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Influences of Environmental Pollutants on Soil Ecosystems
– Soil Contaminations and Microbial Activity –

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환경오염물질이 토양 생태계에 미치는 영향
– 토양오염과 미생물 활성과의 관계 –

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ABSTRACT

The relationships among the contents of Pb, Zn, Cd, Cu and microbial biomass and activity of soil were investigated in Kyongbu, Yongdong, and Chungbu highways. The heavy metal concentrations were the highest in Kyongbu highway with high traffic density. The levels of these metals in soil in three highway sites were much higher than Mt. Kwanak as control site. The highest concentrations of heavy metals were found in the upper layer of soil adjacent to the roadside.

Dehydrogenase activity (DHA) and adenosine tri-phosphate (ATP) contents were generally lowest at distance of 0.5 m from the roadside. Simple regression analysis indicated that DHA and ATP contents were highly negatively correlated with Pb and Zn concentrations.

Key words: Adenosine tri-phosphate, Dehydrogenase activity, Heavy metals, Highway, Microbial biomass

INTRODUCTION

In Korea, the number of registered motor vehicles comes up to two million units, indicating one of the highest motor vehicle concentrations in the world. Even rural roads in agricultural areas have high traffic densities, leading to high heavy metal levels in nearby soil and vegetation. Soils near highway are heavily exposed to road traffic pollutants such as petroleum products combusted by motor vehicles. Lead, cadmium, carbon monoxide, sulphur dioxide, and hydrocarbon substance are released. Moreover,

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tetramethyl or tetraethyl lead were added to gasoline in order to increase its octane number. Eighty percent of all lead in the atmosphere comes from auto exhaust as Wilson (1985) suggested. Cadmium derives primarily from automobile tire whose Cd content varies (Lagerwerft and Specht 1970). The dynamics of Cd transport to soil and vegetation differ from those of Pb. Cd reaches to the soil mainly in runoff water and not through an aerial route. Twenty two percent of airborne copper comes from gasoline and about 31% from coal burning in Cleveland, Ohio, USA (Acres 1975). Even though in minute quantities, these metals can be harmful.

The effects of heavy metals on both environment and organism have been investigated in a considerable number of studies. These studies include the metal concentrations of soil (Moir and Thornton 1989, Tong 1990), the effect of heavy metals on plants, animals, or microorganisms (Berry 1985, Nordgren *et al*. 1988, Majdi and Persson 1989), interactions with enzymes or other elements in soil (Tate 1987, Kim *et al*. 1993), and metal tolerance of organisms (Tyler *et al*. 1989, Cho and Kim 1995).

The aim of present investigation, which was carried out along Kyongbu, Yongdong, and Chungbu highways, was to study levels of several heavy metal concentrations and microbial activity with different construction year and traffic density.

