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Full Length Research Paper

Physical, chemical and biochemical properties of soil in a Korean landfill

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The objective of the present study was to examine the following aspects of soil environment in a landfill site: soil respiration and physical, chemical and biochemical properties. The K-Bad and Y-Bad sites showed lower soil respiration and higher soil temperature than the K-Good and Y-Good sites. The study results showed that increasing soil temperature up to 30℃ was very closely related with increasing soil respiration; however, soil respiration decreased over 30℃. Dehydrogenase activity increased with increasing organic carbon content. Dehydrogenase and phosphatase activities reacted sensitively to fluctuations in soil temperature. We considered that the high temperature obstructed the root growth and microbial activities. In the terrestrial ecosystem cycle, these results can have an indirectly negative effect on plant growth, by putting down roots and germination of other plant species, and have a direct effect on soil fertility for a long time.

Key words: Korea, dehydrogenase, landfill, physical characteristics, phosphatase, soil enzymes.

INTRODUCTION

Tree establishment and growth at landfill sites are potentially affected by many environmental factors, as investigated in a number of studies (Chan et al., 1997; 1998). The factors limiting good growth include the toxicity of landfill generated gases (CO_2 and CH_4) to root systems, low soil oxygen supply, thin cover soil, low nutrient status, low water holding capacity, low soil moisture, high soil temperature, high soil compaction, poor soil structures and sensitive plant species. Therefore, their soil properties and physical traits vary.

Various pollutants are also known to affect the metabolic activity of soil. Nevertheless, the relation between the plant physiology of the ground and soil biochemistry has rarely been studied (Schinner et al., 1996; Van Beelen and Doelman, 1997; Margesin et al., 2000).

Korea has approximately 1,170 closed domestic waste landfills and 232 active domestic landfills (Ministry of Environment, 2003). Modern landfill sites are designed and engineered to control leachates and gases, while legislation and planning regulations also define the criteria for site restoration and after-use. Prior to the 1980s, however, land filling was far less stringently regulated. Post-closure restoration received less attention, many sites were inadequately capped, and soil cover was minimal and came at random. These factors were affected by numerous environmental factors, such as the establishment and growth of plants. Sudokwon landfill site, located near Seoul in a new town in the province of Incheon, is the largest one (19.9 km^2) in Asia. Its use has therefore been subjected to various demands of the residents from many points of view. The ‘Sudokwon’ landfill site management is trying to ensure that it plays an important role, not only as a place for waste reclamation but also as a leisure venue with the establishment of rest areas within the landfill.

The objective of the present study was to examine the soil environment such as soil respiration, and the physical, chemical and biochemical properties in the landfill site.

MATERIALS AND METHODS

Site description

Sudokwon landfill site is located in Baegseugdong, Seogu, in the province of Incheon, Korea at latitude 37°33′ to 37°37′ N and

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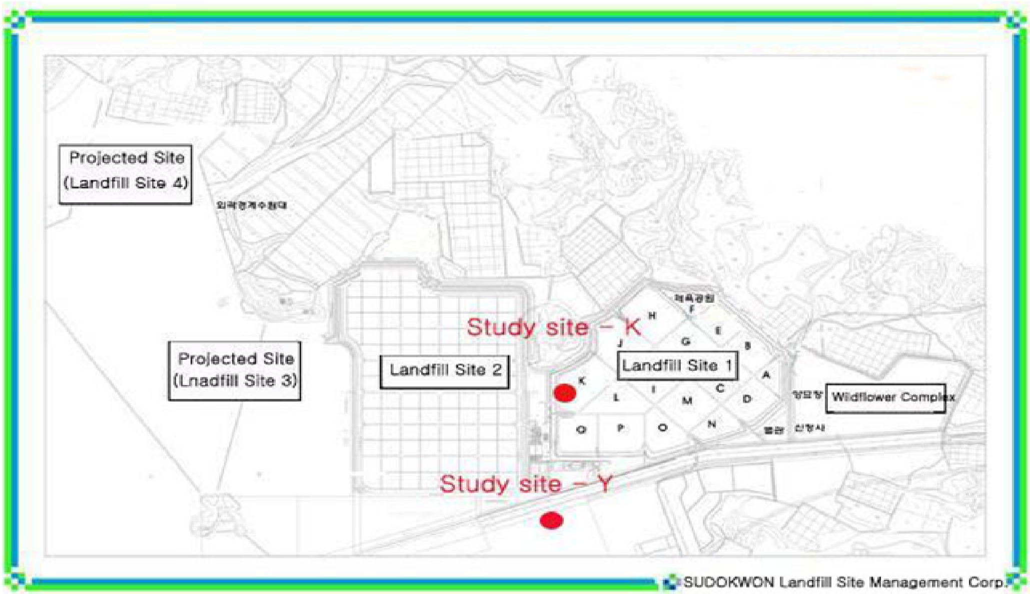

Figure 1. Description of the study area in Sudokwon landfill site.

