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Investigation of Heavy Metals Pollution along the Nigde-Kayseri Road, Turkey

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The study area comprises the D765 state road connecting Nigde and Kayseri cities in the central Anatolia. The aim of this study is to determine the heavy metal contamination in off roadside soils along the D765 state road. Heavy metal concentrations were measured with Spectro-Xepos Benchtop X-Ray Fluorescence Spectrometer. Results of heavy metal analyses on soil samples reveal a significant contamination. Average heavy metal concentrations and standard deviations of samples collected from off roadside soils along the D765 state road are as follows: As: 27.90 (7.64), Cd: 3.99 (0.35), Co: 35.80 (2.19), Cr: 158.33 (46.27), Cu: 48.37 (24.73), Fe: 31516.83 (6545.26), Mn: 771.83 (121.41), Mo: 28.52 (5.51), Ni: 118.11 (27.90), Pb: 107.48 (37.90), Sn: 6.34 (1.35), Ti: 3369.87 (1172.44) Zn: 135.64 (32.42) mg/kg. In this study, among the heavy metals, As, Cd, Co, Cr, Mo, Ni and Pb are toxic metals. Heavy metal accumulations in soil were determined to be closely associated with traffic intensity.

Key Words: Heavy metal, Toxic, Traffic Nigde, Kayseri, Soil contamination.

INTRODUCTION

The D765 state road in central Anatolia is the only road connecting the Nigde and Kayseri cities from southern part to central part of Turkey (Fig. 1). Therefore, D765 state road is one of the most important roads in the region. Since the D765 road between the Nigde and Kayseri cities also extends through two towns of the Kayseri city, it has an intense traffic load. Therefore, D765 state road has a special importance by means of environmental pollution.

Heavy metals due to various reasons are accumulated in soil along the roads. This accumulation is the main indicator for contamination[1-4]. The concentrations of heavy metal accumulation in off roadside soils were compared with concentrations of these metals in the earth crust and acceptable

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limits in Turkey (Table-1). In this respect, heavy metal accumulation in off roadside soils along the D765 state road was determined. Among these metals, Fe, Cu, Pb, Zn, Cd, Ni, Cr, Co, Mn, Ti, Sn, Mo and As are the important pollutants.

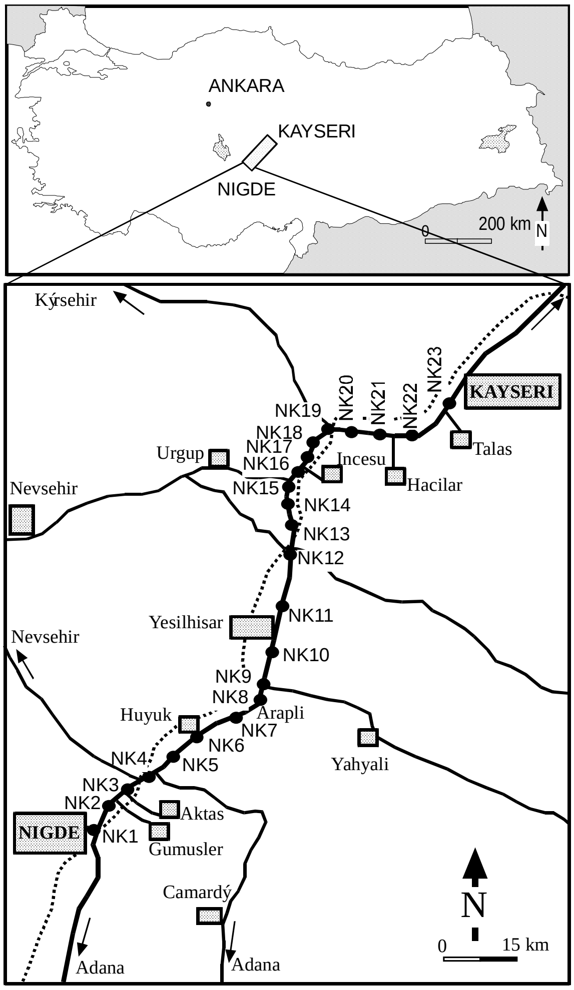

Fig. 1. Study area and sampling map

Heavy metal concentrations in the environment negatively affect the brain activities and behaviours of humans[11]. Therefore, investigation of heavy metal accumulation along the D765 state road was selected as the topic of this research. Heavy metals may be derived from traffic, industrial activities and home wastes[4,12-14]. The maximum Pb concentration in off roadside soils is observed in ramps, oil stations, junctions and repair sites[4,15]. In addition, heavy metals are also found in repair sites at both sides of a road under heavy traffic.

