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Effect of cement dust pollution on microbial properties and enzyme activities in cultivated and no-till soils

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Cement dust pollution is one of the sources of atmospheric pollution. The main impacts of the cement activity to the environment are the broadcasts of dusts and gases. The objective of this study is to determine the effects of cement dust pollution, which was generated by cement plant, on soil microbial population, microbial respiration, and some enzyme activities in cultivated wheat (CT) and no-till (NT) soils. The fields are located at distances of 1, 3, 5, 7, 10 and 15 km away from the cement plant. In dominant wind direction, three replicated 36 soil samples were taken from a depth of 0 to 20 cm and analyzed for chemical, physical and microbiological properties. Soil microbial population and CO₂-C production showed significant ($p < 0.05$) positive correlation in CT and NT soils. The highest microbial population and CO₂-C production was observed at 15 km away from the cement plant in CT and NT soils. Acid phosphatase, urease and dehydrogenase enzyme activities of the soils showed significant ($p < 0.01$) positive correlation with distance in CT and NT ($r^2 = 0.80-0.86$; $r^2 = 0.90$ to 0.92 ; $r^2 = 0.79$ to 0.82 , respectively). There was negative correlation between alkaline phosphatase enzyme activity and distance in CT and NT ($r^2 = 0.60$, $r^2 = 0.68$; $p < 0.05$).

Key words: Microbial respiration, CO₂-C production, microbial population, cement dust pollution, soil enzyme activity.

INTRODUCTION

Air pollutants generated by the cement manufacturing process consist primarily of alkaline particulates from the raw and finished materials. The direct effects of cement dust pollution are the alkalization of the ecosystem and the changing of the chemical composition of soils (Mandre, 1995). The main impacts of the cement activity on the environment are the broadcasts of dusts and gases. The pollutant particles can enter into soil as dry, humid or occult deposits and can undermine its physicochemical properties (Laj and Sellegri, 2003). Thus, cement dust pollution has a negative effect on the physico-chemical properties and the biological activity of the soil. Soil microbial activity is important for the nutrient biogeochemical cycling and it is negatively affected by the cement dust pollution (Ocak et al., 2004; Nowak et al., 2003). The most commonly used microbial activity indicators for soil health monitoring are microbial biomass, soil respiration and soil enzyme activity (Nielsen and Winding, 2002).

Microorganisms are the main source of enzymes in soils. It is well known that all biochemical reactions are catalyzed by enzymes, which are proteins with catalytic properties owing to their power of specific activation. Soil enzyme activities are often used as indices of microbial growth and activity in soils. Enzyme activities play key roles in the biochemical functioning of soils, including soil organic matter formation and degradation, nutrient cycling, and decomposition of xenobiotics (Frankerberger and Dick, 1983; Chen et al., 2003; Acosta-Martínez et al., 2007). Their activity may correlate well with nutrient availability and soil fertility (Nannipieri et al., 2003; Baum et al., 2003).

Soil enzymatic activities depend on optimum conditions of moisture, pH, temperature and substrate concentration. Soil pH can affect enzyme activity by influencing the concentration of inhibitors or activators in the soil solution and the effective concentration of the substrate. Enzymatic activities may vary under stress when soil is contaminated

by heavy metals (Dick, 1997; Dick et al., 2000). Enzyme activities have been found to be very responsive to different agricultural soil conservation practices such as non-tillage (Bergstrom et al., 1998), organic amendments, and crop rotation (Miller and Dick, 1995). The difference in microbial dynamics and population, due to soil management practices, may also be reflected in the differences in enzyme activities of soils. Although it has been demonstrated that adoption of long-term cropping system may affect several soil properties, limited information is available about the effect of tillage on enzyme activities of soils. Tillage and management practices may lead to significant changes in biological, chemical and biochemical properties of soils and alter the composition, distribution, and activities of soil microbial community and enzymes (Dick, 1984; Dick et al., 1988). Acid phosphatase, alkaline phosphatase, arylsulfatase, invertase, amidase, and urease activity in 0 to 7.5 cm surface soils were significantly greater in soils from no-till plots, as compared with those from conventional tillage plots (Dick, 1984).

