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Heavy Metal Contamination Along the Nigde-Adana Highway, Turkey

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This study was conducted on the route of D805 and D750 state highways and TEM E90 motorway connecting the Nigde and Adana cities in central and southern Anatolia. The aim of study is to determine the heavy metal contamination in upper level of soil along the D805, D750 and TEM highways. 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. It was determined that heavy metal accumulation is closely associated with traffic intensity. The heavy metal ranges and averages for soil samples at D805, D750 and TEM E90 roads were found as 16980-62790 / 37907.76, 17.8-98.6 / 43.62, 20-217 / 71.65, 56.5-405.9 / 165.55, 3.6-5.1 / 4.33, 75.5-596.2 / 175.76, 169-1167 / 554.9, 24-79 / 39.47, 316-1289 / 764.97, 1830-5048 / 3088.23, 6.8-15 / 8.56, 22-26 / 23.89, 2.8-63.4 / 13.86 mg/kg for Fe, Cu, Pb, Zn, Cd, Ni, Cr, Co, Mn, Ti, Sn, Mo and As elements, respectively. In this study, all heavy metal contents to have a toxic effect.

Key Words: Heavy metal, Traffic contamination, Toxic, Highway, Nigde, Adana, Turkey.

INTRODUCTION

The Nigde-Adana highway is the most important road connecting the southern part of Turkey to the central (Kayseri and Nevsehir) and northern Anatolia (Fig. 1). The city of Nigde in the central Anatolia is an old settlement area. The city of Adana in the southern Anatolia is one of the most important industrial regions in Turkey. Therefore, population density of Adana has getting increased (*ca.* 1.9 million in 2000) and small- and moderate-scaled industrial facilities were intensified along the highway.

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Transhumance is very common in the Tekir region along the highway route between Adana and Pozanti. Due to increase in population, development of industry and traffic density, the amount of emissions was also increased accordingly. Therefore, there is a serious risk for environmental pollution.