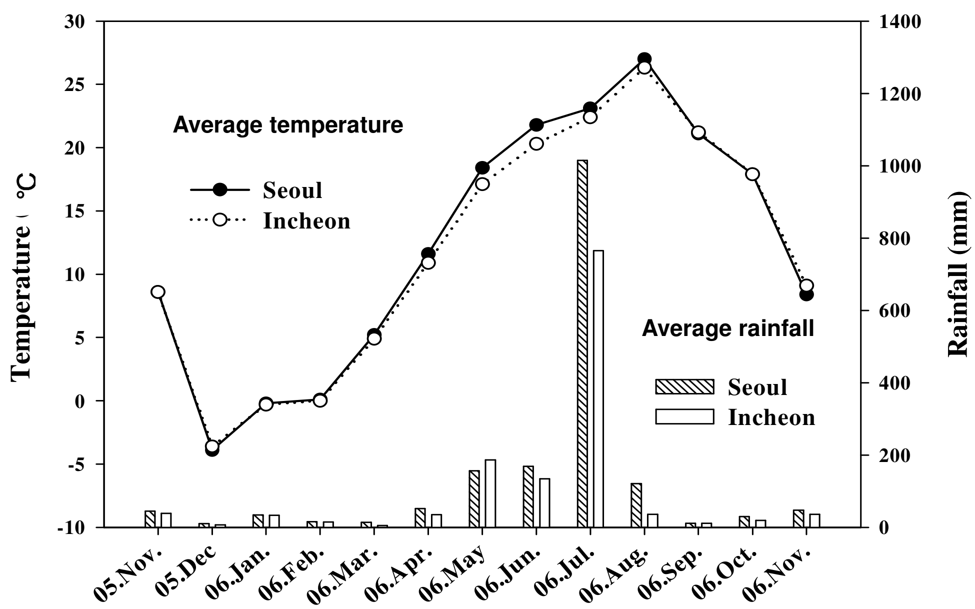

Figure 2. Monthly rainfall and mean temperature during the trial period (from November 2005 till November 2006) both in Seoul (control site) and in Incheon (landfill site).

longitude 126°36′ to 126°40′ E. The landfill is comprised of three sites: the first is land reclaimed from February, 1999 to October, 2000, the second from October, 2000 up to now, and the third is land that will be reclaimed from 2010 (Figure 1). The first landfill site will be used for various sports facilities such as public golf course, scenic observation park, trekking course, community sports facility and parking lot. Our research was conducted in the first landfill site, and in two control sites (Mt. Baebong and a tree planting site on school) located at the University of Seoul in Dongdaemun-gu, Seoul, Korea. Their general weather conditions were very similar (Figure 2).

Experimental design

Site selection was based on the visible state of the trees in the planting area in the landfill. Of the sites selected, K site (a waste landfill) and Y site (land reclaimed from the sea), both were divided

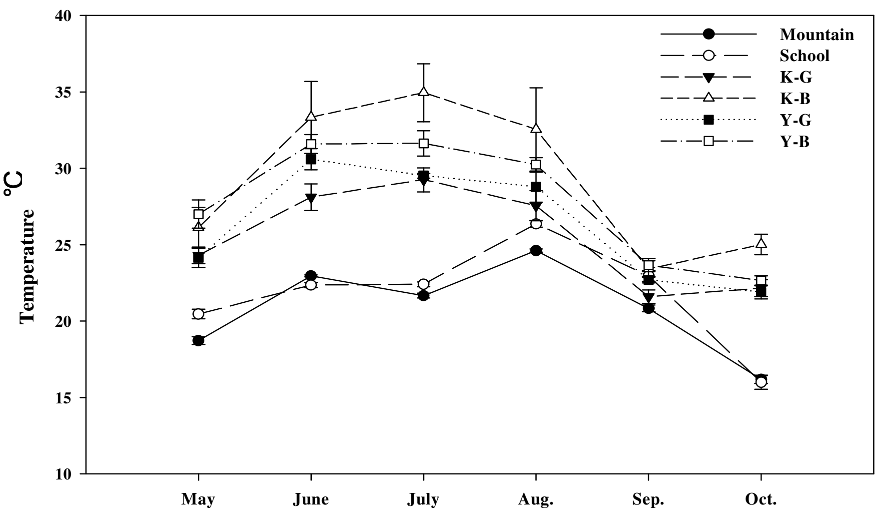

Figure 3. Seasonal change of soil temperature in each site (K-G: K-good, K-B: K-bad, Y-G: Y-Good, Y-B: Y-Bad in landfill). Error bars represent standard errors.

into two areas with good (designate as Good site) or bad (designate as Bad site) tree growth. As control, two sites were selected in the University of Seoul: Mt. Baebong (nearby school) and a tree planting site on school. At each site, either three or four replicate experimental plots were established (each 1 × 1 m) (Figure 3).

Tree species in study area

The main species were legume (*Robinia pseudoacacia* and *Lespedeza bicolor)* and Salix *(Salix koreensis)* species. Among them, *R. pseudoacacia* and *S. koreensis* were the major tree species in both K and Y sites. Except *Laccaria bicolor*, other species had been introduced from a seed bank in those two sites.

Soil respiration and temperature

Soil CO_2 efflux was measured using a transient gas exchange system (LI-6400, Licor, Lincoln, NE, USA) equipped with a soil CO_2 flux chamber. Measurements were collected from permanently located, 10 cm diameter, 5 cm long, PVC plastic rings inserted 1 cm into the mineral soil. Monthly measurements were taken from each plot. Readings for both plantations were collected within 2 h of solar noon on the same day.

Soil temperature at 15 cm depth was recorded for each measurement using a temperature probe attached to the Licor chamber. Chamber CO_2 concentration was drawn down using the scrub circuit of the Licor.

During each measurement, six flux rate estimates were collected as the CO_2 concentration in the chamber rose from below and passed above the ambient surface concentration. The first interval was discarded to avoid instability, and the three remaining intervals were averaged and measurement points were replicated seven to eight times at each site.

Preparation of soil sample

Soil samples were sealed in air-tight plastic bags after collection and transported to the laboratory from the site. For analysis of the soil chemical properties, the samples were air-dried and crushed to pass through a 2 mm sieve and kept in a dry place.

Soil moisture content

Surface soil (5 to 8 cm) samples were taken from each site with cores, brought to the laboratory, weighed, oven-dried at 105°C, and weighed. The soil moisture content was calculated as follows:

M. C. (%) = [(wet weight of sample (g) – dry weight of sample (g)) / Dry weight of sample (g)] × 100

Chemical properties

Electrical conductivity (EC) and pH, organic carbon (OC), avail-P, total nitrogen (Total N), exchangeable Na content and cation exchange capacity (CEC) were measured for the soil samples.