Phosphatase enzymes can be a good indicator of the organic phosphorus mineralization potential and biological activity of soils (Dick and Tabatabai, 1993). Phosphatase activity, which is related to soil and vegetation conditions, responds to changes in management (Herbien and Neal, 1990), and can be related to seasonal changes in soil temperature and moisture (Speir and Cowling, 1991). The phosphatases are significantly affected by soil pH, which controls phosphorus availability in soil, and this could occur despite the level of organic matter content or disturbance (Acosta-Martínez et al., 2007). Studies showed that acid phosphatase is predominant in acidic soils but alkaline phosphatase is predominant in alkaline soils (Deng and Tabatabai, 1997). The inverse relationship between phosphatase activity and soil pH suggests that the rate of synthesis and release of this enzyme by soil microorganisms or the stability of this enzyme are related to soil pH. Since higher plants are devoid of alkaline phosphatase activity, the alkaline phosphatase activity in soils seems derived totally from microorganisms (Dick et al., 1983).

Urease is a ubiquitous cell-free exoenzyme in nature that is produced by plants and microorganisms. Urea is the most widely used nitrogenous fertilizer in world agriculture today. It is hydrolyzed enzymatically by soil urease and the resulting release of ammonia and rise in pH can lead to some problems. These problems are accentuated in alkali soils where the high soil pH can induce appreciable ammonia volatilization (Brynes and Frency, 1995). Alkali soils have low amounts of organic carbon and nitrogen and low levels of urease and dehydrogenase activity (Rao and Ghai, 1985).

Dehydrogenase activity is commonly used as an indicator of biological activity in soil (Beyer et al., 1992). Dehydrogenase enzymes play a significant role in the biological oxidation of soil organic matter by transferring protons and electrons from substrates to acceptors (Dick

and Tabatabai, 1993). According to Frankenberger and Dick (1983), dehydrogenase activity is often correlated with microbial respiration when exogenous C sources are added to soil. Skujins (1973) and Casida (1977) reported close correlations of dehydrogenase activity with CO₂ release and O₂ uptake, respectively. The highest activity occurred in top 3 cm of an arid soil, but there was no correlation with microbial number because the dehydrogenase activity depends on the total metabolic activity and soil microorganisms. The value of metabolic activity and soil microorganisms in different soils, containing different populations, does not always reflect the total numbers of viable microorganisms that are isolated on a particular medium.

In this study, we aimed to detect possible impacts of cement dust pollution, which are generated by cement factory, on microbial population (bacteria and fungi), microbial respiration (CO₂-C production) and some enzyme (acid, alkaline phosphatase, urease and dehydrogenase) activities in cultivated with wheat and no-till soils.

MATERIALS AND METHODS

Experimental site, soil sampling and soil analysis

The study was conducted in the vicinity of Askale town cement plant (39°54' N and 41°13' E at 1883 m above mean sea level), west of the Erzurum, Turkey. Based on area distribution within a soil - mapping unit, the sampling sites at 1, 3, 5, 7, 10 and 15 km away from the Askale cement plant were randomly selected in cultivated (CT) vs. no-till (NT) soils. The chimney height of the Askale cement plant was 50 m. The composition of emissions for cement plant were particle matter (48 kg h⁻¹), CO (146 kg h⁻¹), NO₂ (186 kg h⁻¹) and SO₂ (6 kg h⁻¹). The dominant wind direction is north-west, and soil sampling was coincided with the same wind direction. The minimum and maximum temperatures were 11.4 and 26.5°C respectively, and average annual temperature was 15.4°C. The mean relative humidity, wind speed, daily sunshine, total precipitation, and total evaporation were in order 57.42%, 4.71 m s⁻¹, 11.12 h, 61.4 mm, and 389.4 mm in 2008 (1 May to 29 Sept.). Three replicated sub-plots were selected within each site. Total 36 sampling sites (6 distance x 2 tillage x 3 replications) were selected for soil collection. The soil was classified as Askale series (ustorthents) according to the USDA soil taxonomy (Soil Survey Staff, 1999). The experiment area soil texture classes were determined loam to clay. The site has a semiarid climate and average annual rainfall of 427 mm. The major crops grown in this area are wheat, barley, secale, maize, cabbage, cotton, sugar beat, and potatoes.

