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DETERMINATION OF HEAVY METAL CONTAMINATION IN SURFACE SOILS BY ARTIFICIAL TRACTS USING CROSS SECTIONAL ANALYSIS

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Abstract

In this study, the concentrations of cadmium, lead and chrome were determined in soil samples collected in and around the Çorlu District in Tekirdağ (Thrace) province, where industry is highly developed and there are fertile lands for agricultural production. Soil samples collected from 14 agricultural lands have been prepared for analysis through extraction process in a microwave oven. Heavy metal concentrations have been studied through ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry). Additionally, physical and chemical characteristics of the soil have been analysed. Correlation between Cd, Pb and Cr has been specified through physical and chemical analysis results of soil samples and the results obtained have been statistically evaluated. We measure the effects of the physical and chemical characteristics on three different heavy metals using cross sectional regression analysis.

Key words: *Heavy metal, Lead, Cadmium, Chrome, Cross-section*

1. INTRODUCTION

Heavy metals found within the structure of the chemicals are used in industry and agriculture accumulates in the soil and, thus, they cause the soil to be polluted. Accumulation of heavy metals in the soil affects the fertility. Cadmium (Cd) mixes into the soil through different ways. 54-58% of Cd, which mixes in the soil surface from utilisation of fertilizers, 39-47% of which from atmosphere and 2-5% of which from sewage, and it is pointed out that total amount of the element in the soil does not hold importance but the dynamism of the element and the fact that existence of the element in the soil as organic or inorganic complexes are more important [1]. Cd found in the sediment beneath the oceans' bed reaches the soil through raw phosphate and consequently phosphorous fertilizers. However, the amount of the Cd that mixes in the soil is not definitely known [2-3].

Every year at least 5 million tons of lead cause lead contamination to increase in our environment and foods as a result of various usages. The most important cause of contamination is tetraethyl lead, which is added to petrol with the purpose of improving its octane rating. Therefore, lead contamination has been observed in the milk of various farm animals that crop on the grasslands close to motorways [4].

It is stated that 300 ppm Cr exists in the soils of Germany, which are contaminated with mostly 5-100 ppm industrial waste water [5]. In Italy, 31-317 ppm Cr has been found on the surface soils of agricultural lands where iron-steel and electronic industries are located [6]

In Turkey, the Regulation for Soil Contamination Control has delivered maximum concentration level for total chrome as 100 mg/kg in agricultural soils, which holds the value pH>6 [7]. Chrome is generally found as +3 value +6 value chrome is commonly used in alutation, electroplating, dye

pigment and dye works, steel and automobile manufacturing industries +6 value chrome is also found in nuclear waste of energy establishments [8].

In this study, the concentrations of cadmium, lead and chrome were determined in the soil samples collected in and around Çorlu District in Tekirdağ (Thrace) province. Then, the effects of the physical and chemical characteristics on three different heavy metals were measured using cross sectional regression analysis.

2. MATERIALS AND METHODS

2.1. Experimental Methods

Within the scope of the study, with the purpose of determining the dimensions of soil contamination in and around Çorlu, which possess fertile soils used for agricultural production and in the areas where industry is intensively located, soil samples were taken from 14 different stations that may represent soil characteristics between May 2006 and May 2007 within 4 separate periods as May 2006, September 2006, January 2007 and May 2007. The samples were first air-dried and then pressed and crushed with the purpose of turning them into homogeneous form from lump form. After they were dried in a drying oven for 24 hours at 105^0C, it was beaten within porcelain mortar without crushing stone, etc. Various physical and chemical treatments were applied to the samples, which were filtered with a 2 mm diameter sieve [9]. Through glass electrode pH meter device from saturated soil-paste [10], through Scheibler calcimetre with (%$CaCO_3$) lime percentage, total nitrogen (N%) macro-Kjeldahl method [11], through removable phosphor (P%) Bingham method [12]. Heavy metals in the soils (Cd, Pb, and Cr) have been extracted within the liquid, which has been prepared in a microwave oven and they have been measured with [13] ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry, Perkin Elmer Optima 2100 DV) device.