The pH and EC in water at 1:5 ratio were measured using a pH meter (Metter Toledo, USA) and an EC meter, respectively. OC content was determined by dichromate oxidation (Nelson and Sommers, 1996). Total N was measured by the Kjeldahl method (Kjeldahl 2300, FOSS, Sweden). The available phosphorus was analyzed by the Bray No. 1 method (Kuo, 1996). The exchangeable Na (Helmke and Sparks, 1996) and CEC (Sumner and Miller, 1996) were determined using the 1 N CH_3COONH_4 method and the official fixture method (Ministry of Environment, 1996), respectively.

Biochemical properties (dehydrogenase and phosphatase)

Dehydrogenase activity

Dehydrogenase activity was determined by the 2,3,5,-triphenyltetrazolium chloride (TTC) method. A 6 g soil sample, including 1% $CaCO_3$, was treated with 3 ml of 3% TTC and 2.5 ml of distilled water, and then incubated for 24 h at 37°C. The sample was then extracted with 10 ml of methanol prior to filtration using ashless filter paper (Whatman number 42). Triphenyl formazan (ED unnecessary acronym as it is not used anywhere in the paper) was

Table 1. Physico-chemical properties of the soils used in this study.

	OC	T-N	C/N	Avail-P	Exch-Na	CEC	pH	EC	Soil texture
	(%)			(cmol kg^{-1})				(dS· m^{-1})	
Mountain	2.76	0.16	17.1	9.5	11.5	12.1	4.2	45.2	Sandy loam
School	1.41	0.11	12.9	101.7	7.5	13.9	5.4	23.1	Sandy loam
K - Good	0.26	0.03	10.1	30.9	8.5	10.3	6.8	36.5	Sandy loam
K - Bad	0.32	0.03	11.6	7.8	18.7	16.3	7.1	56.4	Clay loam
Y - Good	0.73	0.03	21.9	4.1	97.5	9.7	7.2	55.7	Sandy loam
Y - Bad	0.40	0.04	10.6	5.8	299.2	7.3	8.5	177.8	Loamy sand

OC: organic carbon content; T-N: total N content; C/N: ratio of organic carbon and total N content; Avail-P: available P content; Exch-Na: Exchangeable Na content; CEC: cation exchange capacity; EC: electrical conductivity, Mountain: Mt. Baebong; School: school in University of Seoul; K-Good, K-Bad, Y-Good and Y-Bad: landfill sites.

used as the standard solution. The solution's absorbance was read at 485 nm with a UV-spectrophotometer (Gong, 1997; Park, 1998).

Phosphatase activity

A 1 g sample of each soil was added to 4 ml of modified universal buffer (MUB, pH 6.5), 0.2 ml of toluene and 1 ml of p-nitrophenyl phosphate solution, and the mixture was incubated at 37℃. After 1 h, 1 ml of 0.5 M calcium chloride and 4 ml of 0.5 M sodium hydroxide was added, swirled for a few seconds, and filtered through a Whatman number 2 filter. The solution's absorbance was read at 400 nm with a UV-spectrophotometer (Tabatabai and Bremner, 1969). The p-nitrophenol content was calculated by referring to a calibration curve obtained with standards containing 0, 10, 20, 30, 40 and 50 ppm of p-nitrophenol.

RESULTS AND DISCUSSION

Soil properties

Rhizodeposition is the soil OC derived from the turnover of fine roots, root hairs and mycorrhizae, secretion of soluble root exudates, and turnover of rhizosphere-associated microbial biomass. OC and total N contents were much lower in soil from landfill sites than in soils from the control sites (Table 1). Nitrogen is one of the main limiting factors of litter decomposition. It determines the microbial activity and influences the mineralization of OC. The exchangeable Na content of the soil markedly was significantly higher in Y-Bad and showed a distinct difference between Good and Bad in the landfill site. It was the same result reported by Hernández et al. (1999). The avail-P content in the soil from the control site on school showed the highest value. K-Good soil had a higher avail-P content than K-Bad soil, whereas Y-Good soil had a lower value than Y-Bad soil. Usually, the C:N ratio is assumed to be a key determinant of N release for a wide range of organic residues (Seneviratne, 2000).

The C:N ratio in the control sites was higher than that in the landfill site, except for Y-Good, in which the C:N ratio was similar with that of the control sites. Soil texture strongly mediates plant water availability through its control of the soil hydraulic characteristics (Hacke et al., 2000; Sperry and Hacke, 2002).

On the whole soil texture was sandy loam except for K-Bad and Y-Bad, which were clay loam and loamy sand respectively. Coarser textured soils have larger pores and higher saturated conductivity than finer textured soils (Jury et al. 1991). Therefore, K-Bad was considered to have poor drainage. Landfill gas, especially methane, has indirect effects on vascular plants; however, it can reduce O_2 in the rhizosphere by direct displacement, utilization of the O_2 by methane-consuming bacteria, or a combination of both (Leone et al., 1977). Wong and Yu (1989) detected a high level of ammonia nitrogen in landfill areas, represented by high level of methane.