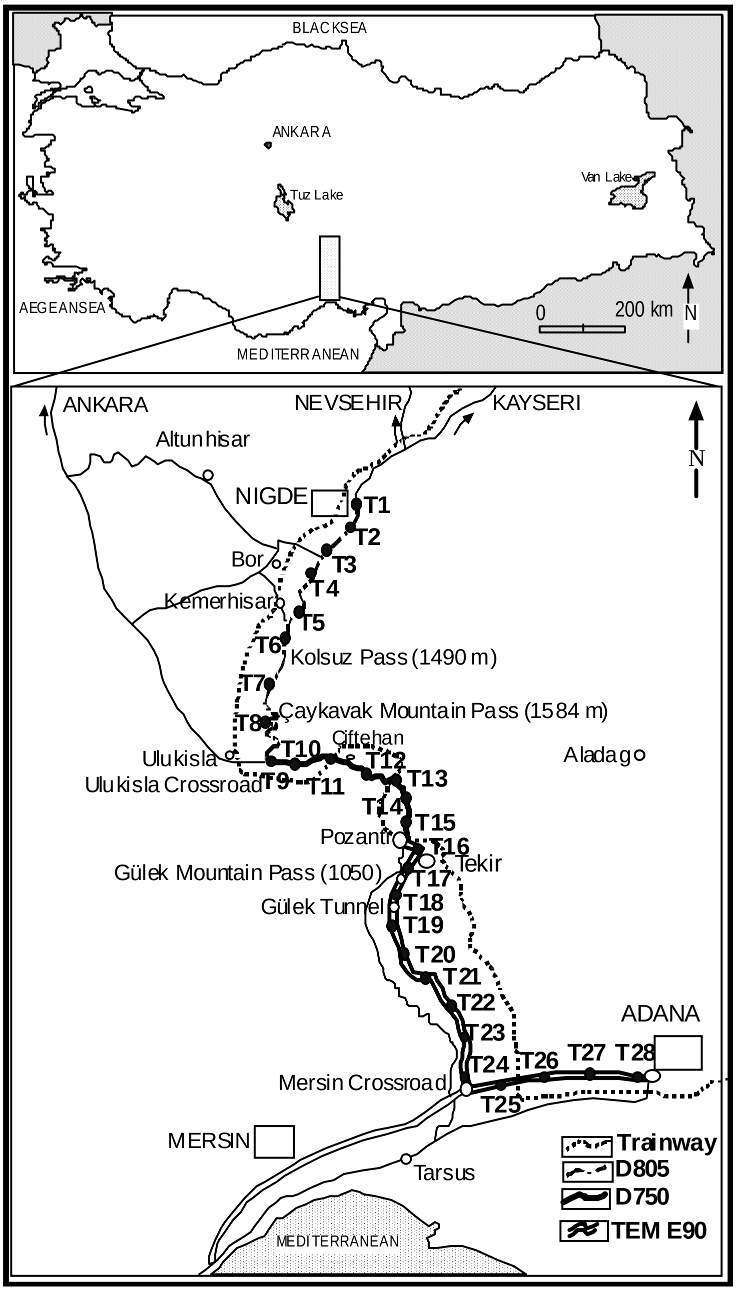

Fig. 1. Study area and sampling map

Heavy metals such as Fe, Cu, Pb, Zn, Cd, Ni, Cr, Co, Mn, Ti, Sn, Mo and As are the main reason for this pollution. Abundances of these elements in the earth crust are given in Table-1. In Turkey, by means of health, these concentrations may not be seriously taken into consideration (Table-1). Heavy metals are accumulated on the soil due to various reasons. This accumulation is the main indicator of the pollution[1-4].

TABLE-1
ABUNDANCE OF ELEMENTS IN THE EARTH CRUST[5]
AND THEIR ACCEPTABLE LIMITS[6]

Elements	Concentration in the earth crust (mg/kg)	Acceptable limit (mg/kg) (National Soil Pollution Control Regulation)
Fe	5.4×10^4	-
Cu	50	50
Pb	12.5	50
Zn	70	150
Cd	0.15	1
Ni	75	30
Cr	100	100
Co	20	20
Mn	1000	-
Ti	5000	-
Sn	2.5	20
Mo	1.5	10
As	1.8	20

Heavy metals such as lead, cadmium, tin, arsenic *etc.* are accumulated in high concentrations in the environment, may negatively affect the brain activities and behaviours of humans[7].

Therefore, heavy metals were selected as the topic of this research. Heavy metals may be derived from traffic, industrial activities and home wastes[4,8-10]. The maximum lead concentration in the soil along a highway is observed in ramps, oil stations, junctions and repair sites[4,11]. In addition, heavy metals are also found in repair sites at both sides of a road under heavy traffic. The close relation between heavy metal concentrations (particularly lead) and repair sites-heavy traffic-ramps was investigated by various workers[4,12-17]. Copper, iron, chromium and zinc elements in soil along the roads are the main material of various alloys, pipe, cable and tire in a car[18]. Nickel in gasoline and cadmium and zinc in tires and motor oils were found in high concentrations in several other works[19,20].

Recent studies indicate that environmental contamination along the roads is an important problem. Therefore, determination of environmental pollution along the roads and taking the necessary measurements are vitally important for human health and a cleaner environment. The aim of this study is to investigate the environmental pollution characteristics on the basis of heavy metal accumulation in the upper soil layer along the TEM E90, D750 and D805 highways which connect Southern and Central Anatolia (Kayseri and Nevsehir cities) and Northern Anatolia.

EXPERIMENTAL

In this study, the Nigde-Adana highways (Fig. 1) were selected in order to investigate the heavy metal contamination (Fe, Cu, Pb, Zn, Cd, Ni, Cr, Co, Mn, Ti, Sn, Mo and As) in the upper soil layer along the road sides. The study was conducted as a profile of 57 km at D805, 38 km at D750 and 110 km at TEM E90 highways.

The route selected acts as an important bridge between the Southern Anatolia and Central Anatolia/Northern Anatolia. There is a heavy traffic load, industry and population in the city of Adana. Compared to D805 and D750 highways, TEM E90 has higher standards. It was built in international standards following the construction of D805 and D750 highways.

Daily vehicle load for the year of 2004 is 3392 for D805, 11498 for D750 and 3556600 for TEM E90. It is noticeable that traveling time of vehicles on D750 is longer than those on D850 and TEM E90 [21].