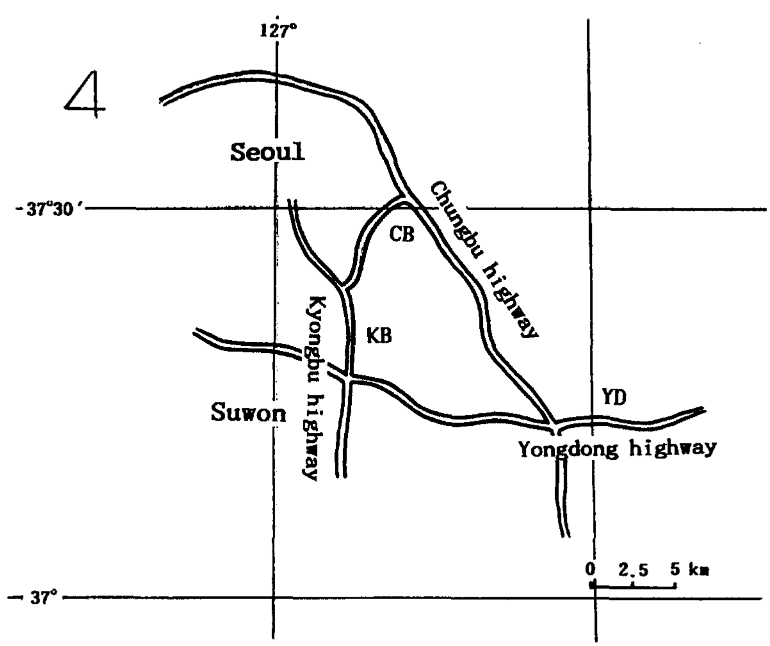

Fig. 1. Map showing sampling sites near Chugchun Serice Area (KB), Ich'on Interchange (YD), and the Plaza for Mannam (CB) of three highways.

MATERIALS AND METHODS

Study sites

The soil samples were collected from Kyongbu (KB), Yongdong (YD), and Chungbu (CB) highways in Oct. 1994. Sampling sites were near Chugchun Service Area (KB), Ich'on Interchange (YD), and the Plaza for Mannam (CB) of three highways (Fig. 1). KB between Seoul and Suwon was constructed in Dec. 1968, YD between Saemal and Kangnung in Oct. 1975, and CB between Hanam and Nami in Dec. 1987. The traffic densities of KD, YD, and CB are 69,113, 16,740, and 43,829 vehicles per day, respectively. The soil samples of Mt. Kwanak as the control site were collected to compare with three highway sites.

Soil sampling and analysis

The soil samples were collected along a transect perpendicular to the roadside at distance of 0.5, 10, and 100 m and soil depths of 0~5, 5~10 cm from the soil surface with 10 cm soil corer. The samples were placed in sterile plastic bags, and in the laboratory were unpacked and chopped under aseptic conditions and stored at 5℃ until needed for analysis of microbial biomass and activity. Subsamples of soil were taken for pH (ORION Model 520A), moisture content, and water holding capacity determinations. The remainder of the sample was air-dried, lightly ground with mortar, passed through a 5 mm stainless steel mesh sieve, and used for the analysis of extractable Pb, Zn, Cd, and Cu. The heavy metal concentrations were measured with atomic absorption spectrophotometer (Perkin Elmer 2380) by microwave digestion (CEM MDS-2000) twice in conc. HNO_3 and conc. HCl.

Measurement of microbial biomass and activity

Microbial biomass and activity were estimated by dehydrogenase activity (DHA) and adenosine 5'-triphosphate (ATP). DHA method used was the colorimetric determination of 2,3,5-triphenyl formazan (TPF) produced by reduction of 2,3,5-triphenyltetrazolium-chloride (TTC) by soil microorganisms (Tabatabai 1982).

ATP content as a means of estimating the microbial biomass was measured by the method of Inubushi *et al.* (1989). The soil samples were kept at 50% water holding capacity for 5 days at 24℃. ATP in soil was extracted by a trichloroacetic acid phosphate-paraquat reagent. The extractants were sonicated and filtered on ice. The soil extract /tris-EDTA buffer mixture was allowed to react with LUMIT luciferin-luciferase enzyme (Boehringer Mannheim Gmbh) and light output was determined by Auto Lumit LB 953. Three replicates were measured for each sample.

Analysis of variance between the heavy metal concentrations and microbiological characteristics was caried out by SAS Package.

Table 1. Mean values (±S.D.) of physicochemical characteristics of soils in the investigated sites with distance from roadside and depth