Soil respiration

Soil respiration exhibited seasonal variation (Figure 4). The soil respiration peaked in July and August in the Good sites, due to both the maximum solar irradiance and the long period of high air and soil temperatures in July and August, as reported in Högberg et al. (2001) and Bhupinderpal-Singh et al. (2003). However, K-Bad and Y-Bad sites in July had a slight decreasing tendency. Among the landfill sites, K-Good and Y-Good had a drastic decrease with seasonal changes. They showed very sensitive changes following climate changes and a higher respiration than other sites. Soil respiration is closely coupled to photosynthesis and the subsequent photosynthate translocation to the roots. Half or more of soil respiration is based on the respiration of newly produced photosynthates by roots, ectomycorrhizal fungi

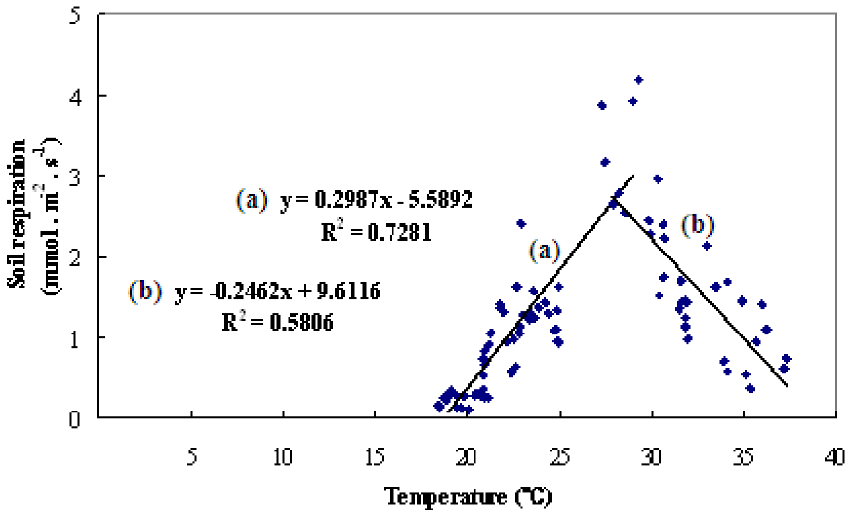

Figure 4. Soil respiration response to soil temperature.

and rhizosphere organisms (Ekblad and Högberg, 2001; Högberg et al., 2001), and the rest on the decomposition of soil organic matter by soil heterotrophs.

Generally, root respiration accounts for 33 to 60% of total soil respiration (Anderson, 1992; Bowden et al., 1993), and consumes 8 to 52% of the carbon fixed by photosynthesis (Lambers et al., 1996). It is reasonable to expect a level of belowground activity because the growth and maintenance of roots has a large influence on soil CO_2 efflux.

Soil temperature

In general, the soil temperature increased from May to July and followed the overall seasonal changes. The landfill sites, K and Y, had a higher temperature than the two control sites (Mountain and School). Especially, K-Bad and Y-Bad, this had a high temperature, showed a clear difference from K-Good and Y-Good, respectively. This difference was strongest in the summer season, from June to August.

Peng and Dang (2003) suggested that soil temperature significantly affected root biomass, foliage biomass, stem biomass and total mass of the seedling, and the relation between biomass and soil temperature was modeled using third-order polynomials. Root respiration is connected with soil respiration (Ekblad and Högberg, 2001; Högberg et al., 2001). Therefore, we considered the relations between soil temperature, soil respiration and root vitality. The temperature and soil respiration were positively correlated until 28~29℃ (r^2=0.7281), but negatively correlated as the temperature increased over 30℃ (r^2=0.5806) (Figure 4).

Soil respiration is generally more sensitive to variation in soil temperature at low temperatures, but less so at high temperatures (Lloyd and Taylor, 1994; Qi et al., 2002; Sjögersten and Wookey, 2002; Rey et al., 2002). Nevertheless, soil temperature does not exert a major influence on soil respiration, which is related to various rhizosphere conditions, including root respiration, mycorrhizal respiration, and nitrogenase activity. Root respiration, which accounts for 33~60%, or more than soil respiration, is influenced by various environmental factors, including temperature, moisture, and nutrients (Zogg et al., 1996; Atkin et al., 2000; Bryla et al., 2001). Many researchers suggested that the sensitivity of root respiration decreases with increasing temperature, due to the shift from an enzyme capacity limitation at low temperature to a substrate limitation at high temperature (Atkin et al., 2000; Atkin and Tjoelker, 2003).

Soil moisture

Soil moisture peaked in June with low values at the beginning and end of the growing season. Soil moisture content was in the range of 5~20% (Figure 5). Y-Bad showed the highest moisture content. This result, however, was not significantly different from that of the Mountain control site and Y-Good. Although, there were no significant differences, the mean values were higher in Y-Bad than in Y-Good site. K-Good and K- Bad exhibited a similar tendency. Fluctuations in soil temperature and soil moisture were closely linked (Lloyd and Taylor, 1994; Qi et al., 2002), but those two factors have rarely been studied together.

Soil moisture affects root physiology not only directly but also indirectly, by influencing the soil thermal properties. Thus, dry soil typically exhibits wider fluctuation in daily temperature than wet soil does. Root respiration decreases as soil moisture is depleted (Burton