2.1.1. Methodology

This paper considers regression models for cross-section data that exhibit cross-section dependence due to common shocks, such as macroeconomic shocks. By common shocks, we mean environmental and health shocks. Andrews [14] quotes that according to him [15] it seems apparent that common shocks are a likely feature of cross-section economic data. This is true whether the population units in the cross-section regression are individuals, households, industrial pollution, plants, and soil. The results of our paper allow for cross-section dependence of various soil species collected from different stations. These shocks typically are not the same across different population units. Various soil species are different according to their physical and chemical characteristics. In the extreme, some common shocks may have no affect on some population units.

A standard model of panel data set composed of cross sectional and time series units can be specified as follows:

$$y_{it} = x_{it}b_{it} + e_{it} \qquad (1)$$

where i = 1, 2, ..., N refers to a cross-section unit (individual), and t = 1, 2, ..., T refers to time period. y_{it} and x_{it} are the dependent variable and the vector of non-stochastic explanatory variables for individual i at time t, respectively. b_{it} are unknown coefficients that are assumed to vary with respect to individuals and time, and e_{it} is the error term. The restrictive assumptions on these coefficients lead to various models. In our paper, we estimate the cross-sectional regressions, which can be given as follows:

$$Cd_i = \alpha_i + \beta' X_i + u_i \quad (2)$$

where dependent variable Cd_i (mg/kg) denotes heavy metal. X_i is the independent variables, which are pH, total salt, phosphor, $CaCO_3$, organic substance and nitrogen. u_i is an unobserved scalar error. β_i are unknown coefficients that vary with respect to individuals. The restrictive assumptions on these coefficients lead to various models. The model given by equation (2) is estimated for 14 different stations including soil species.

$$Pb_i = \alpha_i + \beta' X_i + u_i \quad (3)$$

where dependent variable Pb_i(mg/kg) denotes heavy metal X_i are the independent variables which are pH, total salt, phosphor, $CaCO_3$, organic substance and nitrogen. u_i is an unobserved scalar error. For the model given by equation (3) the cross sectional units are 14 different stations including soil species.

$$Cr_i = \alpha_i + \beta' X_i + u_i \quad (4)$$

where dependent variable Cr_i(mg/kg) denotes heavy metal. X_i is the independent variables, which are pH, total salt, phosphor, $CaCO_3$, organic substance and nitrogen. u_i is an unobserved scalar error.

2.2. Results and Discussion

The effects of the physical and chemical characteristics on three different heavy metals' concentrations were determined. All regressions are undertaken using Eviews 6 program. In all regressions, the cross sectional units are 14 different stations including soil species.

As a result of the analyses carried out, it has been observed that soil samples contain a pH value varying between light acid and light alkene but they are lime-poor and do not have any problem of salt. Also, 42% of the soil samples are humic soil (2-4%), and 58% of soil samples are humus-poor (1-2%)

It has also been observed that Cd content of the sample soils are between 0 and 2.44 mg/kg, Pb content is between 12.15 and 181.5 mg/kg, Cr content is between 10.13 and 150.1 mg/kg.

2.2.1. *Cd Heavy Metal Levels Measured in May 2006 and Its Determinants*

The OLS results of estimating Cd heavy metal levels measured in may 2006 using the independent variables such as pH, total salt, phosphor, $CaCO_3$, organic substance and nitrogen are shown in table1.

Table1.

Cr Measured in May 2006

Dependent Variable: CrMay2006				
Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficient	Std.	t-	Prob.
c	0.164	0.500	0.328	0.743
trend	0.152	0.011	13.26	0.000
pH	-0.333	0.079	-4.202	0.000

Totalsalt	2.568	0.322	7.957	0.000
Phosfor	-0.021	0.002	-8.662	0.000
Nitrogen	32.24	4.213	7.653	0.000
$CaC0_3$	0.538	0.116	4.637	0.000
Ors	-0.755	0.105	-7.140	0.000
R-squared	0.590	Mean dependent		0.214
Adjusted R-squared	0.575	S.D. dependent		0.635
S.E. of regression	0.414	Akaike info		1.115
Sum squared resid	32.25	Schwarz criterion		1.248
Log likelihood	-101.28	Hannan-Quinn		1.169
F-statistic	38.766	Durbin-Watson		2.044
Prob(F-statistic)	0.0000			