Along the D805 profile, metamorphic rocks of the Nigde massive and the Alihocali Ophiolite are exposed. Metamorphic rocks of the Nigde massive are composed of gneiss, schist marble and quartzite alternation[22]. Rocks of the Alihocali Ophiolite are observed along about halt of the D750 route. Then until the Mersin junction of TEM E90 highway, limestone and dolomites of the Trodos Platform Carbonates are exposed. From the Mersin junction to the city center of Adana, limestone, dolomite, conglomerate, sand, clay and siltstones are cropped out[23].

Sampling and analyses

Soil sampling was made in November 2005 period. Total 32 samples were collected from soils along the D805, D750 and TEM E90 highways. 8 of the samples (T1-T8) are from D805, 7 (T9-T15) from D750 and 9 (T16-T24) from Mersin junction on TEM E90 and 4 from (T25-T28) on TEM E90 between Mersin junction and Adana. Samples were systematically collected in a 7-km distance from Nigde to Adana[4].

Samples were collected from the upper layer of soil at a depth of 5-10 cm and 28 of the samples were collected in a 10-m vertical distance to the road (Table-3) and 4 of them are along a 300-m vertical distance to the road (Table-4). All soil samples were collected with a stainless steel shovel. Samples were stored in plastic containers. Samples were dried at 105°C for 24 h. In order to separate conglomerates then they were sieved through

TABLE-2
RESULTS OF SAMPLES COLLECTED ALONG THE D805, D750 AND TEM E90 HIGHWAYS/MOTORWAYS

D805	Fe	Cu	Pb	Zn	Cd	Ni	Cr	Co	Mn	Ti	Sn	Mo	As	Explanations
T1	17830	18.4	43.7	78.5	4.7	25.9	311	22	451	2003	8.5	26	42	Nigde main junction
T2	16980	19	37.6	172.4	4.2	31.7	230	22	364	1667	8.6	26	17.2	In the vicinity of domain road junction
T3	51780	131.9	125.7	257.5	4.6	194.8	1024	56	1018	2529	7.5	24	16	After the Sazlıca town. close to oil station
T4	33060	32.1	105.6	220	4.8	57.2	764	27	805	2693	8.3	24	21.5	Havuzlu village junction
T5	42460	34.1	62.4	219.3	4.8	97.9	621	55	1080	3217	8.3	25	16.5	Climb down
T6	53090	33.3	34	121.5	5.2	105.1	183	57.5	3456	3066	8.7	23	13.6	Ramp
T7	51250	73.9	63.6	166.1	4.6	164.8	311	55.4	4087	3432	7.0	23	9.9	Next to new highway
T8	54420	54.4	94.3	269.1	4.6	121.6	243	87	1178	4480	6.8	22	11.1	Çaykavak climb down
Min	16980	18.4	34	78.5	4.2	25.9	183	22	364	1667	6.8	22	9.9	
Max	54420	131.9	125.7	269.1	5.2	194.8	1024	87	4087	4480	8.7	26	42	
Mean	**39227**	**54.74**	**72.66**	**185.2**	**4.69**	**101.97**	**489.4**	**49.09**	**1689**	**2923.4**	**7.92**	**24.1**	**19.97**	
D750	Fe	Cu	Pb	Zn	Cd	Ni	Cr	Co	Mn	Ti	Sn	Mo	As	
T9	38780	32.7	78.8	152.1	5.1	121.4	288	43.6	872	3786	8.1	26	8	Ulukışla junction (4km after)
T10	41170	40.3	50.4	90.4	4.4	106.2	274	51	853	3676	9.2	23	6.3	In the vicinity of settlement site (3km after)
T11	39140	54.7	80	247.1	4.7	109.5	169	49	833	2929	7.9	24	21.7	In the vicinity of settlement site and railway underpass
T12	37050	47.3	55	138	4.7	87.3	415	35.5	1004	3057	8.2	23	13.6	After the settlement site
T13	39620	47.9	171	213	4.8	213	366	30.8	833	3402	7.7	22	63.4	Railway overpass
T14	27220	48.8	217	405.9	4.2	96.5	321	27	709	2732	8.3	25	25.1	Pozantı Hayat Water
T15	35440	71.15	118.7	200.5	4.6	121.4	866	30.7	718	1830	8.3	25	5	Pozantı settlement area
Min	27220	32.7	50.4	90.4	4.2	87.3	169	27	709	1830	7.7	22	5	
Max	41170	71.15	217	405.9	5.1	213	866	51	1004	3786	9.2	26	63.4	