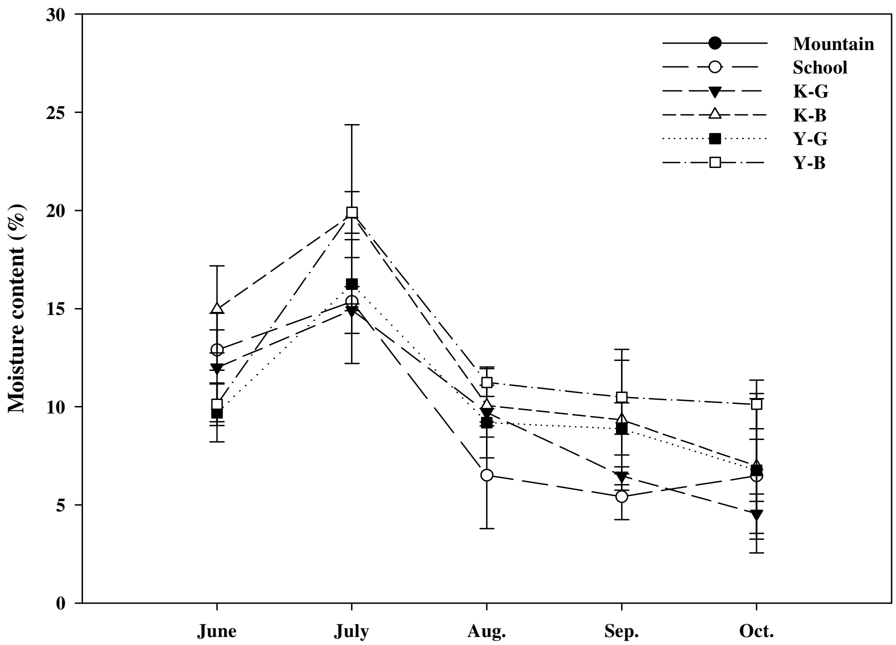

Figure 5. Seasonal change of soil moisture content in each site (K-G: K-good, K-B: K-bad, Y-G: Y-Good, Y-B: Y-Bad in landfill). Error bars represent standard.

et al., 1998; Huang and Fu, 2000; Bryla et al., 2001). Huang et al. (2005) reported that under moist soil conditions, root respiration increased exponentially with increasing temperatures between 10 and 33°C, but only negligibly between 33 and 38°C. In our study, soil moisture content was relatively higher in Bad sites than in Good sites of both K and Y sites, while soil respiration was not higher in Bad sites than in Good sites. These results indicated that increasing soil temperature affected the soil respiration more than the soil moisture.

Dehydrogenase activity

Soil enzymes integrate information on soil microbial status and soil physicochemical conditions and thus are a useful sensor to study the effects of environmental changes of soil fertility (Kandeler et al., 1999; Baum et al., 2003). In the present study, dehydrogenase and acid phosphatase activities were measured because they are indicators of microbial activity and P mineralization.

The dehydrogenase assay is used as a sensitive indicator of environmental stress and may be useful to assess microbial activities in soil amended with organic residues, composted municipal solid wastes, and sewage sludge for beneficial use in the environment (Albiach et al., 2000; García-Gil et al., 2000; Yang et al., 2003; Dungan et al., 2006). Soil dehydrogenase activities are intracellular enzymes involved in microbial respiratory metabolism and are thus considered to reflect the total viable microbial population and microbiological activity. Dehydrogenase activity was higher in both control sites than in any of the landfill sites. Among the landfill sites, Y site had higher activity than K site (Figure 6).

The Good sites had higher dehydrogenase activities than the Bad sites of K and Y. Overall, they exhibited seasonal changes, with the activity increasing throughout the growing seasons, especially in June. Dehydrogenase activity increased the same as the increase in soil respiration reported in Margesin et al. (2000). These results corresponded with the seasonal changes. The increase in soil water and temperature induced higher dehydrogenase activities (Görres et al., 1998). We considered that the release of organic compounds influenced the soil microbial biomass (Table 1). The soil microbial biomass is the driving force in nutrient cycling and soil organic matter decomposition. The microbial population size and activity in soils are related to organic matter and available nutrient contents (Leirós et al., 2000; Zeller et al., 2001). However, the increase in K-Good despite the low organic matter content indicated that dehydrogenase was more closely correlated with plant cover, so that dehydrogenase activity decreased due to the decreased level of plant cover. On the other hand, Quilchano and Marañón (2002) suggested that nutrient supply and soil pH were better predictors of dehydrogenase than the amount and quality (based on its C:N ratio) of the soil organic matter. However, the pH and dehydrogenase activity showed little relation (Figure 6).

Quilchano and Marañón (2002) found a positive

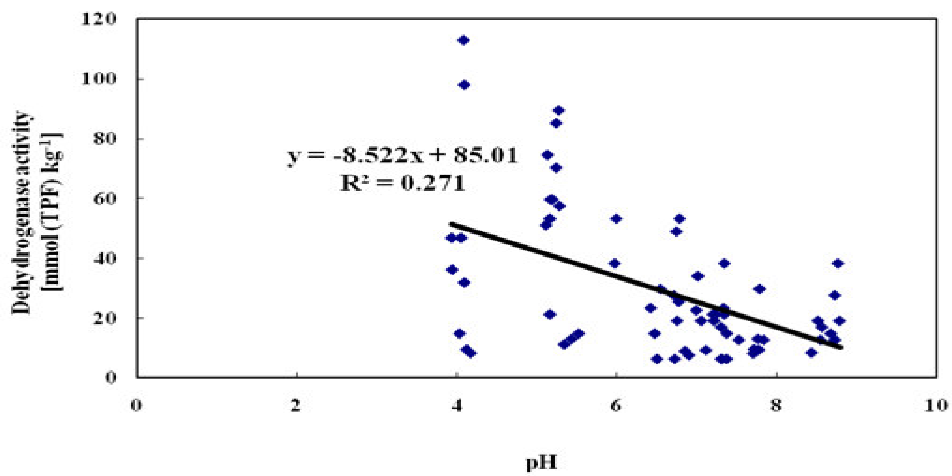

Figure 6. The relationship between pH and dehydrogenase activity.