CdMay2006=0.16+0.15trend-0.33pH+2.56Totalsalt-0.02phosphor+32.24Nitrogen+0.53$CaCO_3$-0.75Ors (5)

where CdMay2006 shows the Cd(mg/kg) level measured in May 2006 and Ors denotes organic substance in equation (5). In Model 1 all variables are found to be significant. The goodness-of-fit statistics are reported in Table 1, which are adjusted R square, sum of error of regression, Durbin Watson statistics for autocorrelation. Adjusted R-square indicates that physical and chemical characteristics explain 59% of the variation in Cd (mg/kg) heavy metal measured in May 2006. The sum of errors of regression for Model 1 is found to be 0.41, which is quite low. Durbin Watson test statistics for autocorrelation is found to be 2.044 indicating no autocorrelation for this model. According to model 1 Cd heavy metal level measured in May 2006 is affected positively by trend, total salt, nitrogen and $CaCO_3$ variables. However, it is affected negatively by pH and phosphor variables. Nitrogen variable is the most effective variable on Cd heavy metal measurement level, since its coefficient is found to be the 32.24.

2.2.1.1.Cd Heavy Metal Levels Measured in September 2006 and Its Determinants

The OLS results of estimating Cd heavy metal levels measured in September 2006 using the independent variables explanatory variables such as pH, total salt, phosphor, $CaCO_3$, organic substance and nitrogen are shown in table 2.

Table2.

Cr Measured in September 2006

Dependent Variable: CrSep2006				
Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficient	Std.	t-Statistic	Prob.
c	-0.457	0.23	-1.907	0.057
trend	-0.002	0.00	-0.448	0.654
pH	0.040	0.03	1.056	0.291
Totalsalt	-0.431	0.15	-2.791	0.005
Phosfor	0.007	0.00	5.996	0.000
Nitrogen	26.43	2.01	13.09	0.000
$CaC0_3$	-0.103	0.05	-1.865	0.063
Ors	-0.740	0.05	-14.58	0.000
R-squared	0.895	Mean dependent		0.167
Adjusted R-squared	0.892	S.D. dependent		0.604
S.E. of regression	0.198	Akaike info		-0.355
Sum squared resid	7.408	Schwarz criterion		-0.222
Log likelihood	42.87	Hannan-Quinn		-0.301
F-statistic	231.17	Durbin-Watson		1.467
Prob(F-statistic)	0.000			

CdSep2006=-0.457-0.002trend+0.04pH-0.431Totalsalt+0.007phosphor+26.43Nitrogen-0.103$CaCO_3$-0.74Ors (6)

where CdSep2006 shows the Cd(mg/kg) level measured in September 2006 and Ors denotes organic substance in equation (6). In Model 2, total salt, phosphor, nitrogen, $CaCO_3$ and ors variables are found to be statistically significant at 5% significance level. The goodness-of-fit statistics reported in Table 2 suggest that R-square is 0.89. Therefore, physical and chemical characteristics explain 89% of the variation in Cd (mg/kg) heavy metal measured in September 2006. The sum of errors of regression for Model 2 is found to be 0.19, which is lower than that of Model 1. Model 2 is found to be a better description of Cd(mg/kg) heavy metal measurements than Model 1. According to model 2, Cd heavy metal level measured in September 2006 is affected positively by pH, phosphor and nitrogen levels. This finding contrasts with the findings of Model 1, where Cd measurement level is affected positively pH and phosfor levels. Cd(mg/kg) heavy metal measurements are affected negatively by trend, total salt, $CaCO_3$ and ors variables. Similarly,

nitrogen is found to be the most effective variable on Cd heavy metal measurement level, since its coefficient is found to be 26.43.

2.3. *Cd Heavy Metal Levels Measured in May 2007 and Its Determinants*

The OLS results of estimating Cd heavy metal levels measured in May 2007 using the independent variables explanatory variables such as pH, total salt, phosphor, $CaCO_3$, organic substance and nitrogen are shown in table 3.

Table3.