D805	Fe	Cu	Pb	Zn	Cd	Ni	Cr	Co	Mn	Ti	Sn	Mo	As	Explanations
Mean	**36312.22**	**49.63**	**115.37**	**215.92**	**4.64**	**128.4**	**414.89**	**38.4**	**837.22**	**3003.11**	**8.29**	**24**	**23.5**	
TEM E90	Fe	Cu	Pb	Zn	Cd	Ni	Cr	Co	Mn	Ti	Sn	Mo	As	
T16	55980	56.7	24.7	126.5	4.2	303.4	748	50.9	1289	3083	7.7	22	5.3	Highway ramp lane
T17	42120	40.6	104.3	175.2	4.4	596.2	1089	79	740	2078	7.8	25	2.8	Tekir ramp resting site, close to overpass, plateau
T18	62790	58.1	82.9	349.5	4.5	299.1	653	58	1280	5048	7.8	25	7.8	Entrance of Gülek Tunnel
T19	24590	17.8	20	75.5	4.5	75.5	612	31.7	316	1965	8.1	26	11.2	In the vicinity of Çamlıyayla junction, under the Tekir ramp
T20	30020	98.6	72.5	217.8	4	136.7	488	28	328	2101	8	24	9.1	Highway climb down, inside the slope
T21	41850	36.9	36	115.6	4.2	90	178	31	686	3368	8	26	9.3	Highway climb down
T22	35720	32	32.4	81.8	3.7	177.6	519	30	790	2696	15	24	7.3	Flat area
T23	27110	22.4	37.4	103.3	4.1	115.5	1167	24	807	2776	6.8	24	11.4	In the vicinity of Adana garbage dump, under the overpass
T24	36130	21.6	22.3	56.5	4.5	117.7	422	28.6	736	3590	7.1	23	9.9	Mersin junction
T25	38840	24.5	25.8	70.5	3.6	182.6	414	33	692	3353	13	22	11	Flat area
T26	35190	24.1	29.7	59.4	4.4	128.3	558	37.5	765	3512	7.2	24	8.8	New ticket windows
T27	43470	29.8	44.1	144.3	4.4	157.8	874	40.3	557	4043	7	23	12.2	Flat area
T28	34870	42.7	56.9	131.3	4.2	122.2	931	41.7	627	3675	7.3	23	6.7	Northern entrance to the Adana city
Min	24590	17.8	20	56.5	3.6	75.5	178	24	316	1965	6.8	22	2.8	
Max	62790	98.6	104.3	349.5	4.5	596.2	1167	79	1289	5048	15	26	12.2	
Mean	**39737.33**	**41.48**	**47.55**	**140.88**	**4.19**	**211.62**	**666.53**	**41.11**	**747.87**	**3220.07**	**8.84**	**23.93**	**8.52**	
General														
Min	24590	17.8	20	56.5	3.6	75.5	169	24	316	1830	6.8	22	2.8	
Max	62790	98.6	217	405.9	5.1	596.2	1167	79	1289	5048	15	26	63.4	
Mean	**37907.76**	**43.62**	**71.65**	**165.55**	**4.33**	**175.76**	**554.90**	**39.47**	**764.97**	**3088.23**	**8.56**	**23.89**	**13.86**	

the 2 mm plastic sieve. In the next stage, samples were homogenized with an agate mortar to a grain size of less than 2 mm. 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. Detection system is drift detector with Peltier cooling, energy resolution FWHM < 170 eV, measured for the Mn Kα line with an input count vote of 10.000 pulses, Microprocessor controlled detector and electronics.

In order to avoid from contamination during the sampling, preparation for analyses of samples, a special care was given to sample containers. The agate that was used for homogenization of samples was cleaned and rinsed for each sample. Results are given as mg/kg (Tables 2 and 3).