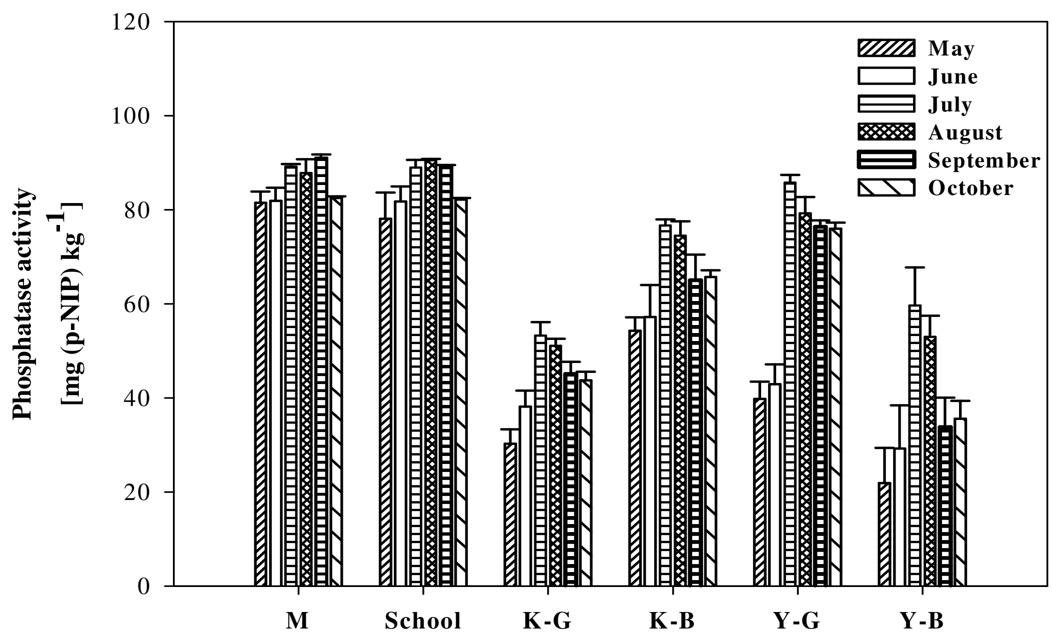

Figure 7. Seasonal change of phosphatase activity in each site (K-G: K-good, K-B: K-bad, Y-G: Y-Good, Y-B: Y-Bad in landfill). Error bars represent standard errors.

relation between clay content and dehydrogenase activity. Based on our results, we propose that organic matter and soil temperature may have greater importance in regulating dehydrogenase activity than pH and soil texture.

Phosphatase activity

Phosphatases are involved in the transformation of organic and inorganic phosphorus compounds in soil, and the phosphatase activity is an important factor in maintaining and controlling the rate of P cycling through soils. The various phosphatases involved in P transformation include phosphomonoesterase, inorganic pyrophosphatase and phosphodiesterase. From two phosphomonoesterases, acid phosphomonoesterase and alkaline phosphomonoesterase, we studied the action of the acid phosphatase enzyme in catalyzing the mineralization of organic P to inorganic P.

Similar to dehydrogenase activity, phosphatase activity fluctuated seasonally (Figure 7). The increase in soil water and temperature in summer increased the microbiological activity (Li and Sarah, 2003; Sardans and

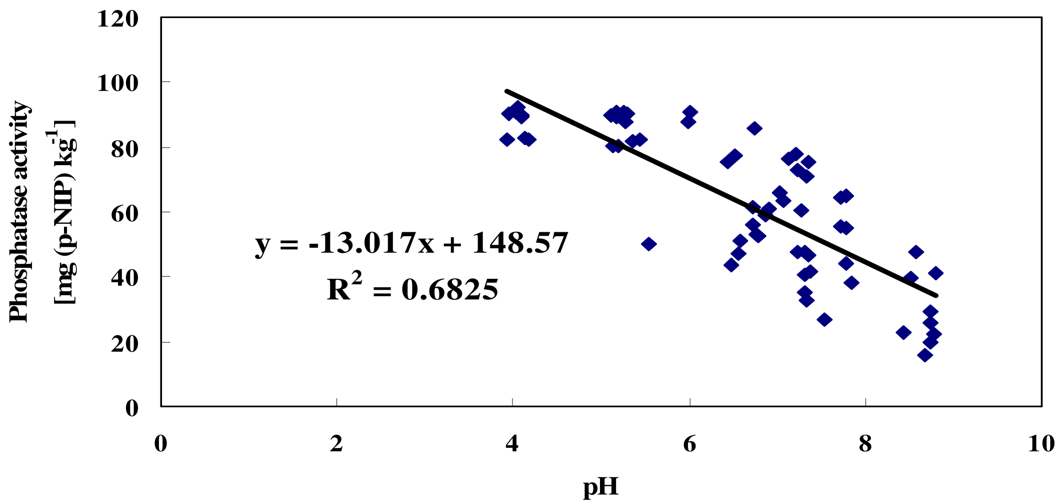

Figure 8. The relationship between pH and acid phosphatase activity.

Peñuelas, 2005). However, phosphatase activity was less sensitive to seasonal changes than dehydrogenase activity. Overall, the two control sites had higher phosphatase activity than the landfill sites (K and Y sites).

On the other hand, contrary to dehydrogenase activity, phosphate activity had no relation to soil respiration in K-site (Figure 8). These results indicated that phosphatase activity was considerably correlated with P supply (Table 1). Several studies have shown that phosphatase activity was enhanced at low P supply (Kamh et al., 2002; Lizarazo et al., 2005). A negative correlation between this enzyme activity and the amount of P was expected because the synthesis of this enzyme was repressed by inorganic P in the soil (Nannipieri et al., 1990). However, our study results showed the opposite. Although, the two control sites had higher P contents than the landfill sites, they had higher phosphatase activity than the landfill sites. This apparent discrepancy (with increasing P content, increasing phosphatase activity for the two control sites but decreasing phosphatase activity for the landfill sites) could be explained by the soil pH. Acid phosphomonoesterase is predominant in acid soils, and alkaline phosphomonoesterase is predominant in alkaline soils (Eivazi and Tabatabai, 1977).