In this research, soil samples were taken from 0 to 20 cm depth (tillage layer) in September 2008. The samples were composited and 2-mm sieved to remove stones, roots, and large organic residues and analyzed. Total organic matter (SOM) content was determined by following the standard loss-on-ignition (LOI) method (Nelson and Sommers, 1996). The CaCO₃ content was determined by using the pressure calcimeter method (Leoppert and Suarez, 1996). Total N content of soil was measured by the micro-Kjeldahl method (Bremner, 1996). Soil pH was determined by using a glass electrode meter in 1:2.5 soil: water ratio (Handershot et al., 1993). Effective cation exchange capacity was calculated as the sum of exchangeable cations (Sumner and Miller, 1996). Melich I solution was used to extract exchangeable cations and determined by atomic absorption spectrophotometer (Hanlon and DeVore, 1989). The available P in soil was determined by following ammonium molybdate-ascorbic acid

method (Knudsen and Beegle, 1988). Microelements in the soils were determined by DTPA extraction method (Lindsay and Norvell, 1978). Soil particle size distribution was determined by the hydrometer method (Gee and Bauder, 1986). Soil textural class was determined by following the USDA textural triangle. Electrical conductivity was measured in saturation extracts according to Rhoades (1996). The soils were analyzed for selected physical and chemical properties (Table 1).

Soil biological analysis

Culturable bacteria and fungi cells were enumerated by using spread soil dilution plate method. For bacteria and fungi, each dilution of the series (10^6-10^7) in PBS (0.15 M potassium phosphate 0.85% NaCl, pH 7.2) was prepared and placed onto Petri-dishes (Zuberer, 1994). Soil extract agar (SEA) was used for bacterial incubation at 30°C for 7-d (Zuberer, 1994), dextrose-peptone agar (DPA) was used for fungal incubation at 25°C for 7-d (Parkinson, 1994). After the incubation, the average colony forming units (CFU) per gram of oven-dried equivalent (ODE) of field-moist soil was calculated by using an automated colony counter (Madigon et al., 2006) (Table 2).

Basal respiration (BR), as a measure of soil biological activity, was determined by using in vitro static incubation of unamended field-moist soil (Islam and Weil, 2000). About 20 g ODE of field-moist soil adjusted at 70% water-filled porosity (WFP) was taken in 25 ml glass beakers. Each soil sample was placed in a 1 L mason jar along with a glass vial containing 10 mL of distilled deionized water to maintain humidity and a plastic vial containing 10 mL of 0.5 M NaOH to trap CO₂ evolved from the incubated soil. The mason jars were sealed airtight and incubated in the dark at 25 ± 1°C for 20 days. The CO₂ evolved over time was absorbed in the 0.5 M NaOH followed by precipitation as BaCO₃ by the addition of excess 1M BaCl₂. The remaining NaOH in each vial was then titrated to the phenolphthalein endpoint with a standardized 0.5 M HCl solution (Table 2). The BR rate was calculated as below:

$$\text{BR rates (mg CO}_2\text{/kg soil)} = (\text{CO}_2\text{soil} - \text{CO}_2\text{air})/20 \text{ days}$$

Urease enzyme (UE) activity was assayed by using urea solution and expressed as µg NH₄-N per g soil and incubation time (2 h). Acid phosphatase (AcdP) and alkaline phosphatase (Alk-P) activities were assayed by using substrate pNPP (para-nitrophenyl phosphate) and expressed as I µg pNPP per gram soil and incubation time (hours). Dehydrogenase enzyme (DHE) activity was determined with TTC (triphenyl tetrazolium chloride) and expressed as µg TPF per gram soil and incubation time (24 h) according to Tabatabai (1994) (Figure 1a,b, 2, 3).

Statistical analysis

Statistical analysis was done for soil microorganism population and CO₂-C production using repeated measures analysis of variance (ANOVA). Comparison of means was performed, when the F-test for treatment was significant at the 5% level, using Duncan's multiple means tests. In addition, we tested effects of cement dust pollution on soil enzyme activities by calculating regression equation and simple linear correlation coefficient (r) procedures. SPSS 17.0 package was used for all statistical tests.