TABLE-3
ANALYSES RESULTS OF SAMPLES COLLECTED FROM 300 M INSIDE AT SOME STATIONS

	Fe	Cu	Pb	Zn	Cd	Ni	Cr	Co	Mn	Ti	Sn	Mo	As
T8a	31326	35.20	17.5	82.3	0.24	76.0	80	22.20	780	3642	2.8	1.0	3.7
T15a	32357	33.21	20.6	75.7	0.20	76.3	126	18.40	565	1120	4.3	1.0	1.5
T20a	28988	34.50	15.6	77.4	0.15	78.8	110	18.00	220	1852	4.2	1.2	2.9
T28a	30126	31.50	12.1	71.1	0.16	75.3	134	20.30	473	2864	3.2	1.2	2.5

a: collected from 300 m inside

RESULTS AND DISCUSSION

The heavy metal concentration range and averages for soil samples collected from D805, D750 and TEM E90 highways for Fe, Cu, Pb, Zn, Cd, Ni, Cr,Co, Mn, Ti, Sn, Mo and As elements are 16980-62790/37907.76, 17.8-98.6/43.62, 20-217/71.65, 56.5-405.9/165.55, 3.6-5.1/4.33, 75.5-596.2/175.76, 169-1167/554.9, 24-79/39.47, 316-1289/764.97, 1830-5048/3088.23, 6.8-15/8.56, 22-26/23.89, 2.8-63.4/13.86 mg/kg, respectively.

General overview of results for the D805, D750 and TEM E90 highways reveals that concentrations of Fe and Ti do not exceed the maximum abundance of these elements in the earth crust and that required by the National Soil Pollution Control Regulation. Sn concentrations are above the maximum abundance level in the earth crust but lower than that of the National Soil Pollution Control Regulation. Cd, Ni, Cr, Co and Mo concentrations exceed the maximum abundance of these elements in the earth crust and that of the National Soil Pollution Control Regulation and therefore, they are of toxic character.

As shown from Table-2, along all the soil profile, Fe accumulation is 16980 mg/kg as the minimum at T2 and 62790 mg/kg as the maximum at T18; Cu accumulation is 17.8 mg/kg as the minimum at T19 and 131.9 mg/kg as the maximum at T3; Pb accumulation is 20 mg/kg as the minimum at T19 and 217 mg/kg as the maximum at T14; Zn accumulation is 56.5 mg/kg as the minimum at T24 and 405.9 mg/kg as the maximum at T14; Cd accumulation is 3.6 mg/kg as the minimum at T25 and 5.2 mg/kg as the maximum at T6; Ni accumulation is 25.9 mg/kg as the minimum at T1 and 596.2 mg/kg as the maximum at T17; Cr accumulation is 169 mg/kg as the minimum at T11 and 1167 mg/kg as the maximum at T23; Co accumulation is 22 mg/kg as the minimum at T1 and 87 mg/kg as the maximum at T8; Mn accumulation is 316 mg/kg as the minimum at T19 and 4087 mg/kg as the maximum at T7; Ti accumulation is 1667 mg/kg as the minimum at T2 and 5048 mg/kg as the maximum at T18; Sn accumulation is 6.8 mg/kg as the minimum at T23 and 15 mg/kg as the maximum at T22; Mo accumulation is 22 mg/kg as the minimum at T8, T13, T16 and T25 and 26 mg/kg as the maximum at T1, T2, T9, T19 and T21 and As accumulation is 2.8 mg/kg as the minimum at T17 and 63.4 mg/kg as the maximum.