Site	Distance (m)	0.5		10		100	
	Depth (cm)	0~5	5~10	0~5	5~10	0~5	5~10
KB	pH	7.67±0.02	7.72±0.17	6.63±0.08	6.53±0.18	5.32±0.01	5.27±0.01
	MC(%)	13.27±0.64	14.30±1.08	11.13±0.99	16.07±2.23	15.80±0.40	15.57±0.87
	WHC(g/g)	0.45±0.16	0.48±0.18	0.33±0.08	0.70±0.18	0.43±0.08	0.48±0.09
YD	pH	8.40±0.03	8.11±0.08	4.58±0.09	4.46±0.03	4.96±0.03	4.89±0.01
	MC(%)	8.40±0.00	7.40±1.51	10.87±4.05	14.67±3.14	15.33±2.81	18.60±5.48
	WHC(g/g)	0.34±0.07	0.49±0.28	0.47±0.11	0.56±0.03	0.53±0.12	0.69±0.11
CB	pH	8.02±0.25	8.48±0.10	6.53±0.26	5.95±0.19	4.76±0.06	4.64±0.04
	MC(%)	18.27±2.12	16.60±2.08	19.87±0.42	18.73±2.30	21.53±0.12	20.80±0.72
	WHC(g/g)	0.57±0.17	0.76±0.10	0.38±0.10	0.55±0.24	0.55±0.10	0.52±0.04

KB: Kyongbu, YD: Yongdong, CB: Chungbu, MC: moisture content, WHC: water holding capacity

RESULTS AND DISCUSSION

The mean values of physicochemical characteristics of the soil samples are shown in Table 1 with distance and depth per site. The pH ranged from 4.46 to 8.48 and was significant with distance (P=0.001) and site (P=0.001). Moisture content was significant with distance (P=0.01) and site (P=0.001). Soil pH decreased with increasing distance from the roadside. There were ranges of 7.40~21.53% in moisture content and 0.33~0.76 g/g in water holding capacity. There was a tendency of increased water holding capacity with increasing depth.

Fig. 2 shows mean Pb, Zn, Cd, and Cu concentrations in three sites with soil distance and depth. The highest mean heavy metal concentration was found in KB for the top soil (0~5 cm) away 0.5 m from the roadside. The mean heavy metal concentrations of CB were higher than those of YD, although CB was constructed later. This is considered to be due to a higher traffic density.

Warren and Birch (1987) reported the mean concentration of heavy metals in soil along the mortorway which is a major arterial roadway in East London carrying approximately 70,000 vehicles per day. And Kim *et al.* (1993) studied the relationship between heavy metal concentration and the microbial biomass in public park soils of London with distance from roadside and profile. These results with distance from the road coincided with the present data decreasing with distance.

The metal concentration in Mt. Kwanak as control site ranged from 44.02 to 75.24 μg/g for Pb, 115.71~117.33 μg/g for Zn, 1.83~1.97 μg/g for Cd, and 10.40~13.07 μg/g for Cu. These values were low compared to those of three highway sites.

Tables 2 and 3 show microbiological characteristics of DHA and ATP, respectively, in