RESULTS

Some chemical and physical properties of the studied soils are given in Table 1. According to Table 1, most soils had an alkaline reaction between pH 7.40 to 9.24. Soil pH

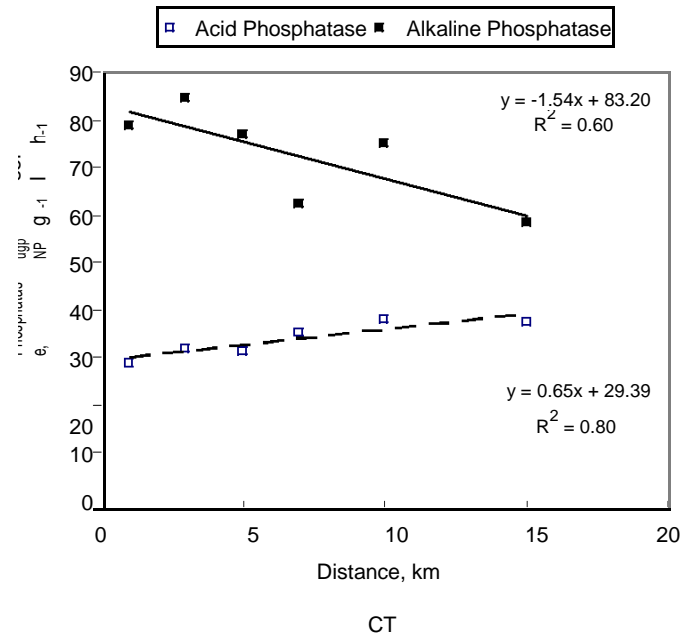


Figure 1a. Acid phosphatase enzyme activities vs. polluted distance by cement dust in CT soils.

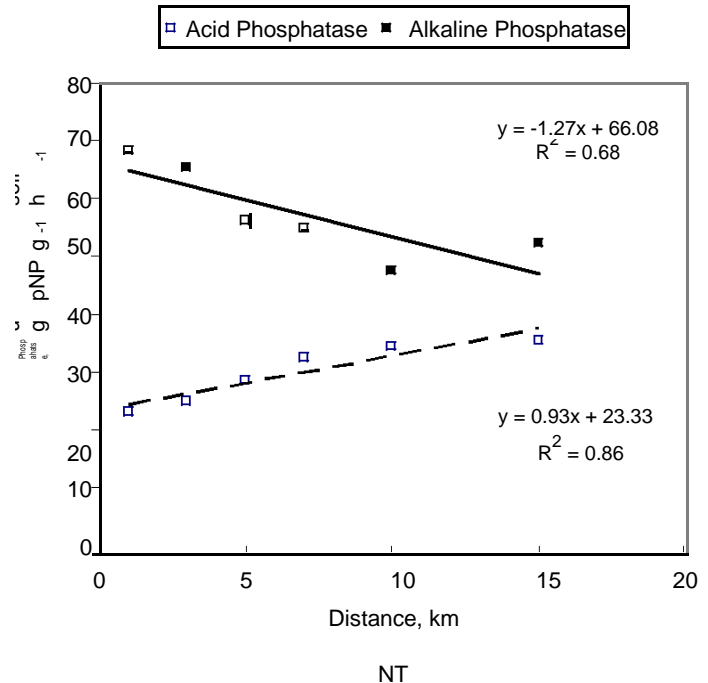


Figure 1b. Alkaline phosphatase enzyme activities vs. polluted distance by cement dust in NT soils.

values at a distance of 1 km were 8.83 in CT and 8.52 in NT and at distance of 15 km 7.40 in CT and NT soils. Increasing distance from cement plant decreased soil pH in CT and NT soils. The soils did not exhibit any salinity

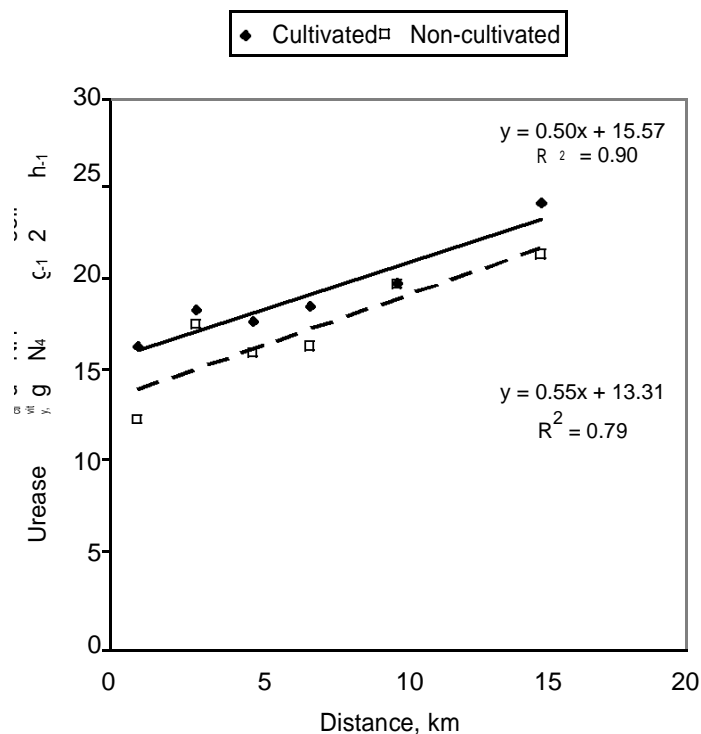


Figure 2. Urease enzyme activities vs. polluted distance by cement dust in CT and NT soils.