Cr Measured in May 2007

Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficient	Std.	t-Statistic	Prob.
c	-5.136	0.40	-12.76	0.00
trend	0.012	0.00	1.598	0.16
pH	0.755	0.06	11.82	0.00
Totalsalt	-0.312	0.25	-1.204	0.22
Phosfor	0.028	0.00	14.58	0.00
Nitrogen	-32.37	3.38	-9.557	0.00
$CaC0_3$	-0.860	0.09	-9.209	0.00
Ors	0.477	0.08	5.611	0.00
R-squared	0.666	Mean dependent		0.280
Adjusted R-squared	0.654	S.D. dependent		0.566
S.E. of regression	0.333	Akaike info		0.678
Sum squared resid	20.85	Schwarz criterion		0.812
Log likelihood	-58.53	Hannan-Quinn		0.733
F-statistic	53.76	Durbin-Watson		2.961
Prob(F-statistic)	0.000			

$$CdMay2007=-5.136+0.012trend+0.755pH-0.312Totalsalt+0.028phosphor-32.37Nitrogen-0.86CaCO_3+0.477Ors \quad (7)$$

where CdMay2007 shows the Cd (mg/kg) level measured in May 2007 and Ors denotes organic substance in equation (7). In Model 3, other than total salt level, all variables are found to be statistically significant. The goodness-of-fit statistics reported in Table 3 suggest that R-square is 0.66. So that physical and chemical characteristics explain 66% of the variation in Cd(mg/kg) heavy metal measured in May 2007. The sum of errors of regression for Model 3 is found to be 0.33.

According to Model 3, Cd heavy metal level measured in May 2007 is affected positively by pH, phosphor and organic substance levels, whereas it is affected negatively by total salt, nitrogen and $CaCO_3$ levels. Still, nitrogen is the most effective variable for determining Cd measurements, which took place in May 2007.

2.4. *Pb Heavy Metal Levels Measured in May 2006 and Its Determinants*

The OLS results of estimating Pb heavy metal levels measured in May 2006 using the physical and chemical characteristics as independent variables are presented in table 4.

Table4.

Pb Measured in May 2006

Dependent Variable: PbMay2006				
Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficient	Std.	t-Statistic	Prob.
c	75.48	18.4	4.083	0.0001
trend	1.601	0.42	3.775	0.0002
pH	-13.39	2.93	-4.566	0.00
Totalsalt	78.60	11.9	6.595	0.00
Phosfor	-0.413	0.09	-4.580	0.00
Nitrogen	494.9	155.	3.181	0.0017
$CaC0_3$	29.95	4.29	6.982	0.00
Ors	-3.654	3.90	-0.934	0.351
R-squared	0.499	Mean dependent		49.110
Adjusted R-squared	0.481	S.D. dependent		21.236
S.E. of regression	15.29	Akaike info		8.3330
Sum squared resid	43987.48	Schwarz criterion		8.4668
Log likelihood	-808.63	Hannan-Quinn		8.3872
F-statistic	26.83	Durbin-Watson		1.3181
Prob(F-statistic)	0.000			

$$PbMay2006=75.48-1.6trend-13.29pH+78.6Totalsalt-0.413phosphor+494.9Nitrogen+29.95CaCO_3-3.65Ors \quad (8)$$

where PbMay2006 shows the Pb (mg/kg) level measured in May 2006 and Ors denotes organic substance in equation (8). In Model 4 other than ors level, all variables are found to be statistically significant. R-square indicates that physical and chemical characteristics explain 49% of the variation in Pb (mg/kg) heavy metal measured in May 2006. The sum of errors of regression for

Model 5 is found to be 15.29. According to Model 4 Pb heavy metal level measured in May 2006 is affected positively and very effectively by total salt, nitrogen and $CaCO_3$ variables, whereas pH, phosphorus and organic substance levels affect it negatively. Nitrogen and total salt are found to be most important variables affecting Pb levels.

2.5. Pb Heavy Metal Levels Measured in September 2006 and Its Determinants

The OLS results of estimating Pb heavy metal levels measured in September 2006 using the physical and chemical characteristics as independent variables are presented in table 5.

Table5.