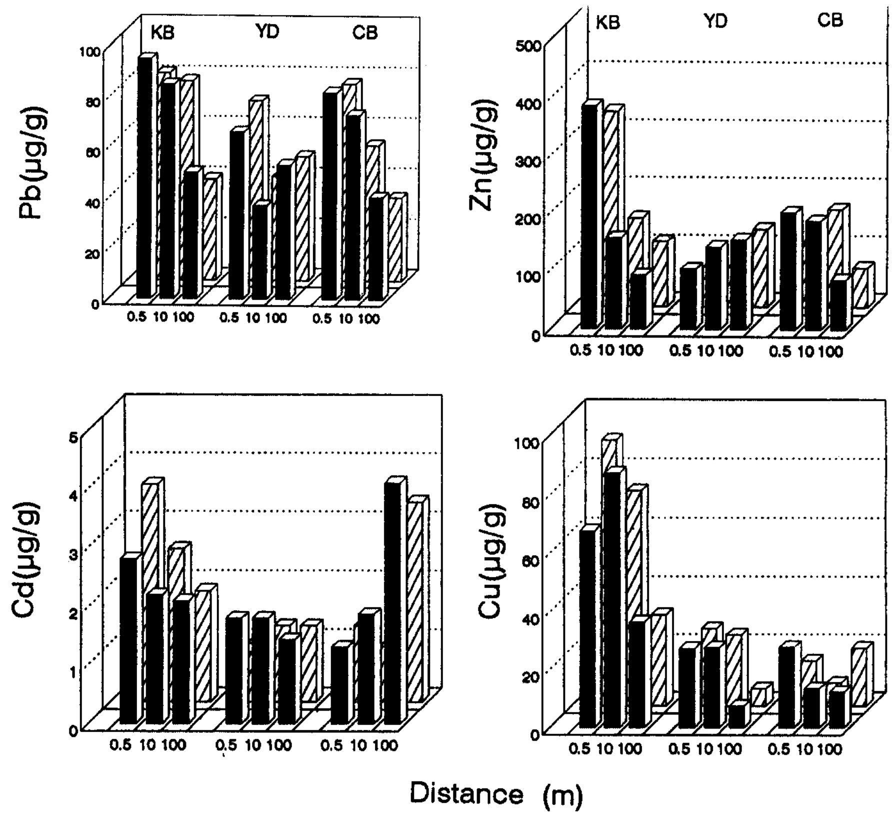

Fig. 2. Lead, zinc, cadmium, and copper concentrations along the distance from roadside and depth of soil sample in investigatde sites. KB:Kyongbu, YD:Yongdong, CB:Chungbu. Soil depths; ■ 0~5cm, ▨ 5~10cm

investigated sites with distance and depth. DHA indicates the activity of the soil microbial populations because dehydrogenation is the oxidation of carbon compound and is used as an index of respiration in the soil. Microbial biomass and activities are important as soil biological parameters in any assessment of the impact of street and disturbance.

There were tendencies having high values at distance of 10 m in both DHA and ATP content. The contents of two parameters were relatively low in the soil at the distance of 0.5m from the roadside having high metal concentrations. DHA values were significant with distance ($P=0.01$), and ATP contents were significant with sites ($P=0.05$) from ANOVA.

The soil of Mt. Kwanak had ranges of 494.34~848.18 μg/g in DHA and 1.28~1.67 μg/g in ATP contents in the upper layer. Brookes and McGrath (1984) reported that ATP concentrations were lower in soils with high metal contents than those with low metal contents. These results showed similar tendency to the present data. But according to

Table 2. Dehydrogenase activity in soils as expressed with TPF contents ($\mu g/g$) along distance from roadside and depth in investigated sites

Site	Depth (cm)	Distance (m)		
		0.5	10	100
KB	0~ 5	255.03±32.11	245.37±31.12	159.12±21.03
	5~10	112.17±14.23	227.01±28.37	79.42±9.92
YD	0~ 5	63.70±8.59	300.48±37.56	118.73±12.34
	5~10	20.27±3.71	443.15±55.67	254.41±31.80
CB	0~ 5	17.74±2.96	102.07±10.01	33.88±4.74
	5~10	34.35±4.88	327.78±42.11	28.35±3.93

KB: Kyongbu, YD: Yongdong, CB: Chungbu

Kim *et al.* (1993), microbial biomass and activity even in 0.5 m soil from the roadside were not relatively low in spite of high metal concentrations. This was considered to be due to car oil, pedestrian litter and animal excrements providing an organic input. These conflicting results probably arose because sampling sites were different. The present sampling sites were near highway road, but the above sites were near urban park which many people visited frequently.

Table 4 showed correlation coefficients obtained by simple regression analysis (Statistical Graphics Corporation 1987) of microbial characteristics in three soil sites. DHA and ATP contents were negatively related to pH, but were positively to moisutre content and water holding capacity.