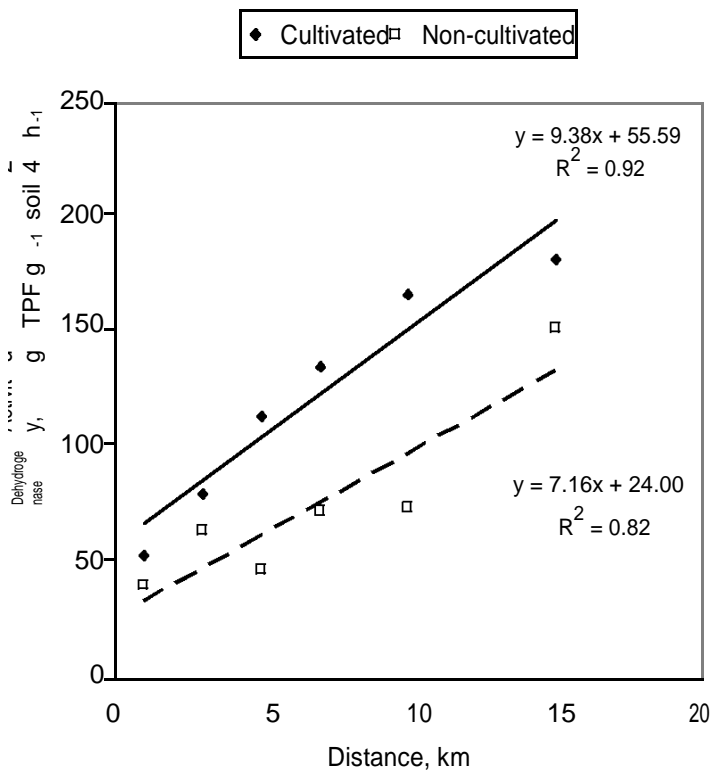


Figure 3. Dehydrogenase enzyme activities vs. polluted distance by cement dust in CT and NT soils.

problem but there was enough lime (3.42 to 5.63%) present in the soil to be classified calcareous soils. Contents of organic matter of the soils were determined between 1.45 to 2.86% (low-middle), total nitrogen between 0.1 to 0.29% and contained sufficient N, available phosphorus between 11.50 to 18.70 mg kg⁻¹ (low) (FAO, 1990), and cation exchangeable capacity between 30.34 to 38.42 cmol kg⁻¹.

Effects of spatial variation on microbial population and CO₂-C production

The quantitative analysis of bacteria, fungi, and soil CO₂-C production in CT and NT soils are given in Table 2. According to the results of ANOVA, significant (p < 0.05) differences on average number of bacteria and fungi were observed among different distances from the cement factory in CT and NT soils.

The highest number of bacteria were observed at distance of 15 km (387.2 x 10⁶ CFU g⁻¹ soil) from the cement plant in CT and the lowest were observed at distance of 1 km (296.3 x 10⁶ CFU g⁻¹ soil) from the cement plant in CT. The highest number of bacteria were obtained at a distance of 15 km (370.6 x 10⁶ CFU g⁻¹ soil) in NT and the lowest were obtained at distance of 1 km (215.7 x 10⁶ CFU g⁻¹ soil) from the cement plant in NT soils. Average numbers of bacteria were higher in CT (332.5 x 10⁶ CFU g⁻¹ soil) soils than in NT (282.8 x 10⁶ CFU g⁻¹ soil) soils. Soil microbial population showed a significantly positive correlation with distance in CT and NT (r² = 0.53; r² = 0.56, p < 0.05) soils.