Pb Measured in September 2006

Dependent Variable: PbSep2006				
Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficien	Std.	t-Statistic	Prob.
c	242.62	42.8	5.662	0.00
trend	-4.7397	0.98	-4.820	0.00
pH	-8.8363	6.80	-1.299	0.195
Total salt	-62.694	27.6	-2.269	0.024
Phosphor	0.9756	0.20	4.667	0.00
Nitrogen	-1519.27	360.	-4.212	0.00
$CaC0_3$	-22.343	9.94	-2.246	0.025
Ors	2.2201	9.06	0.245	0.806
R-squared	0.363	Mean dependent		67.24
Adjusted R-squared	0.339	S.D. dependent		43.64
S.E. of regression	35.460	Akaike info		10.01
Sum squared resid	236405.7	Schwarz criterion		10.148
Log likelihood	-973.440	Hannan-Quinn		10.068
F-statistic	15.350	Durbin-Watson		2.7307
Prob(F-statistic)	0.0000			

$$PbSep2006=242.62-4.73trend-8.83pH-62.69Totalsalt-0.97phosphor-1519.27Nitrogen-22.34CaCO_3+2.22Ors \quad (9)$$

where PbSep2006 shows the Pb (mg/kg) level measured in September 2006 and Ors denotes organic substance in equation (9). In Model 5 other than pH and ors variables, all variables are found to be statistically significant. R-square indicates that physical and chemical characteristics explain 36% of the variation in Pb (mg/kg) heavy metal measured in September 2006. The sum of errors of regression for Model 5 is found to be 35.46. According to model 5 Pb heavy metal level measured in September 2006 is affected positively by phosphorus and ors levels, on the other hand

it is affected negatively by pH, total salt, nitrogen and $CaCO_3$ variables. Similar to Model 4 nitrogen and total salt are found to be most important variables affecting Pb levels.

3. Pb Heavy Metal Levels Measured in January 2007 and Its Determinants

The OLS results of estimating Pb heavy metal levels measured in January 2007 using the physical and chemical characteristics as independent variables are presented in Table 6.

Table 6.

Pb Measured in January 2007

Dependent Variable: PbJan2007				
Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficient	Std.	t-Statistic	Prob.
c	1.659	15.0	0.109	0.912
trend	-0.772	0.34	-2.231	0.026
pH	2.160	2.39	0.902	0.368
Totalsalt	78.42	9.72	8.061	0.000
Phosfor	-0.113	0.07	-1.543	0.124
Nitrogen	-149.95	126.	-1.180	0.239
$CaC0_3$	7.687	3.50	2.195	0.029
Ors	3.664	3.19	1.148	0.252
R-squared	0.643	Mean dependent		53.1
Adjusted R-squared	0.630	S.D. dependent		20.53
S.E. of regression	12.48	Akaike info		7.926
Sum squared resid	29306.2	Schwarz criterion		8.060
Log likelihood	-768.81	Hannan-Quinn		7.981
F-statistic	48.488	Durbin-Watson		1.702
Prob(F-statistic)	0.000			

$$PbJan2007=1.659-0.772trend+2.16pH+78.42Totalsalt-0.113phosphor-149.95Nitrogen-7.68CaCO_3+3.664Ors \quad (10)$$

where PbJan2007 shows the Pb (mg/kg) level measured in January 2007 and Ors denotes organic substance in equation (10). In Model 6 trend, total salt and $CaCO_3$ variables are found to be statistically significant. R-square indicates that physical and chemical characteristics explain 64% of the variation in Pb (mg/kg) heavy metal measured in January 2007. The sum of errors of regression for Model 6 is found to be 12.48. According to model 6 Pb heavy metal level measured in January 2007 is affected positively by pH, total salt, $CaCO_3$ and Ors, on the other hand it is

affected negatively by trend, phosphor and nitrogen variables. Total salt is found to be most important variable affecting Pb levels significantly.

3.1.Pb Heavy Metal Levels Measured in May 2007 and Its Determinants

The OLS results of estimating Pb heavy metal levels measured in May 2007 using the physical and chemical characteristics as independent variables are presented in table7.

Table 7.