On the basis of results of analyses conducted on soil samples and correlation relations among the metals, there is moderate positive correlation for Ni-Fe, Mo-Fe, Pb-Cu, Pb-Ni, As-Ni and Mo-Ti metals ($r_{Ni\text{-}Fe}$ = 0.443 [sig(2-ta) = 0.018, α = 0.05, N = 28], $r_{Mo\text{-}Fe}$ = -0.467 [sig(2-ta) = 0.012, α = 0.05, N = 28], $r_{Pb\text{-}Cu}$ = 0.455 [sig(2-ta) = 0.015, α = 0.05, N = 28], $r_{Pb\text{-}Ni}$ = 0.385 [sig(2-ta) = 0.043, α = 0.05, N = 28], $r_{As\text{-}Ni}$ = -0.376 [sig(2-ta) = 0.049, α = 0.05, N = 28], $r_{Mo\text{-}Ti}$ = -0.437 [sig(2-ta) = 0.020, α = 0.05, N = 28]) (Table-4). Similarly, there is strong positive correlation for Mn-Fe, Sn-Cd, Cr-Ni and Mn-Co metals ($r_{Mn\text{-}Fe}$ = 0.556 [sig(2-ta) = 0.002, α = 0.05, N = 28], $r_{Ti\text{-}Fe}$ = 0.661 [sig(2-ta) = 0.000, α = 0.05, N = 28], $r_{Cr\text{-}Pb}$ = 0.487 [sig(2-ta) = 0.009, α = 0.05, N = 28], $r_{Sn\text{-}Cd}$ = 0.537[sig(2-ta) = 0.003, α = 0.05, N = 28], $r_{Cr\text{-}Ni}$ = 0.505 [sig(2-ta) = 0.006, α = 0.05, N = 28], $r_{Mn\text{-}Co}$ = 0.533 [sig(2-ta) = 0.004, α = 0.05, N = 28]) (Table-4). Therefore, it was thought that metals with strong positive correlation have the same possible pollution sources.

Variance analysis was performed among 13 elements for total 28 samples collected along the route and the results are given in Table-6. For the elements, 0.109 (F), 1.000 (significant) was determined. In addition, the value of variance was found as very low (R^2 = 0.009). In this respect, it is believed that even the number of samples had been increased to more than 28, results of analyses would not be changed.

TABLE-4
CORRELATION COEFFICIENTS AMONG THE METAL CONCENTRATIONS

	Fe	Cu	Pb	Zn	Cd	Ni	Cr	Co	Mn	Ti	Sn	Mo	As
Fe	1000												
Cu	0.040	1000											
Pb	0.239	0.455*	1000										
Zn	0.284	0.199	0.360	1000									
Cd	0.226	0.004	-0.036	-0.117	1000								
Ni	0.443*	0.015	0.385*	0.253	-0.076	1000							
Cr	0.051	0.248	0.487**	0.008	-0.056	0.505**	1000						
Co	0.312	0.110	-0.203	-0.281	0.309	0.024	-0.010	1000					
Mn	0.556**	-0.016	-0.023	0.067	0.290	0.093	-0.228	0.533**	1000				
Ti	0.661**	-0.278	-0.026	0.127	0.242	0.047	-0.154	0.223	0.246	1000			
Sn	-0.106	0.100	0.101	0.067	0.537**	-0.029	0.057	0.021	-0.116	-0.132	1000		
Mo	-0.467*	0.097	0.114	0.241	0.049	-0.093	-0.015	-0.335	-0.316	-0.437*	0.186	1000	
As	-0.107	-0.189	-0.333	-0.112	0.138	-0.376*	-0.249	0.000	-0.006	0.049	0.156	-0.223	1000

*Correlations is significant at the 0.05 level, **Correlations is significant at the 0.01 level

TABLE-5

TESTS BETWEEN CONCENTRATIONS OF ALL OF THE 28 DATA

Source	Type III sum of squares	Df (degree of freedom)	Mean square (average of squares)	F	Significant
Corrected model	358031418[a]	27	13260422.88	0.109	1.000
Intercept	4944864858	1	4944864858	40.706	0.000
Element	358031418	27	13260422.88	0.109	1.000
Error	4.082 E ± 10	336	121477804.1		
Total	4.612 E ± 10	364			
Corrected total	4.117 E ± 10	363			

In samples of D805, heavy metals with concentrations above the maximum abundance of the earth crust and the National Soil Pollution Control Regulation are found as Cu, Pb, Zn, Cd, Ni, Cr, Co, Mn and Mo which have a toxic effect. Sn and Sr concentrations are close to limit values. In samples of D750, heavy metals with concentrations high than the maximum abundance of the earth crust and the National Soil Pollution Control Regulation are determined as Pb, Zn, Cd, Ni, Cr, Co, Mo and As. Concentrations of Cu, Mn and Sn are close to limit values. In samples of TEM E90, heavy metals with concentrations above the maximum abundance of the earth crust and the National Soil Pollution Control Regulation are found as Cd, Ni, Cr, Co and Mo. Concentrations of Pb, Zn, Mn, Sn and As are close to limit values.