TABLE-1
ABUNDANCE OF HEAVY METALS IN THE EARTH CRUST AND THEIR ACCEPTABLE LIMITS

Metals	Concentration in soil	Concentration in shale (mg/kg)[9]	Concentration in the earth crust (mg/kg)[9]	Acceptable limit in Turkey (mg/kg)[10]
Fe	2.1×10^4**	4.7×10^4	5.4×10^4	–
Cu	15**	50	50	50
Pb	17**	20	12.5	50
Zn	36**	90	70	150
Cd	0.1-0.5*	0.3	0.15	1
Ni	17**	80	75	30
Cr	43**	100	100	100
Co	10**	20	20	20
Mn	320**	850	1000	–
Ti	–	4500	5000	–
Sn	10***	6	2.5	20
Mo	2.5***	2	1.5	10
As	7.5**	10	1.8	20
Al	14.7#	9.2×10^4	8.1×10^4	–

*Ref. 5, **Ref. 6, ***Ref. 7, #Ref. 8

The close relation between heavy metal concentrations such as Pb and repair sites, heavy traffic and ramps was investigated by various workers[4,16-21]. Cu, Fe, Cr and Zn elements in off roadside soils are the main materials of various alloys, pipe, cable and tire in a car[22]. Ni in gasoline and Cd and Zn in tires and motor oils were determined to be high concentrations in several other works[23,24].

Recent studies indicate that environmental pollution along the heavy-traffic roads is an important problem. The aim of this study is to investigate the heavy metal pollution in off roadside soils along the D765 road which connects the Nigde and Kayseri cities.

EXPERIMENTAL

The city of Nigde in central Anatolia has a population of about 350,000 and a population density of 45 person/km^2. The population of Kayseri city, which is an important industrial and trade center in central Anatolia, is approximately 1,000,000 and population density is 62 person/km^2.

In this study, heavy metal pollution (Fe, Cu, Pb, Zn, Cd, Ni, Cr, Co, Mn, Ti, Sn, Mo and As) was examined in the upper soil layer along the D765 road of 116 km connecting the Nigde and Kayseri cities. In 2004, daily total vehicle intensity[25] on this road was 3571.

Along the D765 road profile, metamorphic rocks of the Nigde massive are observed until the Nigde exit. In the following part towards to Kayseri, alluvium deposits of sand, clay and silts of Neogene and Pliocene age are traced. Metamorphic rocks of the Nigde massive are made of gneiss, schist, marble and quartzite alternations[26].

Sampling and analyses

Soil sampling was conducted in the November-2005 period. A total of 23 soil samples[4] of 20 g were systematically collected from a depth of 5-10 cm about 5-10 m distance from the road side at every 5 km along the D765 road from Nigde to Kayseri.

All soil samples were collected with plastic sample shovel and stored in plastic containers for analyses. Samples were heated at 105ºC for 24 h to avoid of humidity. Dried samples were sieved through 2 mm plastic sieve and thus separated from conglomerates. Sample containers were carefully[27] handled during the collection, storing, drying and sieving of samples to prevent from a possible contamination.

In the next stage, samples were homogenized[27] with an agate mortar to a grain size of less than 2 mm. The mortar was washed with HNO_3 and rinsed with distilled water before the each sample process. Double sided film tablet of 32 mm diameter was prepared from each sample. Measurements on sample tablets for Fe, Cu, Pb, Zn, Cd, Ni, Cr, Co, Mn, Ti, Sn, Mo and As elements were carried out with Spectro Xepos Benchtop X-Ray Fluorescence spectrometer[27]. Detection system is drift detector with Peltier cooling, energy resolution FWHM < 170 eV, measured for the MnK_α line with an input count vote of 10,000 pulses, Microprocessor controlled detector and electronics.