Pb Measured in May 2007

Dependent Variable: PbMay2007				
Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficien	Std.	t-Statistic	Prob.
c	36.12	15.49	2.331	0.02
trend	-0.975	0.355	-2.742	0.006
pH	-2.924	2.459	-1.189	0.23
Totalsalt	72.01	9.991	7.207	0.00
Phosfor	-0.105	0.075	-1.397	0.164
Nitrogen	-67.31	130.4	-0.516	0.606
$CaC0_3$	11.84	3.596	3.293	0.001
Ors	-0.348	3.276	-0.106	0.915
R-squared	0.593	Mean dependent var		45.75
Adjusted R-squared	0.578	S.D. dependent var		19.75
S.E. of regression	12.82	Akaike info criterion		7.980
Sum squared resid	30913.3	Schwarz criterion		8.114
Log likelihood	-774.0	Hannan-Quinn		8.034
F-statistic	39.241	Durbin-Watson stat		2.044
Prob(F-statistic)	0.000			

$$PbMay2007=36.12-0.975trend-2.924pH+72.01Totalsalt-0.105phosphor -67.31Nitrogen-11.84CaCO_3-0.593Ors \quad (11)$$

where PbMay2007 shows the Pb (mg/kg) level measured in May 2007 and Ors denotes organic substance in equation (11). In Model 7 trend, total salt and $CaCO_3$ variables are found to be statistically significant. R-square indicates that physical and chemical characteristics explain 59% of the variation in Pb (mg/kg) heavy metal measured in January 2007. The sum of errors of regression for Model 7 is found to be 12.82. According to Model 7 Pb heavy metal level measured in May 2007 is affected positively by total salt and $CaCO_3$, on the other hand it is affected

negatively by pH, trend, phosphor, ors and nitrogen variables. Total salt is found to be most important variable affecting Pb levels significantly.

3.1.1.Cr Heavy Metal Levels Measured in May 2006 and Its Determinants

The OLS results of estimating Cr heavy metal levels measured in May 2006 using the physical and chemical characteristics as independent variables are presented in table 8.

Table 8.

Cr Measured in May 2006

Dependent Variable: CrMay2006				
Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficien	Std.	t-Statistic	Prob.
c	81.00	23.54	3.439	0.0007
trend	0.474	0.540	0.877	0.38
pH	-10.96	3.737	-2.934	0.0038
Totalsalt	51.48	15.18	3.390	0.0008
Phosfor	-0.410	0.114	-3.573	0.0004
Nitrogen	541.9	198.2	2.734	0.0069
$CaC0_3$	25.458	5.466	4.657	0.00
Ors	-10.58	4.979	-2.125	0.0348
R-squared	0.216	Mean dependent var		38.510
Adjusted R-squared	0.187	S.D. dependent var		21.622
S.E. of regression	19.48	Akaike info criterion		8.8174
Sum squared resid	71403.3	Schwarz criterion		8.9512
Log likelihood	-856.11	Hannan-Quinn		8.8716
F-statistic	7.4358	Durbin-Watson stat		1.6945
Prob(F-statistic)	0.000			

$$CrMay2006=81+0.474trend-10.96pH+51.48Totalsalt-0.41Phosfor+541.48Nitrogen+25.45CaCO_3-10.58Ors \quad (12)$$

where CrMay2006 shows the Cr (mg/kg) level measured in May 2006 and Ors denotes organic substance in equation (12). In Model 8 other than trend all variables are found to be statistically significant. R-square indicates that physical and chemical characteristics explain 21% of the variation in Cr (mg/kg) heavy metal measured in May 2006. The sum of errors of regression for Model 8 is found to be 19.48. According to Model 8 Cr heavy metal level measured in May 2006 is affected positively by total salt, trend and nitrogen, while it is affected negatively by pH, phosphor and ors variables. Nitrogen, total salt and $CaCO_3$ are found to be most important variables affecting Cr levels.

3.2.1. Cr Heavy Metal Levels Measured in September 2006 and Its Determinants

The OLS results of estimating Cr heavy metal levels measured in September 2006 using the physical and chemical characteristics as independent variables are presented in table 9.

Table 9.

