materials and methods

1.1 Materials

Rubbish compost was collected from Tianjin Xiaodian Rubbish-Disposal Factory. It was screened by sieve and then oven dried at 80℃ to constant weight for being used as turfgrass medium. Heavy metal(Cr, Mn, Ni, Cu, Zn, Cd and Pb) background concentrations in rubbish compost were analyzed by the method of ICP-AES(Kong, 2001). EDTA was used as chelating agent. *Festuca arundinacea*.L(F) and *Lolium perenne*.L(L) were chosen as plant materials.

1.2 Methods

A hundred seeds of *Festuca arundinacea*.L or *Lolium perenne*.L were uniformly sown in each culture dish(ϕ = 10 cm)(Duo, 2000) after 30 g compost was added to each dish (Zhao, 2002). At 26 d after sowing, the dishes were amended with different EDTA levels of 0, 10.0, 20.0, 30.0, 40.0 mmol/kg respectively, and with 0 mmol/kg as control(CK). Each treatment was replicated three times. The experiments were carried out in a laboratory with the following conditions: natural light (1700—1900 lx), temperature of 15—27℃, and relative humidity of 30%—70%. Watering was provided daily throughout the study to maintain adequate medium moisture(Huang, 1999).

At the day 53, shoots of turfgrass were harvested (Johnso, 2000), washed with tap water and rinsed with deionized water, oven dried at 105℃ for about 8 h to constant weight. Aboveground net primary production(ANP) was measured. In order to determine heavy metal concentration, the samples were wet digested with nitric/perchlolic acids. Heavy metal(Cr, Mn, Ni, Cu, Zn, Cd, Pb) analysis was performed using an inductively coupled plasma-atomic emission spectrometer (ICP-AES, American Leeman Labs Inc.).

2 Results and analyses

2.1 Effects of EDTA on aboveground net primary

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production(ANP)

Aboveground net primary production(ANP) is of vital importance to phytoremediation of heavy metals. The positive effects of EDTA levels on ANP for L decreased in the order: 10 mmol/kg > 0 mmol/kg > 20 mmol/kg > 30 mmol/kg, with relative percentages of 115.05%, 100.00%, 99.77%, 82.53% and 55.61% respectively. The results for F were: 10 mmol/kg > 0 mmol/kg > 20 mmol/kg > 30 mmol/kg, relative percentages: 104.72%, 100.00%, 81.81%, 52.73% and 40.50% respectively(Fig. 1). EDTA supply lower than 20 mmol/kg increased ANP for L. However, EDTA level higher than 10 mmol/kg reduced ANP for F. At EDTA level of 40 mmol/kg, ANP of L and F decreased to 55.61% and 40.50% of the control respectively. Analysis of variance showed the results of 0 mmol/kg, 10 mmol/kg and 30 mmol/kg($P > 0.01$), among other levels($P < 0.01$) for L; 0 mmol/kg and 10 mmol/kg, 10 mmol/kg and 20 mmol/kg, 30 mmol/kg and 40 mmol/kg($P > 0.01$), among other levels($P < 0.01$) for F.

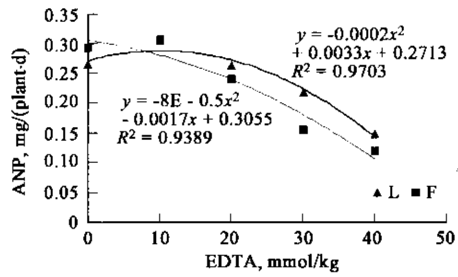

Fig.1 Effects of EDTA on ANP of turfgrass

2.2 Heavy metal accumulation in turfgrass

The accumulation of heavy metals in turfgrass can be evaluated by enrichment coefficient with the formula: enrichment coefficient = heavy metal concentration in turfgrass/heavy metal concentration in compost medium (Zhao, 2002). Table 1 shows the results of enrichment coefficients without EDTA addition.

Table 1 Accumulation of heavy metals in turfgrass(μg/g)

Heavy metals	Heavy metal concentrations in rubbish compost	L		F	
		Heavy metal concentrations	Enrichment coefficient	Heavy metal concentrations	Enrichment coefficient
Cr	38.93	78.65	2.02	40.18	1.03
Mn	530.57	79.26	0.15	91.16	0.17
Ni	33.42	27.03	0.81	20.37	0.75
Cu	238.73	67.30	0.28	11.01	0.16
Zn	496.38	414.12	0.83	157.17	0.38
Cd	1.97	1.54	0.78	5.25	2.67
Pb	172.11	23.99	0.14	50.79	0.30

L showed high ability to accumulate Cr, Ni, Zn and Cd, their enrichment coefficients were all higher than 0.78, and the highest value 2.02 was for Cr. But the enrichment coefficients of Mn, Cu and Pb were all lower than 0.28. F showed high ability to accumulate Cr, Ni and Cd, especially to Cd, with the highest enrichment coefficient of 2.67. But F had low ability to accumulate Mn, Pb, Cu and Zn, with enrichment coefficients of lower than 0.38.