The optimal pH for acid phosphomonoesterase activity and for alkaline phosphomonoesterase is around 6.5 and 11, respectively (Tabatabai and Bremner, 1969; Eivazi and Tabatabai, 1977; Sardans and Peñuelas, 2005). These optimum pH values may vary depending upon the origin of the enzyme and soil microbial community structure.

Conclusion

Based on the study results, K-Bad and Y-Bad sites showed lower soil respiration and higher soil temperature than K-Good and Y-Good sites. Dehydrogenase activity increased with increasing OC content. The dehydrogenase and phosphatase activities were sensitively affected by fluctuations of soil temperature. We considered that the high temperature obstructed root growth and microbial activities.

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REFERENCES

Albiach RR, Canet F, Pomares F, Ingelmo F (2000). Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. Bio. Technol., 75: 43– 48.

Anderson JM (1992). Responses of soils to climate change. Adv. Ecol. Res., 22: 163–210.

Atkin OK, Edwards EJ, Loveys BR (2000). Response of root respiration to changes in temperature and its relevance to global warming. New Phytol., 147: 141-154.

Atkin OK, Tjoelker MG (2003). Thermal acclimation and the dynamic response of plant respiration to temperature. Trends Plant Sci., 8: 343-351.

Baum C, Leinweber P, Schlichting A (2003). Effects of chemical and acid phosphatase activity within the growing season. Appl. Soil Ecol, 22: 167–174.

Bhupinderpal-Singh M, Mellander A, Nordgren A, Ottossonlöfventus A, Högberg MN, Mellander PE, Högberg P (2003). Tree root and soil heterotrophic respiration as revealed by girdling of boreal Scots pine forest: extending observation beyond the first year. Plant Cell Environ., 26: 1287-1296.

Bowden RD, Nadelhoffer KJ, Boone RD, Melillo JM, Garrison JB (1993). Contributions of above ground litter, belowground litter, and root respiration to total soil respiration in a temperate mixed hardwood forest. Can. J. For. Res., 23: 1402-1407.

Bryla DR, Bouma TJ, Hartmond U, Eissenstat DM (2001). Influence of temperature and soil drying on respiration of individual roots in citrus: intergrading greenhouse observations into a predictive model for the field. Plant, Cell and Environ., 24: 781-790.

Burton AJ, Prehitzer KS, Zogg GP, Zak DR (1998). Drought reduces root respiration in sugar maple forests. Ecol. Applic. 8: 771-778.

Chan YSG, Chu LM, Wong MH (1997). Influence of landfill factors on plants and soil fauna. Environ. Pollut., 97: 39-44.

Chan YSG, Wong MH, Whitton BA (1998). Effects of landfill gas on growth and nitrogen fixation of two leguminous trees (*Acacia confusa*, *Leucena leucocephala*). Water Air Soil Pollut., 107: 409-421.

Dungan RS, Kukier U, Lee B (2006). Blending foundry sands with soil: Effect on dehydrogenase activity. Sci.Total Environ. 57: 221– 230.

Eivazi F, Tabatabai MA (1977). Phosphatases in soils. Soil Biol. Biochem., 9: 167-172.

Ekblad A, Högberg P (2001). Natural abundance of ^{13}C of CO_2 respired from forest soils reveals speed of link between photosynthesis and root respiration. Oecol., 127:305-308.

García-Gil JC, Plaza C, Soler-Rovira P, Polo A (2000). Long-term effects of municipal solid waste compost application on soil enzyme activities and microbial biomass. Soil Biol. Biochem., 32: 1907-1913.

Görres JH, Dichiaro MJ, Lyons JB, Amador JA (1998). Spatial and temporal patterns of soil biological activity in a forest and an old field. Soil Biol. Biochem., 30: 219–230.

Gong P (1997). Dehydrogenase activity in soil: A comparison between the TTC and INT assay under their optimum conditions. Soil Biol. BiocheM., 29(2): 211-214.

Hacke UG, Sperry JS, Ewers BE, Ellsworth DS, Schafer KVR, Oren R (2000). Influence of soil porosity on water use in *Pinus taeda*. Oecol., 124: 495–505.

Helmke PA, Sparks DL (1996). Lithium, sodium, potassium, rubidium and cesium. p. 551-574. In: Sparks DL, Page AL, Helmke PA, Loeppert RH, Soltanpour PN, Tabatabai MA, Johnston CT, Sumner ME (ed) Methods of soil analysis part 3: chemical methods. SSSA book series 5. SSSA and ASA, Madison, WI, USA.

Hernández AJ, Adarve MJ, Gil A, Pastor J (1999). Soil salination from landfill leachates: Effects on the macronutrient content and plant growth of four grassland species. Chemos, 38(7): 1693-1711.

Högberg P, Nordgren A, Buchmann N, Taylor AFS, Ekblad A, Högberg MN, Nyberg G, Ottosson-Lofvenlus M, Read DJ (2001). Large scale forest girdling shows that current photosynthesis drives soil respiration. Nature, 411(14): 789-792.

Huang X, Lakso AN, Eissenstat DM (2005). Interactive effects of soil temperature and moisture on Concord grape root respiration. J. Exp. Bot., 56(420): 2651-2660.

Huang B, Fu J (2000). Photosynthesis, respiration and carbon allocation of two cool-season perennial grasses in response to surface soil drying. Plant Soil, 227: 17-26.

Jury WA, Gardner WR, Gardner WH (1991). Soil Physics. John Wiley, New York, USA.

Kamh M, Abdou M, Chude V, Wiesler F, Horst WJ (2002). Mobilization of phophorus contributes to positive rotational effects of leguminous cover crops on maize grown on soils from northern Nigeria. J. Plant Nutr. Soil. Sci., 165: 566-572.