Cr Measured in September 2006

Dependent Variable: CrSep2006				
Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficien	Std.	t-Statistic	Prob.
c	3.426	35.76	0.095	0.92
trend	-2.956	0.820	-3.603	0.0004
pH	11.35	5.675	2.000	0.04
Totalsalt	-34.15	23.06	-1.481	0.140
Phosfor	0.446	0.174	2.557	0.011
Nitrogen	752.2	301.03	2.499	0.013
$CaC0_3$	-17.19	8.301	-2.071	0.039
Ors	-31.41	7.562	-4.153	0.000
R-squared	0.407	Mean dependent var		52.04
Adjusted R-squared	0.385	S.D. dependent var		37.74
S.E. of regression	29.59	Akaike info criterion		9.653
Sum squared resid	164669.9	Schwarz criterion		9.786
Log likelihood	-938.0	Hannan-Quinn		9.707
F-statistic	18.44	Durbin-Watson stat		1.148
Prob(F-statistic)	0.000			

$$CrSep2006=3.426-2.95trend+11.35pH-34.15Totalsalt+0.446Phospor+752.2Nitrogen-17.19CaCO_3-31.41Ors \quad (13)$$

where CrSep2006 shows the Cr (mg/kg) level measured in September 2006 and Ors denotes organic substance in equation (13). In Model 9 other than total salt all variables are found to be statistically significant. R-square indicates that physical and chemical characteristics explain 40% of the variation in Cr (mg/kg) heavy metal measured in September 2006. The sum of errors of regression for Model 9 is found to be 29.59. According to Model 9, Cr heavy metal level measured in September 2006 is affected positively by pH, phosphor and nitrogen, while it is affected negatively by trend, total salt, $CaCO_3$ and ors variables. Nitrogen, total salt and Ors are found to be most important variables affecting Cr levels in this period.

3.2.2. Cr Heavy Metal Levels Measured in January 2007 and Its Determinants

The OLS results of estimating Cr heavy metal levels measured in January 2007 using the physical and chemical characteristics as independent variables are presented in table 10.

Table 10. Cr Measured in January 2007

Dependent Variable: CrJan2007				
Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficien	Std.	t-Statistic	Prob.
c	36.37	7.211	5.043	0.00
trend	-1.521	0.165	-9.197	0.00
pH	-1.075	1.144	-0.939	0.348
Total salt	29.51	4.650	6.347	0.00
Phosphor	-0.262	0.035	-7.454	0.00
Nitrogen	245.8	60.70	4.049	0.0001
$CaC0_3$	12.30	1.674	7.353	0.00
Ors	-3.666	1.524	-2.404	0.017
R-squared	0.811	Mean dependent var		34.30
Adjusted R-squared	0.803	S.D. dependent var		13.47
S.E. of regression	5.968	Akaike info criterion		6.450
Sum squared resid	6696.09	Schwarz criterion		6.584
Log likelihood	-624.16	Hannan-Quinn		6.504
F-statistic	115.2	Durbin-Watson stat		1.567
Prob(F-statistic)	0.000			

$$CrJan2007=36.37-1.521trend-1.075pH+29.51Totalsalt-0.262Phospor+245.8Nitrogen+12.30CaCO_3-3.666Ors \quad (14)$$

where CrJan2007 shows the Cr (mg/kg) level measured in January 2007 and Ors denotes organic substance in equation (14). In Model 10, other than pH variables are found to be statistically significant. R-square indicates that physical and chemical characteristics explain 81% of the variation in Cr (mg/kg) heavy metal measured in January 2007. The sum of errors of regression for Model 10 is found to be 5.96, which shows that this model is a quite good fit. According to Model 10, Cr heavy metal level measured in January 2007 is affected positively by total salt, nitrogen and $CaCO_3$, while it is affected negatively by trend, pH, phospor ors variables. Nitrogen and total salt are found to be most important variables affecting Cr levels in this period.

3.3. Cr Heavy Metal Levels Measured in May 2007 and Its Determinants

The OLS results of estimating Cr heavy metal levels measured in May 2007 using the physical and chemical characteristics as independent variables are presented in table 11.

