Bull. Environ. Contam. Toxicol. (2005) 74:604–609

DOI: 10.1007/s00128-005-0626-y

Bulletin of Environmental Contamination and Toxicology

Effects of Aqueous Extracts from Soils in Nonsanitary Waste Landfills on Germination and Seedling Growth of Some Herbaceous Species

K. D. Kim

Center for Urban Horticulture, University of Washington, Box 354115, Seattle, WA 98195-4115, USA

Received: 14 November 2003/Accepted: 9 December 2004

The leachate produced in waste landfills by rainfall pollutes the surface runoff through a uniform dispersion (Namgung 1992). Plants are influenced by leachate as it seeps through gaps in the cap, at the uncapped site and the edge of landfill (Chan et al. 1999). Although the primary and direct impacts of landfill gas and leachate on plants have been much surveyed (Maurice et al. 1999), their secondary and subsequent impacts caused by them on soil chemical properties and plant growth have not yet been researched. This paper reports on the survey results of the germination ability of herbaceous species in waste landfill and the impacts of aqueous extracts of waste landfill soils on plant germination and growth. The aqueous extracts from soils of nonsanitary waste landfills were specifically studied to verify the role of the soil soaked by waste exudates in nonsanitary waste landfills with an open waste dump blended with cover soils of low quality and without capping.

MATERIALS AND METHODS

Seeds of 31 herbaceous species were collected from 5 flowering culms of 10 individuals per species in populations of Hasanundong landfill, a nonsanitary waste landfill closed since June 1994, on Nov. 1999. The 31 species were tested for germination in sterile Petri dishes (90 × 15 mm) with de-ionized water in the conditions of light 8: dark 16, 25°C, and 70% humidity for 14 days. Seeds of 4 herbaceous species, *Achyranthes japonica, Lactuca indica* var. *laciniata*, *Oenothera biennis* and *Rumex japonica* with high percentage germination and early germination were selected for growth comparison treated with aqueous extracts of landfill soils. In August 2000, approximately 20 kg soils in 0-20 cm depth were collected from two nonsanitary waste landfill sites: the Sangpaedong landfill, an open dumped landfill, closed 8 months ago and the Kyongseodong landfill, a soil-covered landfill, closed 8 years ago. The domestic waste landfilled in both landfills was composed of 32.1% of food wastes, 28.7% of papers, 16.5% of plastics and vinyls, 4.9% of textiles, 1.6% of woods, 3.6% of rubbers and leathers, and 12.6% of others, respectively (Yi et al. 2000). 6 g fresh soils sieved with a 1 mm mesh screen were blended with 50 ml de-ionized water, shaken at 25°C, 200 rpm for 24 hours (Fisher et al. 1998). After shaking, they were still-

Whatman No. 44 was used as growth medium. Distilled water and Hoagland solution were used as a control. In each four Petri dishes with 25 seeds per species at regular intervals, 10 mL of each treatment solution were provided every 3 days. Germination and the shoot and root length of seedlings were checked for 20 days. Aqueous extracts of landfill soils, the leachate, and Hoagland solution were analyzed to compare chemical contents. pH and electric conductivity (EC) were measured with pH meter (Fisher 230A) and EC meter (Philips PW9509/20) (Page et al. 1982). BOD_5 (Biochemical Oxygen Demand in Five Days) and COD (Chemical Oxygen Demand) were analyzed by Winkler method and alkaline permanganate method (APHA 1989). K, Na, Ca and Mg were determined with atomic absorption spectrophotometer. The anion concentrations of F^-, Cl^- and SO_4^{-2} concentration were analyzed by ion chromatography with a Dionex Model 500 chromatograph (Page et al. 1982). NH_4^+ and NO_3^- concentration were analyzed by Kjeldahl methods and PO_4^{-2} concentration was analyzed by molybdate-ascorbic methods (Page et al. 1982). Analysis of Al, As, B, Cd, Co, Cu, Fe, Mn, Ni, Pb and Zn was performed on an ICP emission spectrometer. The mean differences between shoot and root length were compared with ANOVA and Kruskal-Walis test. Their decreasing orders were determined with Tukey test. Comparative analysis of their chemical contents was conducted with Kolmogorov-Smirnov test. All the statistical analyses were performed with the statistical program package SAS.