Kandeler E, Luxhoi J, Tscherko D, Magid J (1999). Xylanase, invertase and protease at the soil–litter interface of a loamy sand. Soil Biol. Biochem., 31: 1171–1179.

Kuo S (1996). Phosphorus. p. 870-919. In: Sparks DL, Page AL, Helmke PA, Loeppert RH, Soltanpour PN, Tabatabai MA, Johnston CT, Sumner ME (ed) Methods of soil analysis part 3:chemical methods. SSSA book series 5. SSSA and ASA, Madison, WI, USA.

Lambers H, Atkin OK, Scheurwater I (1996). Respiratory patterns in roots in relation to their functioning. p 323-362. In: Waisel, Y., Eshel, A. and U. Kafkaki, eds. Plant roots. The hidden half, 2nd edn. New York, USA.

Leirós MC, Trasar-Cepeda C, Seoane S, Gil-Sotres F (2000). Biochemical properties of acid soils under climax vegetation (Atlantic oakwood) in an area of the European temperate humid zone (Galicia, NW Spain): general parameters. Soil Biol. Biochem., 32: 733–745.

Leone IA, Flower FB, Arthur JJ, Gilman EF (1977). Damage to woody species by anaerobic landfill gases. J. Arbor., 3: 221-225.

Li X, Sarah P (2003). Enzyme activities along a climatic transect in the Judean Desert. Catena, 53:349-363.

Lizarazo LM, Jordá JD, Juárez M, Sánchez-Andreu J (2005). Effect of humic amendments on inorganic N, dehydrogenase and alkaline phosphatase activities of a Mediterranean soil. Biol. Fertil. Soils, 42: 172-177.

Lloyd J, Taylor A (1994). On the temperature dependence of soil respiration. Func. Ecol., 8(3): 315-32.

Margesin R, Zimmerbauer A, Schinner F (2000). Monitoring of bioremediation by soil biological actibities. Chemosph, 40: 339-346.

Ministry of Environment (1996). Standard methods of soil analysis. Manual for soil environment conservation service (Government Reg. No. 12000-67630-67-9613). Ministry of Environment. Seoul, Korea.

Ministry of Environment (2003). The status of closed waste landfills. Ministry of Environment Materials. Ministry of Environment. Seoul, Korea.

Nannipieri P, Grego S, Ceccanti B (1990). Ecological significance of biological activity p 293–355. In: Bollag J-M, Stotzky G (eds) Soil biochemistry, vol 6. Dekker, New York, USA.

Nelson DW, Sommers LE (1996). Total carbon, organic carbon and organic matter. Agrono, 9: 961-1110.

Park H (1998). Investigation on forest soil dynamics at Onsan industrial estate and Mt. Mani by the assay of dehydrogenase activity, denitrifying and sulfur-reducing bacteria. J. Kor. For. Soc., 87(1): 106-112.

Peng YY, Dang QL (2003). Effects of soil temperature on biomass production and allocation in seedlings of four boreal tree species. For. Ecol. Manage., 180: 1–9.

Qi Y, Xu M, Wu J (2002). Temperature sensitivity of soil respiration and its effects on ecosystem carbon budget: Nonlinearity begets surprises. Ecol. Model., 153: 131-142.

Quilchano C, Marañón T (2002). Dehydrogenase activity in Mediterranean forest soils. Biol. Fertil. Soils, 35: 102-107.

Rey AE, Pegoraro A, Tedeschi V, De-Parri I, Jarvis PG, Valentini R (2002). Annual variation in soil respiration and its components in a coppice oak forest. Global Change Biol., 8: 851-866.

Sardans J, Peñuelas J (2005). Drought decreases soil enzyme activity in a Mediterranean *Quercus ilex* L. forest. Soil Biol. Biochem., 37: 455–461.

Schinner F, Hinger RO, Kandeler E, Margesin R (1996). Methods in Soil Biology, Springer Lab Manual. Springer, Berlin, Germany.

Seneviratne G (2000). Litter quality and nitrogen release in tropical agriculture: a synthesis. Biol. Fertil. Soils, 31: 60–64.

Sjögersten S, Wookey PA (2002). Climatic and resource quality controls on soil respiration across a forest-tundra ecotone. Soil Biol. Biochem., 11: 149-154.

Sperry JS, Hacke UG (2002). Desert shrub water relations with respect to soil characteristics and plant functional type. Funct. Ecol., 16: 367–378.

Tabatabai MA, Bremner JM (1969). Use of p-nitrophenyl phosphatase for assay of soil phosphatase activity. Soil Biol. Biochem., 1: 301-307.

van Beelen PV, Doelman P (1997). Significance and application of microbial toxicity tests in assessing exotoxicological risk of contaminants in soil and sediment. Chemosphere, 34: 455-499.

Wong MH, Yu CT (1989). Monitoring of Gin Drinkers' Bay Landfill, Hong Kong: Π. Gas Contents, Soil Propertied, and Vegetation Performance on the Side Slope. Environ. Manage., 13(6): 753-762.

Yang YJ, Dungan RS, Ibekwe AM, Valenzuela-Solano C, Crohn DM, Crowley DE (2003). Effect of organic mulches on soil microbial communities one year after application. Biol. Fertil. Soils, 38: 273–281.

Zeller V, Bardgett RD, Tappeiner U (2001). Site and management effects on soil microbial properties of subalpine meadows: a study of land abandonment along a north-south gradient in the European Alps. Soil Biol. Biochem., 33: 639–649.

Zogg GP, Zak DR, Burton AJ, Pregitzer KS (1996). Fine root respiration in northern hardwood forests in relation to temperature and nitrogen availability, Tree Physiol., 16: 719-725.