Table 11. Cr Measured in May 2007

Dependent Variable: CrMay2007				
Method: Pooled Least Squares				
Cross-sections included: 14				
Total pool (balanced) observations: 196				
Variable	Coefficien	Std.	t-Statistic	Prob.
c	-5.903	13.60	-0.433	0.66
trend	-2.014	0.312	-6.451	0.00
pH	6.219	2.159	2.879	0.004
Totalsalt	45.02	8.774	5.130	0.00
Phosfor	-0.079	0.066	-1.200	0.23
Nitrogen	-273.0	114.5	-2.383	0.01
$CaC0_3$	-0.608	3.158	-0.192	0.84
Ors	5.590	2.877	1.942	0.05
R-squared	0.658	Mean dependent var		40.71
Adjusted R-squared	0.646	S.D. dependent var		18.92
S.E. of regression	11.26	Akaike info criterion		7.720
Sum squared resid	23842.9	Schwarz criterion		7.854
Log likelihood	-748.6	Hannan-Quinn		7.7748
F-statistic	51.85	Durbin-Watson stat		1.4056
Prob(F-statistic)	0.000			

$$CrMay2007=-5.903-2.014trend+6.219pH+45.02Totalsalt-0.079Phospor-273Nitrogen-0.608CaCO_3+5.59Ors \quad (15)$$

where CrMay2007 shows the Cr(mg/kg) level measured in May 2007 and Ors denotes organic substance in equation (15). In Model 11, other than phosphor and $CaCO_3$, all variables are found to be statistically significant. R-square indicates that physical and chemical characteristics explain

65% of the variation in Cr (mg/kg) heavy metal measured in May 2007. The sum of errors of regression for Model 10 is found to be 11.26. According to model 11 Cr heavy metal level measured in May 2007 is affected positively by pH, total salt and ors, while it is affected negatively by trend, phosphor, nitrogen, $CaCO_3$ variables. Nitrogen and total salt are found to be most important variables affecting Cr levels in this period.

4. CONCLUSIONS

In general, Cd, Pb and Cr contamination in the soil samples has not been observed in such a way that they can create a risk. However, excessive limit value from time to time and obtaining results, which are very close to permitted values, can be considered an indication that contamination has began within the soil's ecosystem.

The fact that textile, leather, automotive, and metal, chemical, cellulose and paper-carton industries, which enable Cd, Pb and Cr elements to be absorbed, are located in the region can be considered as the cause of observing contamination in Cd, Pb and Cr concentrations in surface soils of the region. Another reason of Cd, Pb and Cr concentration rise in surface soils of the region and that they exceed the limit values are probably the chemicals that are used in industry, and residues of heavy metals within agricultural fertilizers used in agricultural activities in the region where agriculture is the main source of income and which possesses fertile soils, and also residue of pesticide, which is used previously but is prohibited later can create contamination in the soil.

Among the reasons of high level of Pb concentration, in the sample soils taken from the agricultural lands that are closer to vehicle traffic, lead-rich exhaust gas contamination resulting from the burn of Pb-alkyl added petrol used in the previous years can be suggested.

Among the sample points specified in the research region, there are paper, textile and leather industries. It can be suggested that Cr contamination level has risen due to intensive emissions to occur within the periods in which production has increased. It can also be suggested that Cr concentration rises due to heavy metals that agricultural fertilizers used in the region contain. We can also suggest that Cr found in the waste is contaminated in the soil resulting from thoughtless storage of industrial waste, which has formed due to non-existence of regular solid waste storage area in the region where the research and study are being carried out. For all measurement dates, nitrogen is found to be the main determinant for Cd heavy metal measurements. To sum up the results of the estimations for the measurements made in May and September 2006, nitrogen and total salt are found to be the main determinants of Pb levels, whereas for the measurements made in January and May 2007, total salt is found to be the main factors for Pb heavy metal measurements. To sum up the results of the estimations for Cr measurements, we observed that for the measurements made in May 2006 in addition to nitrogen and total salt, $CaCO_3$ variable is found to be the main determinants in this period. For the measurement made in September 2006 in addition to nitrogen and total salt, ors is found to be the main determinant of Cr heavy metal for this period. Finally, for the measurement made in January and May 2007 the common variables nitrogen and total salt are found to be the most important factors affecting Cr levels.

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