In relation to heavy metal concentrations, two parameters were significantly correlated with pH, Pb or Zn. These results suggest that the inhibitory effects of heavy metals can be to some degree evaluated in terms of microbial activity, which agrees with the results of other studies (Pancholy *et al.* 1975, Brookes and McGrath 1984). Pancholy *et al.*

Table 3. Adenosine tri-phosphate contents ($\mu g/g$) along distance from roadside and depth in investigated sites

Site	Depth (cm)	Distance (m)		
		0.5	10	100
KB	0~ 5	1.80±0.61	2.40±0.78	1.54±0.42
	5~10	1.54±0.53	1.09±0.27	1.93±0.34
YD	0~ 5	1.05±0.26	2.86±0.71	2.06±0.49
	5-10	1.02±0.09	2.71±0.68	2.55±0.82
CB	0~ 5	1.30±0.33	1.12±0.28	1.76±0.44
	5~10	1.98±0.64	1.28±0.34	2.08±0.51

KB: Kyongbu, YD: Yongdong, CB: Chungbu

Table 4. Correlation coefficients by simple regression analysis of microbiological characteristics in investigated sites

	pH	MC	WHC	Pb	Zn	Cd	Cu
DHA	-0.86*	0.59	0.53	-0.91*	0.36	-0.44	-0.68
ATP	-0.97***	0.78	0.87*	-0.98***	-0.92*	-0.35	-0.29

* significant at p = 0.05, *** significant at p = 0.001, MC: moisture content, WHC: water holding capacity, DHA: dehydrogenase activity, ATP: adenosine tri-phosphate

(1975) reported a siginificantly larger fungal population in a control compared with a metal polluted site. And Brookes and McGrath (1984) found that amounts of soil microbial biomass in soils receiving sewage sludge containing composts were much smaller than in soils which received farm yard manure over the same period.

But Olson and Thornton (1982) suggested that the bacterial populations could withstand a small input of Cd into the environment without showing a significant change in numbers and bacteria from the highly polluted soil would be less sensitive to Cd additions than isolates from other soils with a relatively low level of contaminating Cd. Ross and Mills (1989) studied bacterial community structure and function along a heavy metal gradient, and found that the concentration of heavy metals was lack of correlation with resistance in the sediment bacterial community and it was due at least in part to the high pH of the river water. These results disagree with the present data to some extent.

Heavy metals may influence the abundance and diversity of organisms as well as activity of microbial populations. Occasionally, certain microbial populations may develop tolerance to such a level that they could respond positively to the inputs of carbon and nitrogen associated with vehicle emissions and other roadside characteristics, despite this being associated with concomitant higher inputs of heavy metals. In addition, there are some striking examples in which particular species appear to require the presence of high metal concentrations, as in the case of *Paecilomyces farinisus*, which was only isolated from soil contaminated with 〉 1,000 μg Cu /g dry weight (Nordgren *et al.* 1983). In such situations, microorganisms are able to increase their abundance because of the reduction in competition from organisms which are more metal sensitive. Therefore, metal tolerance is not simple to define because a metal concentration requiring tolerance for one particular group of organisms may fall within the normal physiological range of another in mixed microbial populations.

적 요

토양의 Pb, Zn, Cd, Cu 함량과 미생물 생체량 및 활성 사이의 관계가 경부 고속국도, 영동 고속국도 및 중부 고속국도 주변에서 조사되었다. 중금속 농도는 일반적으로 고속국도 도로변의 인접한 표토에서 높게 나타났고, 세 고속국도 중에서 교통량이 많은 경부 고속국도 주변에서 가장 높게 나타났다. 건설년도로 보면 영동 고속국도가 중부 고속국도에 비해 더 오래 되었으나 교통밀도가 더 높은 중부 고속국도 주변의 중금속 함량이 더 높게 나타났다. 대조구인 관악산 토양

의 중금속 농도와 비교했을 때 세 고속국도의 중금속 함량이 훨씬 높은 수준을 나타냈다. DHA와 ATP 함량은 중금속 농도가 높은 도로변 0.5 m에서 가장 낮았으며 Pb 및 Zn 농도와 유의적인 부의 상관을 보였다.

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