Anomalies determined along the route are closely associated with the sample locations such as residential areas and ramps on the roads. Heavy metal concentrations at D850 highway show an increase at junctions and ramps. In fact, there is a contamination trend at most of sample sites. In addition, similar results are also observed along the D750 highway. The impact of industrial facilities in the vicinity of residential areas is more pronounced at the D750 highway. Particularly, T13, T14 and T15 locations are characterized with higher heavy metal concentrations. In general, heavy metal contents at TEM E90 are lower which was built later than D805 and D750 highways. There is an increase in heavy metal concentrations at overpass (T17) in the vicinity of a residential site at TEM E90 highway. The reason for this contamination could be heavy traffic as well as an additional pollution from the overpass. Samples collected from D805- D750 and TEM E90 highways were evaluated with variance analysis (Table-6) and the significance of processes was tested. In this respect, it was found that there is no significant difference among the results (Fig. 2). On the basis of statistical analyses, R^2 and r^2 found as 0.009 and -0.071, respectively.

TABLE-6
TESTS BETWEEN CONCENTRATIONS DATA MEAN OF THE D805- D750 -TEM E90 WAYS

Source	Type III sum of squares	Df (degree of freedom)	Mean square (average of squares)	F	Significant
Corrected model	358031418[a]	27	13260422.88	0.109	1.000
Intercept	4039270521	1	4039270521	33.251	0.000
D805- D750 - TEM E90 roads	3058766.367	2	1529383.184	0.013	0.987
Element	100607095	12	8383924.593	0.069	1.000
Roads *Element	254671152	13	19590088.60	0.161	1.000
Error	4.082 E ± 10	336	121477804.1		
Total	4.612 E ± 10	364			
Corrected total	4.117 E ± 10	363			

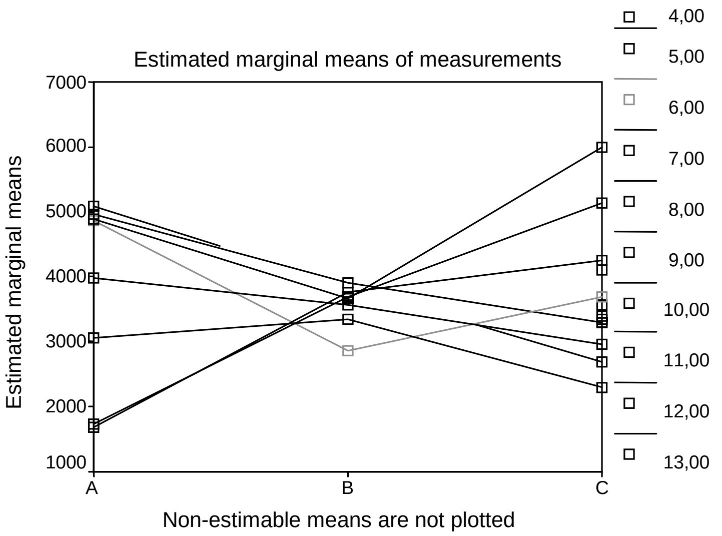

Fig. 2. Limit values of soil concentrations along the D805-D750 and TEM E90 roads

The diagram showing the coefitic distance coefficients of soil samples collected along the D805, D750 and TEM E90 highways is given in Fig. 3. It was shown in this diagram that there is a very high similarity among samples nos. 26, 28, 24, 22 and 12; a high similarity between samples nos. 1 and 2; a similarity between samples nos. 10, 21, 5, 27 and 9, 25, 11. Considering the locations of samples, there is also similarity among the road characteristics.

The average heavy metal concentrations in soils along the D805 and D750 highways are higher than those at TEM E90 motorway. This is attributed to the fact that D805 and D750 highways were built before the TEM E90 motorway and vehicles on the former roads have higher traveling times.