RESULTS AND DISCUSSION

Shoot growth of *Achyranthes japonica* and *Oenothera biennis* treated with aqueous extracts of Sangpaedong and Kyongseodong landfill soils was significantly higher than those treated with distilled water (Figure 1-I and 1-III; $P < 0.01$). At root growth of *Lotus corniculatus* var. *japonicus*, individuals treated with aqueous extracts of Sangpaedong and Kyongseodong landfill soils were significantly higher than those treated with distilled water, showing 3.9 – 7.8 mm differences (Figure 1-II; $P < 0.01$). NH_4^+, Al, As, Fe and Mn contents of aqueous extracts of Kyongseodong landfill soils were significantly higher than that of aqueous extracts of Sangpaedong landfill soils ($P < 0.05$; Table 1). NO_3^- and SO_4^{-2} contents of aqueous extracts of Sangpaedong landfill soils were 5.9 and 7.1 times higher than those of aqueous extracts of Kyongseodong landfill soils, respectively ($P < 0.05$; Table 1). When shoot and root growth of each tested plant treated with aqueous extracts from Sangpaedong and Kyongseodong landfill soils were expressed as percentage of the control growth provided with distilled water, all shoot growth of four species were greater than control growth whereas root growth of three other species, except *Lotus corniculatus* var. *japonicus*, were depressed by aqueous extracts from Sangpaedong landfill soils and root growth of three other species, except *Rumex japonica*, were facilitated by aqueous extracts from Kyongseodong landfill soils (Table 2). Germination rate can be an indicator of measuring environmental impacts of plants (Vasseur et al. 1998). But, germination of the seeds of plants collected in the landfills was not affected in these treatments in this study. NO_3^-, necessary element for plants and growth post germination, is reported to accelerate germination of seeds (Bell et al. 1999). Root

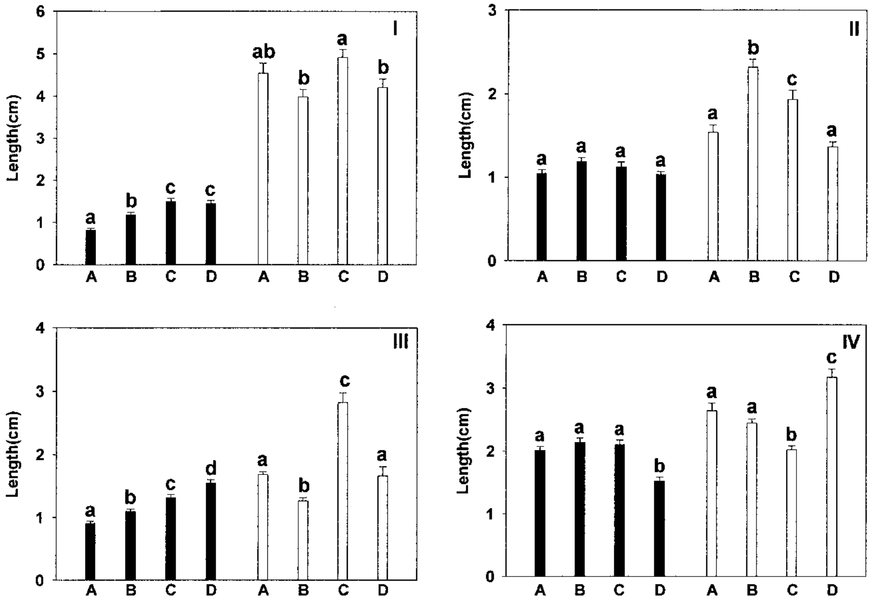

Figure 1. Shoot and root length of *Achyranthes japonica* (I), *Lotus corniculatus* var. *japonicus* (II), *Oenothera biennis* (III) and *Rumex japonica* (IV) treated with distilled water (A), aqueous extracts from Sangpaedong landfill soils (B), aqueous extracts from Kyongseodong landfill soils (C) and Hoagland solution (D). Black and white rod represent shoot and root length, respectively. Dissimilar letters above the bar indicate significant differences within each treatment using Tukey-Kramer procedure for shoot and root length ($n = 64$; $P < 0.01$).