Significant (p < 0.05) differences in average number of fungi were observed among different distances from the cement factory in CT and NT soils. The highest number of fungi was obtained at distance of 7 km and the lowest was obtained at a distance of 1 km from the cement plant in CT (37.2 x 10⁴; 21.6 x 10⁴ CFU g⁻¹ soil) and NT (71.4 x 10⁴; 42.6 x 10⁴ CFU g⁻¹ soil) soil. Average number of fungi was determined 58.1 x 10⁴ CFU g⁻¹ soil in NT and 29.7 x 10⁴ CFU g⁻¹ soil in CT soils. Number of fungi showed significant positive correlation with distance in CT (r² = 0.58; p < 0.05) and NT (r² = 0.74, p < 0.05) soils (Table 2).

According to Table 2, statistical results showed a significant (p < 0.05) differences between distance and average CO₂-C production depending on distance from the cement factory. Increasing distance increased CO₂-C production in CT and NT soils. The highest CO₂-C production was observed at distance of 15 km from cement factory in CT (31.5 mg CO₂-C m² h⁻¹) and NT (21.8 mg CO₂-C m² h⁻¹) soils. The lowest CO₂-C production was observed at distance of 1 km from cement factory in CT (21.6 mg CO₂-C m² h⁻¹) and NT (16.0 mg CO₂-C m² h⁻¹) soils. The average CO₂-C production was determined 27.2 mg CO₂-C m² h⁻¹ soil in CT, and 19.3 mg CO₂-C m² h⁻¹ soil in NT soils. Average soil CO₂-C production showed significant positive correlation with distance in CT and NT (r² = 0.94, p < 0.01) soils.

Table 1. Some chemical and physical properties of CT and NT soils.

Soil properties	Polluted distance by cement dust												
	1 km		3 km		5 km		7 km		10 km		15 km		
	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	
pH (1:2.5) (soil/water)	8.83	8.52	9.24	8.71	8.54	8.21	8.24	7.85	7.82	8.12	7.40	7.40	
Organic matter, %	1.96	1.62	2.04	2.21	2.00	2.26	2.42	2.86	2.01	1.45	2.54	2.32	
CaCO ₃ . %	5.49	3.70	3.83	4.20	4.66	5.26	5.63	4.21	4.38	3.75	4.63	3.42	
Total N, %	0.15	0.10	0.19	0.14	0.25	0.21	0.26	0.17	0.29	0.21	0.19	0.25	
Available P, mg kg ⁻¹ soil	14.23	10.20	18.70	14.20	16.47	18.00	16.47	13.40	17.21	13.70	15.30	11.50	
Exchangeable Cations, cmol kg ⁻¹ soil	Ca ⁺²	23.11	25.46	20.18	24.53	21.65	23.45	21.65	18.46	21.16	21.45	17.56	18.63
	Mg ⁺²	9.70	7.87	8.48	9.56	9.09	8.23	9.09	6.85	8.89	7.23	6.05	7.26
	K ⁺¹	3.17	4.12	2.76	3.74	2.97	1.86	2.97	2.76	2.90	3.25	3.56	4.85
Micro Elements, ppm	Na ⁺¹	0.38	0.26	0.31	0.28	0.35	0.21	0.35	0.18	0.33	0.48	0.31	0.29
	Fe	24.11	25.45	20.54	23.05	21.37	25.93	23.17	17.95	23.30	24.15	21.85	22.83
	Cu	2.56	3.66	2.57	3.60	2.63	3.21	3.48	2.89	4.46	4.99	4.59	3.01
	Zn	2.85	2.19	1.60	1.91	1.23	2.17	2.30	1.06	2.93	2.30	2.82	2.76
	Mn	8.29	9.63	11.19	9.03	13.14	9.15	6.58	11.17	11.16	10.87	13.30	13.83
CEC, cmol kg ⁻¹ soil	36.29	38.24	35.77	38.42	36.03	34.59	36.03	30.65	35.94	33.25	30.34	33.24	
Texture, %	Clay	32.45	36.18	33.20	36.20	28.75	34.33	28.35	33.97	27.33	33.69	33.99	34.55
	Silt	20.25	30.56	25.46	29.50	31.12	28.56	32.00	27.93	28.56	31.05	26.07	21.24
	Sand	47.30	33.26	41.34	34.30	40.13	37.12	39.65	38.10	44.11	35.26	39.94	44.21
Texture class	L	CL	CL	L	CL	CL	L	CL	CL	CL	L	L	

CT : Cultivated wheat, NT : No-Till soil, L : Loam, CL : Clay loam.