RESULTS AND DISCUSSION

The heavy metal concentrations and averages for off roadside soils collected from the D765 road are determined as follows (mg/kg) (Tables 2 and 3); As: 27.90 (± 7.64), Cd: 3.99 (± 0.35), Co: 35.80 (± 2.19), Cr: 158.33 (± 46.27) Cu: 48.37 (± 24.73), Fe: 31516.83 (± 6545.26) Mn: 771.83 (± 121.41), Mo: 28.52 (± 5.51) Ni: 118.11 (± 27.90), Pb: 107.48 (± 37.90), Sn: 6.34 (± 1.35), Ti: 3369.87 (± 1172.44) and Zn: 135.64 (± 32.42).

General overview of results for the D765 state road reveals that average concentrations of As, Cd, Co, Cr, Mo, Ni and Pb exceed the abundance of these elements in the earth crust, soil and shale and also that required by the National soil pollution control regulation and therefore, they have a toxic character. The average concentration of Cu exceeds the limit value for soils but it is lower than its abundance in the earth crust, shale and National soil pollution control regulation.

TABLE-2
RESULTS OF ANALYSES OF SAMPLES COLLECTED ALONG THE D765 NIGDE-KAYSERI ROAD

	As	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sn	Ti	Zn	Location
NK1	12.7	4.1	32.5	255.8	46.5	41588	647	32	98.4	132.2	6.1	2256	166.2	Between Bus station and Ata Industrial site
NK2	45.1	5.1	11.4	200.4	51.2	38512	749	28	125.6	100.1	7.8	2004	102.5	Entrance to the Gümüşler town
NK3	36.5	4.2	35.8	176.4	18.6	22984	601	25	100.5	188.4	8.5	3369	132.6	Before the Aktaş town
NK4	30.5	4.3	40.1	182.5	65.5	30256	877	26	115.4	98.4	4.2	2258	200.8	Nevşehir road junction
NK5	25.8	3.8	58.9	125.4	88.7	21422	654	26	99.4	205.1	6.8	1952	159.7	Following the Çamardi road junction. 2nd km
NK6	27.2	1.6	50.4	99.2	100.8	36410	742	30	168.9	88.4	5.5	2002	165.3	Around Hüyük
NK7	33.3	3.2	35.8	156.4	87.5	26201	852	28	147.8	65.5	7.2	3698	147.2	Entrance to Arapli, 1 km before
NK8	27.0	3.8	39.4	100.6	65.8	30020	1126	26	132.5	122.6	8.0	1852	132.5	Arapli exit
NK9	31.9	3.0	41.8	122.7	42.2	21762	800	21	136.9	136.1	7.2	2698	100.8	Yahyali road junction
NK10	30.8	3.6	42.9	168.6	22.1	39331	741	13	140.5	87.2	6.5	3568	82.5	Entrance to Yeşilhisar
NK11	28.8	3.1	31.6	147.5	45.9	32158	662	29	178.6	108.2	4.2	3005	144.9	Yeşilhisar exit 2nd km
NK12	40.0	4.9	11.7	169.4	40.1	23145	852	35	147.8	69.5	3.3	3215	111.4	Nevşehir road junction across the oil station
NK13	22.5	5.4	25.8	71.9	38.2	31269	521	25	84.5	88.2	5.6	5487	88.4	Bend
NK14	17.8	3.5	36.9	157.8	27.4	22500	745	26	72.1	65.3	6.9	3269	142.8	Junction
NK15	25.9	3.6	42.8	200.6	22.5	32668	801	29	100.9	35.2	6.9	3987	189.4	
NK16	27.2	3.8	9.2	168.7	88.4	38499	765	24	85.7	142.5	5.7	2547	147.5	İncesu entrance 1 km
NK17	32.5	5.6	36.8	234.9	36.4	43251	741	31	123.5	106.9	6.1	4521	124.6	İncesu exit 2 km
NK18	26.8	3.5	52.5	141.1	62.3	32144	722	36	111.7	122.2	4.8	6587	100.4	
NK19	22.4	4.1	41.5	187.7	51.1	30258	763	39	82.4	98.7	7.1	4215	182.5	Entrance to Boğazköprü
NK20	30.5	2.6	32.5	200.9	12.4	38789	852	30	102.6	88.5	8.5	3987	147.6	Between the Boğazköprü and Industry site
NK21	11.4	6.5	28.9	168.7	25.6	32566	925	36	98.7	98.6	6.9	3259	124.6	Industry site
NK22	28.9	4.9	48.7	82.4	34.8	30588	825	32	125.7	125.6	5.8	3669	99.8	Belsin
NK23	26.2	3.6	35.6	122.1	38.5	28566	789	29	136.5	98.7	6.2	4102	125.8	Around the Kayseri bus station
Min	11.4	1.6	9.2	71.9	12.4	21422	521	13	72.1	35.2	3.3	1852	88.4	
Max	45.1	6.5	58.9	255.8	100.8	43251	1126	39	178.6	205.1	8.5	6587	200.8	
SD	7.64	0.35	2.19	46.27	24.73	6545.26	121.41	5.51	27.90	37.90	1.35	1172.44	32.42	
Mean	27.9	3.99	35.8	158.33	48.37	31516.83	771.83	28.52	118.11	107.48	6.34	3369.87	135.64	