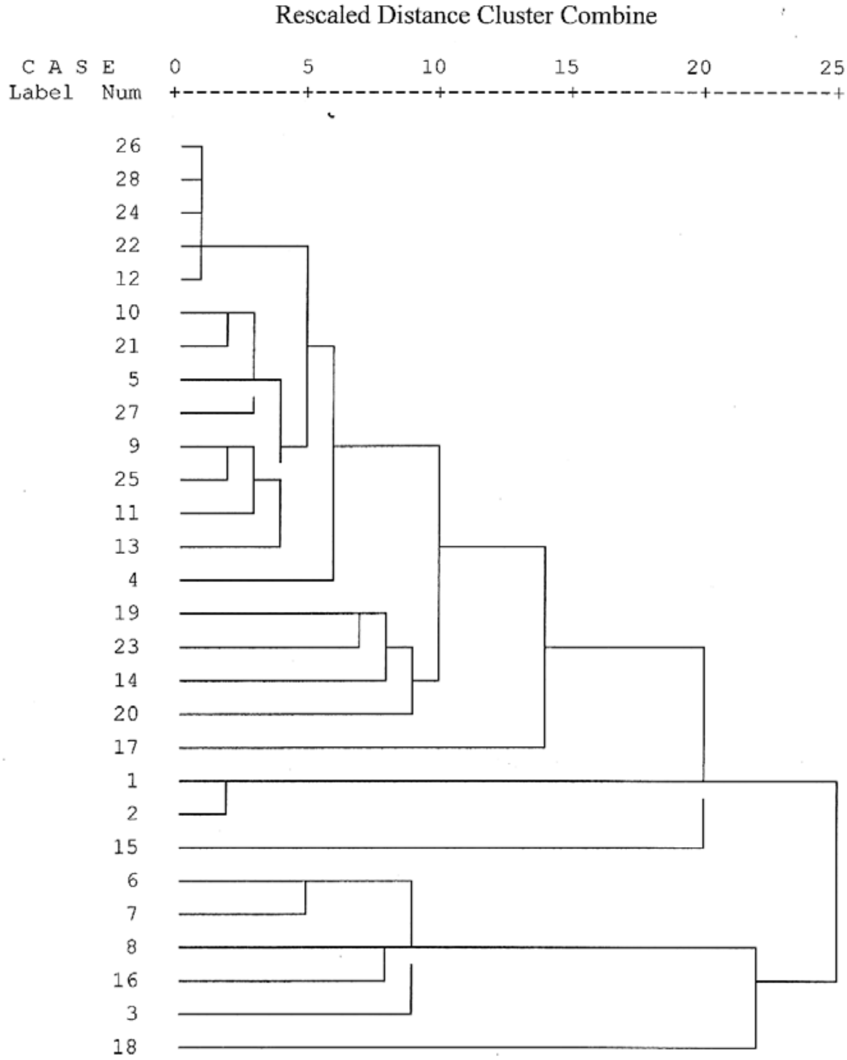

Fig. 3. Coefitic distance coefficients for samples collected from soil along the D805, D750 and TEM E90 highways

The average concentrations of heavy metals along the D805, D750 roads and TEM E90 highway for Fe, Cu, Pb, Zn, Cd, Ni, Cr, Co, Mn, Ti, Sn, Mo and As elements are 37907.76, 43.62, 71.65, 165.55, 4.33, 175.76, 554.9, 39.47, 764.97, 3088.23, 8.56, 23.89 and 13.86 mg/kg, respectively. On the basis of these values, Pb, Zn, Cd, Ni, Cr, Co and Mo show toxic characteristics.

At D750 which is the oldest road among others and has higher traffic load, Pb, Zn, and As concentrations are significant. Cu, Cd, Ni, Mn, Ti, Sn and Mo contents are also high. At D805 between Ulukisla and Nigde, concentrations of Cu, Cd, Co, Mn and Mo are higher in comparison to other roads. Fe, Pb, Zn, Cr and As contents are also high. At TEM E90, concentrations of Fe, Ni, Cr, Ti and Sn are higher in comparison to other roads.

Although heavy metal contamination is the least at TEM E90, it was observed that soil contamination at this road is getting increased in association with heavy traffic.

According to heavy metal contents investigated along the selected routes, agricultural activities around the particularly D805 and D750 highways should be prohibited. All public open parks, schools and game sites for children around these roads are needed to be rebuilt. Residential sites should be rearranged. In general, in order to minimize the heavy metal contamination in the region, a special importance must be given to air, sea and 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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