Table 2. Effects of cement dust pollution on population of bacteria and fungi, CO₂-C production, Duncan test results and correlation coefficient values (r).

Distance (km)	Bacteria x10 ⁶ (CFU g ⁻¹)		Fungi x10 ⁴ (CFU g ⁻¹)		CO ₂ -C Production (mg C m ⁻² h ⁻¹)	
	CT	NT	CT	NT	CT	NT
1	296.3 b	215.7 b	21.6 b	42.6 b	21.6 b	16.0 b
3	315.7 ab	281.5 ab	25.4 b	58.7 ab	24.6 ab	18.4 ab
5	362.5 a	243.0 b	29.8 b	42.2 b	25.6 ab	18.6 ab
7	337.6 ab	343.2 a	37.2 a	71.4 a	29.7 a	20.2 a
10	297.6 b	243.5 b	37.1 a	65.5 a	30.3 a	21.1 a
15	387.2 a	370.6 a	27.0 b	68.4 a	31.5 a	21.8 a
Average	332.5 A	282.8 B	29.7 B	58.1 A	27.2 A	19.3 B
r-values	0.53*	0.56*	0.58*	0.74*	0.94**	0.94**

CT: Cultivated wheat, NT: No-Till Soil, † The means with the same letter are not statistically significant (p < 0.05). *, **: Indicate significance at the 5 and 1%, respectively.

Effects of spatial variation on some soil enzyme activity

We also monitored the activities of four enzyme groups: AcdP, AlkP, urease (UE) and dehydrogenase (DHE) at different distance from the cement plant in CT and NT soils. According to our results, phosphatase enzyme

activities varied widely in relation to distance CT and NT soils. The highest AcdP enzyme activity was observed at distance of 15 km (37.6 µg pNP g⁻¹ soil h⁻¹) in CT and the lowest AcdP enzyme activity was observed at distance of 1 km (29.0 µg pNP g⁻¹ soil h⁻¹) away from the cement factory in CT soils. Similarly, the highest AcdP enzyme activity was obtained at distance of 15 km (35.3 µg pNP g⁻¹ soil h⁻¹)

in NT soils and the lowest AcdP enzyme activity was obtained at distance of 1 km ($23.0 \mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$) away from the cement factory in NT soils. AcdP enzyme activity showed a significant positive correlation with distance in CT ($r^2 = 0.80, p < 0.01$) and NT ($r^2 = 0.86, p < 0.01$) soils (Figure 1a and b).

The highest AlkP enzyme activity was observed at distance of 2 km ($84.60 \mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$), and the lowest AlkP enzyme activity was observed at distance of 15 km ($58.40 \mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$) away from the cement factory in CT soils. The highest AlkP enzyme activity was observed at distance of 1 km ($68.10 \mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$) and the lowest AlkP enzyme activity was observed at distance of 10 km away from the cement factory ($47.50 \mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$) in NT soils. The results in this particular case showed a significant negative correlation between cement dust pollution and distance in CT ($r^2 = 0.60, p < 0.05$) and NT ($r^2 = 0.68, p < 0.05$) soils. AcdP enzyme activity was significantly lower than AlkP enzyme activity in CT and NT soils (Figure 1a and b).

Urease enzyme activity was highly correlated with the distance of CT and NT soils. The regression equations and simple correlation coefficients for these relationships are shown in Fig. 2. The highest UE activity was observed at distance of 15 km ($24.08 \text{ mg NH}_4\text{-N kg}^{-1} \text{ soil 2h}^{-1}$) and the lowest was observed at distance of 1 km ($16.25 \text{ mg NH}_4\text{-N kg}^{-1} \text{ soil 2h}^{-1}$) away from the cement factory in CT soils. The highest UE activity was observed at distance of 15 km ($21.24 \text{ mg NH}_4\text{-N kg}^{-1} \text{ soil 2 h}^{-1}$) and the lowest was observed at distance of 1 km ($12.20 \text{ mg NH}_4\text{-N kg}^{-1} \text{ soil 2 h}^{-1}$) away from the cement factory in NT soils. UE activity showed a significant positive correlation with distances in CT ($r^2 = 0.90, p < 0.01$) and NT ($r^2 = 0.79; p < 0.01$) soils.