TABLE-3
ELEMENT CORRELATIONS IN SOILS ALONG THE NIGDE-KAYSERI ROAD

	As	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sn	Ti	Zn
As	1												
Cd	-0.082												
Co	-0.261	-0.381	1										
Cr	0.018	0.172	-0.296	1									
Cu	0.055	-0.340	0.136	-0.280	1								
Fe	-0.077	0.087	-0.218	0.459(*)	-0.047	1							
Mn	0.040	0.005	-0.020	-0.052	0.072	-0.041	1						
Mo	-0.233	0.257	-0.025	0.181	0.029	0.037	0.128	1					
Ni	0.461(*)	-0.348	0.069	-0.239	0.242	0.033	0.203	-0.109	1				
Pb	0.023	0.045	0.219	-0.122	0.236	-0.194	-0.271	-0.141	-0.147	1			
Sn	0.000	-0.078	0.102	0.129	-0.246	-0.016	0.149	-0.213	-0.334	0.183	1		
Ti	-0.092	0.165	0.135	-0.069	-0.358	0.057	-0.286	0.279	-0.225	-0.262	-0.135	1	
Zn	-0.272	-0.309	0.191	0.368	0.304	0.004	0.117	0.258	-0.181	-0.076	-0.001	-0.343	1

Correlation is significant at the 00.05 level (2-tailed), $r_{Ni-As} = 0.461$ [sig(2-ta) = 0.027, $\alpha = 0.05$, N = 23] and $r_{Fe-Cr} = -0.459$ [sig(2-ta) = 0.028, $\alpha = 0.05$, N= 23]

The average concentrations of Fe and Mn exceed the limit value for soils but are lower than its abundance in the earth crust and shales. The average concentration of Sn exceeds the limit values of the earth crust and shales but is lower than its abundance in soils and National soil pollution control regulation. The average concentration of Ti does not exceed its abundance in the earth crust and shales. The average concentration of Zn exceeds the limit values of soil, shale and the earth crust but is lower than its abundance for National soil pollution control regulation (Table-2).

As shown from Table-2, in soil samples along all the studied profile, Pb accumulation is the maximum in NK5, As is the maximum in NK2, Cd is the maximum in NK21, Co is the maximum in NK5, Cr is the maximum in NK1, Mo is the maximum in NK19 and Ni is the maximum in NK11.