growth of *Lotus corniculatus* var. *japonicus* provided aqueous extracts of Sangpaedong landfill soils was enhanced compared to the other three species due to nitrate ion (Figure 1-II; Table 2). Aqueous extracts of Sangpaedong landfill soils, 8 months old after closure, have significantly higher NO_3^- and SO_4^{-2} contents than those of Kyongseodong landfill soils (Table 1). At sampling, Sangpaedong landfill was in the stage of waste landfilling. Therefore, waste decomposition solution may impact soil chemical characteristics. One evidence is that waste decomposition solution has much total-nitrogen and SO_4^{-2} contents (Ettala et al. 1988). Kinds of waste, landfill methods, sampling methods, site and landfill age will influence the chemical contents of leachate. The concentrations of organic compounds from BOD and COD analyses were similar to those ofstream samples (Kaur et al. 1996). They seemed to be too small to stimulate plant growth due to the natural dilution from precipitation (Table 1). Compared with other countries, the leachate of study sites had much higher K, Na, Cl and NH_4^+ contents (Ettala et al. 1988). Aqueous extracts of Kyongseodong landfill soils having higher Al, As, Fe and Mn contents could inhibit root growth of *Rumex japonica* (Figure 1-IV; Table 2). So, there was a significant decrease in

Table 1. The chemical properties of aqueous extract of landfill soils, landfill leachate and Hoagland solution. Values represent means ± SE (n = 5).

Parameters Analyzed	Sangpaedong landfill aqueous extract	Kyongseodong landfill aqueous extract	Hoagland Solution
pH	7.17^{a}±0.07	7.31^{a}±0.02	5.15±0.02
BOD_5 (mg/L)	10.0^{a}±3.2	8.0^{a}±2.4	N.D.
COD (mg/L)	22.43^{a}±4.27	19.20^{a}±5.48	N.D.
EC (dS/m)	0.30^{b}±0.01	0.11^{a}±0.01	2.09±0.49
K (mg/L)	13.90^{a}±0.89	33.90^{a}±26.95	94.04±45.80
Na (mg/L)	15.76^{a}±1.28	25.58^{a}±15.33	8.71±2.27
Ca (mg/L)	24.53^{a}±4.27	16.20^{a}±9.17	71.47±36.12
Mg (mg/L)	5.00^{a}±0.30	17.42^{a}±14.27	14.91±2.66
Cl (mg/L)	11.25^{a}±0.21	7.23^{a}±2.42	2.89±0.29
F (mg/L)	1.31^{a}±0.02	1.29^{a}±0.01	N.D.
NH_4^+ (mg/L)	2.12^{b}±0.25	4.68^{a}±1.19	0.75±0.16
NO_3^- (mg/L)	38.38^{b}±1.34	6.49^{a}±0.17	95.03±19.37
PO_4^{-2} (mg/L)	0.23^{a}±0.01	0.51^{a}±0.17	31.78±0.16
SO_4^{-2} (mg/L)	26.61^{b}±1.78	3.76^{a}±0.63	181.99±1.79
Al (mg/L)	1.29^{b}±0.56	45.00^{a}±20.51	0.09±0.00
As (mg/L)	0.02^{b}±0.00	0.21^{a}±0.09	0.04±0.00
B (mg/L)	0.08^{a}±0.02	0.07^{a}±0.01	0.50±0.02
Fe (mg/L)	0.96^{b}±0.39	21.35^{a}±8.60	2.65±0.19
Mn (mg/L)	0.02^{b}±0.01	0.50^{a}±0.24	0.42±0.00

Dissimilar superscript letters means significant differences between Sangpaedong and Kyongseodong landfill sites from Kolmogrov-Smirnov Test (P < 0.05); BOD_5: Biochemical Oxygen Demand in Five Days; COD: Chemical Oxygen Demand; EC: Electric Conductivity; N.D.: Not Detected.