The results suggested that the accumulation of heavy metals in turfgrass differed significantly as turfgrass species and heavy metals differed. Without EDTA addition, shoots of two turfgrass accumulate 7 kinds of heavy metals slightly. This result was consistent with other study(Zhao, 2002).

2.3 Heavy metal accumulation in turfgrass with EDTA application

Adding EDTA increased heavy metal accumulation in two turfgrass significantly(Table 2). L had a relatively high ability to accumulate Cr, Ni and Cd, and the highest enrichment coefficients of three metals reached 9.45, 5.13 and 7.55 at EDTA levels of 20, 20 and 10 mmol/kg respectively. As compared with control, Cr, Mn, Ni, Cu, Zn, Cd and Pb enrichment coefficients in L were increased by 4.68-fold, 1.73-fold, 6.56-fold, 7.19-fold, 3.65-fold, 9.68-fold and 11.17-fold respectively. It was shown that EDTA addition enhanced accumulation of each metal in L to a large extent. F showed high ability to accumulate Cr, and the highest coefficient reached 6.33 at EDTA level of 10 mmol/kg. Cr, Mn, Ni, Cu, Zn, Cd and Pb enrichment coefficients in F were raised by 6.15-fold, 1.47-fold, 5.43-fold, 4.44-fold, 5.24-fold, 1.33-fold and 2.86-fold respectively as compared with control. EDTA addition significantly increased heavy metal concentrations in shoots of turfgrass, moreover, EDTA had a better effect on L than on F.

Table 2 Heavy metal concentrations in turfgrass with EDTA application (μg/g)

EDTA levels, mmol/kg	0		10		20		30		40	
Turfgrass	L	F	L	F	L	F	L	F	L	F
Cr	78.65	40.18	294.63	246.49	367.68	198.24	310.66	192.02	300.23	171.01
Mn	79.26	91.16	107.02	108.80	132.00	132.20	139.54	120.13	116.45	94.59
Ni	27.03	20.37	164.30	135.92	171.58	107.68	86.23	82.80	57.77	78.68
Cu	67.30	11.01	147.27	168.22	203.97	125.18	234.95	116.79	479.46	85.85
Zn	414.12	157.17	1315.70	989.53	1502.11	733.33	1042.31	667.86	890.91	416.23
Cd	1.54	5.25	14.88	7.02	7.44	5.66	2.11	5.41	1.85	3.93
Pb	23.99	50.79	162.56	148.74	267.89	117.08	127.31	70.13	62.64	50.92

2.4 Analyses on synthetic effects of EDTA on heavy metal accumulation

Because rubbish compost medium is a complex-polluted system with mutiple heavy metals present, how to evaluate synthetic remediation effects of different EDTA levels is an important issue. In another word, accumulation of heavy metals in plants will increase with more amounts of EDTA addition, but plant growth will be inhibited significantly and biomass will decrease. Otherwise, when EDTA addition is less, plant growth will not be inhibited greatly, but accumulation of heavy metals will decrease. Therefore, synthetic remediation index (SRI) was applied to evaluate synthetic remediation effects of heavy metals in rubbish compost at different EDTA levels (Zhao, 2002). It is closely related to heavy metal accumulation amounts. *SRI* can be calculated by the formula: $SRI = RP \times \sum C_i/7$. *RP* is the relative ratio of ANP at EDTA levels with control; $\sum C_i$ is the weighted sum of ratio of metal concentration at EDTA levels with the highest concentration.

The results of *SRI* were presented in Table 3. It was found that EDTA at a rate of 10 mmol/kg was the optimum dosage for heavy metal remediation in rubbish compost by two turfgrass, and remediation effectiveness decreased in the order: 10 mmol/kg > 20 mmol/kg > 30 mmol/kg > 40 mmol/kg ≈ 0 mmol/kg. Two turfgrass could not play a role in remediating heavy metals in compost when EDTA level was increased to 40 mmol/kg.