On the basis of results of analyses conducted on soil samples and correlation relations among the metals, positive correlations were detected between Ni & As and Fe & Cr. Correlation coefficients among these metals were calculated as $r_{Ni-As} = 0.461$ [sig(2-ta) = 0.027, $\alpha = 0.05$, N = 23] and $r_{Fe-Cr} = -0.459$ [sig(2-ta) = 0.028, $\alpha = 0.05$, N = 23] (Table-3). Similarly, on the basis of correlations among the metals, it was thought that metals with moderately positive correlations have the same possible pollution sources.

According to heavy metal contents of samples collected at 23 stations along the route, Hierarchical cluster analysis dendogram was drawn considering the distance coefficient. NK3, NK12, NK14, NK5 and NK9 stations have similar characteristics. Moreover, NK13 and NK18; NK11,

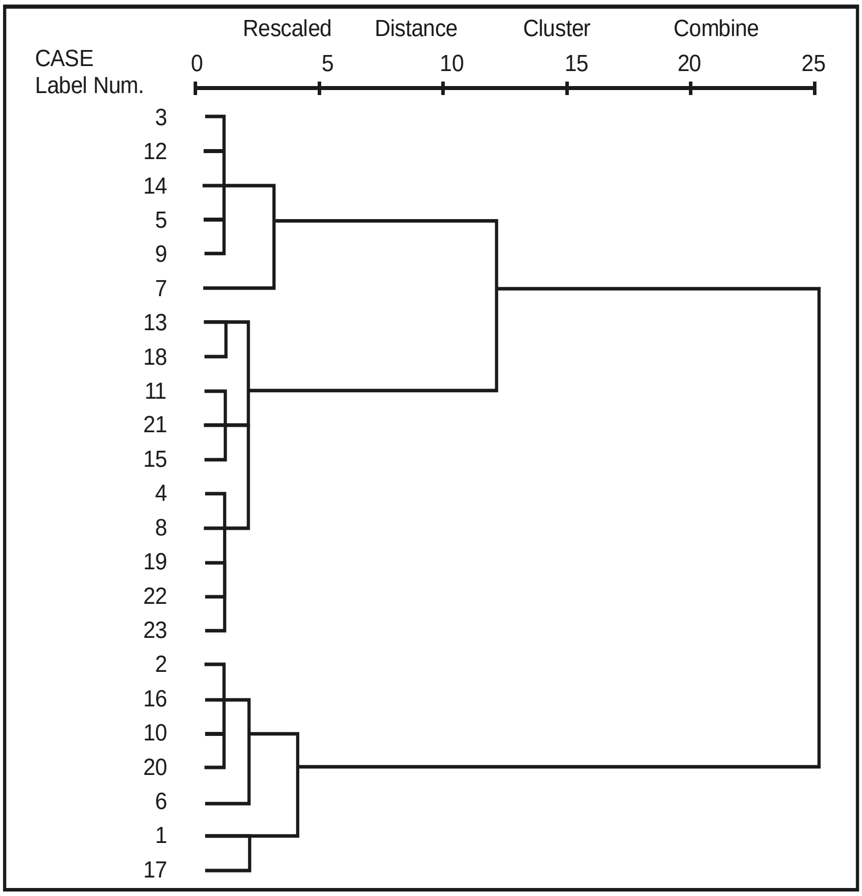

Fig. 2. Hierarchical cluster analysis dendogram for soil samples along the Nigde-Kayseri road

NK21 and NK15; NK4, NK8, NK19, NK22 and NK23; NK2, NK16, NK10 and NK20 stations also show similar characteristics. It was determined that the stations with similar features have also similar element contents. In this respect, it is thought that there is no different change along the route and the source of pollution is completely derived from intense traffic load (Fig. 2).

According to heavy metal contents investigated along the selected route, all the public open parks, schools and game sites around the D765 road are needed to be rebuilt. Residential sites should be rearranged. In general, in order to reduce the heavy metal contamination, the priority must be given to railway transportation. In establishment of new settlement areas and roads, the effect of traffic-based pollution should be taken into account. The use of unleaded oil products and LPG are needed to be encouraged.

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