Table 2. Growth of shoot and root length of *Achyranthes japonica* (I), *Lotus corniculatus* var. *japonicus* (II), *Oenothera biennis* (III) and *Rumex japonica* (IV) treated with aqueous extracts from Sangpaedong landfill soils and aqueous extracts from Kyongseodong landfill soils relative to controls treated with distilled water.

Landfill soils	Shoot [%, relative to controls]				Root			
	I	II	III	IV	I	II	III	IV
Sangpaedong	143	113	121	106	87	150	74	92
Kyongseodong	182	107	145	104	108	125	167	76
Control	100	100	100	100	100	100	100	100

root growth compared to the other three treatments. Osmotic inhibition from high cation contents such as K and Ca and high anions contents like nitrate and sulfate in Hoagland solution seems to show abnormal growth pattern of depressed shoot growth and extravagant root growth of *Rumex japonica* (Figure 1-IV). Shoot and root growth treated with aqueous extracts of landfill soils showed different trends according to species but, with an exception of the case of *Rumex japonica* where shoot growth of seedlings treated with aqueous extracts of landfill soils was nearly similar to that treated with distilled water, shoot growth of *Achyranthes japonica*, *Lotus corniculatus* var. *japonicus* and *Oenothera biennis* was presumed to be enhanced by aqueous extracts of landfill soils (Table 2). In the case of root growth, this study shows different patterns according to species and sources of aqueous extracts of landfill soils (Table 2). The growth and distribution of plants in nonsanitary landfills can reflect the impacts of these elements if these chemicals concentrate locally. The conspicuously aggregated patches of grass population on nonsanitary waste landfills may reflect the distinct distribution of these soil chemicals.

Acknowledgments. I thank Ms. So-Young Choe for her assistance in the field.

REFERENCES

APHA (1989) Standard methods for the examination of water and waste water, 17th ed. American Public Health Association, Washington DC

Bell DT, King LA, Plummer JA (1999) Ecophysiological effects of light quality and nitrate on seed germination in species from Western Australia. Australian J Ecol 24:2-10

Chan YSG, Wong MH, Whitton BA (1999) Effects of landfill leachate on growth and nitrogen fixation of two leguminous trees (*Acacia confusa*, *Leucaena leucocephala*). Water Air Soil Pollut 111:29-40

Ettala M, Rahkonen P, Kitunen V, Valo O, Salkinoja-Salonen M (1988) Quality of refuse, gas and water at a sanitary landfill. Aquat Fenn 18:15-28

Fisher E, Thornton B, Hudson G, Edwards AC (1998) The variability in total and extractable soil phosphorus under a grazed pasture. Plant Soil 203:249-255

Kaur R, Buckley B, Park SS, Kim YK, Cooper KR (1996) Toxicity test on Nanji island landfill (Seoul, Korea) leachate using Japanese Medaka (*Oryzias latipes*) embryo larval assay. Bull Environ Contam Toxicol 57:84-90

Maurice C, Ettala M, Lagerkvist A (1999) Effects of leachate irrigation on landfill vegetation and subsequent methane emissions. Water Air Soil Pollut 113:203-216

Namgung W (1992) The criterion of sites selection for waste landfill. The Korean Society of Environmental Science Research, Seoul, p 141

Page AL, Miller RH, Keeney DR (1982) Methods of soil analysis, part 2, Chemical and microbiological properties. American Society of Agronomy, Inc. and Soil Science Society of America, Inc, Madison

Vasseur L, Fortin MJ, Cyr J (1998) Clover and cress as indicator species of impacts from limed sewage sludge and landfill wastewater land application. Sci Total Environ 217:231-239

Yi JH, Moon DH, Kim JW (2000) The composition and physicochemical characteristics of MSW treated in Sudokwon landfill. J Korean Solid Wastes Eng Soc 17:363-369