Table 3 Synthetic remediation index (*SRI*)

Turfgrass	L					F				
EDTA levels, mmol/kg	0	10	20	30	40	0	10	20	30	40
RP	1.0000	1.1505	0.9977	0.8253	0.5561	1.0000	1.0472	0.8182	0.5273	0.4050
Cr concentration ratio (C_1)	0.2139	0.8013	1.0000	0.8449	0.8166	0.1630	1.0000	0.8043	0.7790	0.6938
Mn concentration ratio (C_2)	0.5680	0.7669	0.9460	1.0000	0.8345	0.6896	0.8175	1.0000	0.9087	0.7155
Ni concentration ratio (C_3)	0.1575	0.9576	1.0000	0.5026	0.3368	0.1499	1.0000	0.7922	0.6092	0.5787
Cu concentration ratio (C_4)	0.1404	0.3072	0.4245	0.4900	1.0000	0.0655	1.0000	0.7441	0.6943	0.5103
Zn concentration ratio (C_5)	0.2757	0.8759	1.0000	0.6939	0.5931	0.1518	1.0000	0.7411	0.6749	0.4307
Cd concentration ratio (C_6)	0.1035	1.0000	0.5000	0.1418	0.1243	0.7479	1.0000	0.8063	0.7707	0.5582
Pb concentration ratio (C_7)	0.0896	0.6076	1.0000	0.4752	0.2338	0.3414	1.0000	0.7871	0.4715	0.3423
$I = \sum C_i/7$	0.2212	0.7595	0.8383	0.5926	0.5627	0.3299	0.9739	0.8107	0.7012	0.5470
$SRI = I \times RP$	0.2212	0.8853	0.8364	0.4891	0.3129	0.2399	1.0199	0.6633	0.3697	0.2215
SRI order	5	1	2	3	4	4	1	2	3	5

3 Discussion

Heavy metal contamination leads to toxic effects on plants probably by the following ecological ways. Firstly, in organisms, considerable amounts of heavy metal ions disturbed original equilibrium among ions, hindered natural ion absorption, transportation, infiltration and adjustment, and resulted in metabolic disorder (Ni, 2003). Secondly, heavy metal ions combined with non-active group of some zymoprotein and made them denaturation (Peng, 2003; Chen, 2000). Thirdly, long-term accumulation of heavy metals in plants could induce cytotoxicity like chromosome aberration etc. (Faustand, 2000). Finally, in a view of ecosystem, heavy metals could be transported and magnified in food chain, and would endanger public health (Antoniadis, 2003). Heavy metals in rubbish compost would result in their accumulation in plants and negatively affect plant growth (Wu, 2003). What is needed to point out, large differences occurred among different plants in toxicity of heavy metals, perhaps it was relevant to geochemical properties of elements, background concentrations in environment, physiological metabolic mechanisms of plants and coevolution of organisms with environmental elements.

It has been reported that EDTA had different ecological effects on plant growth. In this study, low EDTA level increased ANP of two turfgrass, however, EDTA supply higher than 20 mmol/kg decreased ANP, and decreased significantly with increasing EDTA levels. In application of phytoremediation, ANP of plants is exceptionally important because its reduction would result in decreasing the amount of metal accumulation (Quiroz, 2002). EDTA supply lower than 10 mmol/kg increased ANP of two turfgrass. At the range of EDTA dosages, two turfgrass showed no visible symptoms of yellowing. So the ecological threshold of EDTA should be higher in practical application than theoretical value, and two turfgrass could tolerate high concentrations of heavy metals (Khan, 1999).

Without EDTA application, accumulation of heavy metals in shoots was low (Zhao, 2002). However, two turfgrass responded to the application of EDTA by significantly increased uptake of heavy metals. The enrichment coefficients of L and F to Cr reached 9.45 and 6.15 respectively. Although metal accumulation was enhanced with the application of EDTA, EDTA at high levels inhibited turfgrass growth. Therefore, EDTA optimum dosage was analyzed and evaluated using SRI, and the results for two turfgrass were all between 10 mmol/kg and 20 mmol/kg. Of course, the accurate dosage of EDTA addition is still a question needed to further study in the future. Large differences occurred among different heavy metals in phytoremediation by two turfgrass with EDTA application. L had high ability to accumulate Cr, Cd, Ni and Zn, showing good remediation effects for heavy metals in rubbish compost, but F had high ability to accumulate Cr, Ni, Cu and Zn. The result would provide a scientific basis for screening turfgrass with high accumulation ability in a large range.

Heavy metal contamination in rubbish compost is a serious issue, also affects normal growth of plants and imposes risk on the local ecosystem (Kandeler, 2000). There are many reports on phytoremediation of heavy metal contamination. Compared with other hyperaccumulators, turfgrass has characteristics of high adaptability, fast growth, high regeneration capacity and large aboveground biomass (Pathan, 2003). If turfgrass is used to remediate heavy metal contamination in rubbish compost, heavy metals would be extracted gradually by mowing several times in one year (Zhao, 2002). Turfgrass mowed might be landfilled with safety or heavy metals might be recovered from the biomass (Paul, 2000). The approach of applying EDTA to increase metal accumulation in turfgrass and to remediate heavy metals in rubbish compost was very effective. The study could provide a scientific basis for remediation of heavy metal polluted compost by turfgrass and realization of rubbish compost utilization, as well as for remediation of heavy metal contaminated sites by turfgrass.

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