Maximum variation based on distance from the cement factory was observed for dehydrogenase activity in various soils. The highest DHE activity was determined at 15 km distance ($180 \text{ mg TPF kg}^{-1} \text{ soil 24 h}^{-1}$) and the lowest was determined at 1 km distance ($51.16 \text{ mg TPF kg}^{-1} \text{ soil 24 h}^{-1}$) away from the cement factory in CT soils. The highest DHE activity was observed at distance of 15 km ($150 \text{ mg TPF kg}^{-1} \text{ soil 24 h}^{-1}$) and the lowest was obtained at a 1 km distance ($37.88 \text{ mg TPF kg}^{-1} \text{ soil 24 h}^{-1}$) from the cement factory in NT soils. Strong positive correlation among DHE enzyme activity and distances was observed in CT ($r^2 = 0.92, p < 0.01$) and NT ($r^2 = 0.82, p < 0.01$) soils (Figure 3).

DISCUSSION

Our findings that soils under cement dust have lower enzyme activity, compared to the CT and NT soils, are due to the negative impacts of the cement dust on soil properties including the microbial populations and activities. The effects of cement dust on soil microbial population and $\text{CO}_2\text{-C}$ fluxes were significantly correlated with distance in CT and NT soils. Increasing distance increased the average number of bacteria, fungi and soil

$\text{CO}_2\text{-C}$ production and decreased lime contents of the soil in CT and NT soils (Table 1 and 2). The increases in amount of lime were related to the increase of soil pH.

Microorganism activity was affected negatively by cement pollution and the other environmental conditions resulting from cement pollution; it most likely would have negative effects on the other ecosystem functions (Bayhan et al. 2002; Nowak et al. 2003; Fabbri et al. 2004; Ocak et al. 2004).

The pH affected the activity of enzymes as amino acid functional groups that alter conformational and chemical changes of amino acids essential for binding and catalysis were very sensitive to pH range (Dick et al., 2000). Phosphomonoesterases such as AcdP and AlkP significantly were affected by changes in soil pH (Table 1 and Figure 1) and each enzyme was observed more predominant in acidic and alkaline soils, respectively (Deng and Tabatabai, 1997). Changing soil pH is connected with content of cement dust of the soil. Cement dust pollution effected soil pH directly, and affected soil acid phosphatase enzyme activity in directly. AcdP responded negatively to the soil acidity and the tested enzymes were ordered according to their susceptibility of soil acidity as follows: dehydrogenases>urease>alkaline phosphatase>acid phosphatase (Wyszkowska et al., 2006).

The highest urease activity was observed around pH = 7.4 and the lowest urease activity was at pH = 8.8 (Table 2). Optimum pH for soil UE activity was 8.8 to 9.0 (Tabatabai and Bremner, 1972; May and Douglas, 1976). However, Singh and Nye (1984) reported that soil pH for UE activity was around 6 for the overall reaction and 6.8 for the high affinity reaction. Alkaline soils have low amounts of organic carbon and nitrogen and low levels of urease and dehydrogenase enzyme activity. Urease enzyme activity was significantly correlated not only with organic carbon and CaCO_3 , but also with pH (Rao and Ghai, 1985). Urease turned out to be more resistant to soil acidity than dehydrogenases (Wyszkowska et al., 2006). Phosphatase and urease enzyme activities were greater in CT soils than NT soils (Gupta and Bhardwaj, 1990). Especially, urease activity was much lower in NT soils than in CT soils. When compared to the corresponding undisturbed or less-disturbed soils, our results are in agreement with previous studies showing enzyme activity values reported by Acosta-Martinez et al. (2004) and Fenn et al. (1992).

Dehydrogenase enzyme activity showed a positive correlation with decreasing cement dust, CaCO_3 , and pH in CT and NT soils (Figure 3, Table 1). The maximum dehydrogenase enzyme activity was observed at pH 7.4 under wheat vegetation. Similar results were observed in pH 6.6-7.2 during barley vegetation under different air-water conditions (Brzezinska et al., 2001). We determined positive correlation between dehydrogenase enzyme activity and pH. Similarly, Moore and Russell (1972) and Onet et al. (2007) observed that there was strong correlation between dehydrogenase enzyme activity and

organic matter (Khan, 1999) and weakly positive with pH and nitrogen. Dehydrogenase enzyme activity in CT (pH 7.4-8.52) soils was greater than NT (pH 7.4 to 9.24) soils. Dehydrogenase enzyme activity decreased significantly with the decline in soil pH values in acidic soils. These results are in agreement with that reported by Rao and Ghai (1985) and Aoyama and Nagumo (1996).

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