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ENVIRONMENTAL PHYSICS

RELATION BETWEEN VEHICLE TRAFFIC AND HEAVY METALS CONTENT FROM THE PARTICULATE MATTERS

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Abstract. The aim of this paper is to prove relation between vehicle traffic and heavy metals content, lead and cadmium, from suspended particulate matters. The field study was conducted for a year in a street canyon with high vehicle traffic (Pitesti), which can be considered hot spot, by comparison with a blank area, without vehicle traffic (Calinesti, Arges). Heavy metals contents were determined after 24 hours samplings along 2008.

In urban area, lead content is higher during working days, whereas cadmium content remains constant. Moreover, correlations between lead, carbon monoxide and PM10 are much better than in rural area.

Keywords: vehicle traffic, heavy metals, atomic absorption, air pollution, particulate matters.

1. INTRODUCTION

Heavy metals represent a class of omnipresent pollutants, with toxic potential, in some cases even at low exposure levels. They concentrate in each trophic level because of their weak mobility, so the concentration in plants is higher than in soil, in herbivore animals higher than in plants, in carnivores' tissues higher than in herbivore, the highest concentration being reached at the end of the trophic chain, at big predacious and human bodies.

Systemic pollutants such heavy metals are very dangerous because of their long time retention in soil and their accumulation by plants and animals. These can combine with minerals and oligominerals becoming blockers for these and bereaving the living organisms of these elements needful for life. Heavy metals accumulate in the body and block the intracellular biochemical processes; they don't decay by food preparation.

Every year, millions of tones of toxic pollutants are emitted in the air, both from natural sources and especially from anthropogenic sources. There are four categories of emission sources: stationary (industrial processes, industrial and domestic combustions); mobile (road and stationary traffic); natural (volcanic eruptions, forest fires); accidental pollutions (discharges, industrial fires) [10].

In the most cases, heavy metals pollution is a problem associated with the intense industrialized areas. However, high vehicle traffic was proven to be one of the important heavy metals emissions sources. Zinc, copper and lead are three of the most common heavy metals emitted by vehicle traffic, totaling at least 90% from the total emitted quantity. Also, vehicle traffic is responsible for the emission of some small quantities of other metals, like nickel and cadmium [11].

In urban areas the population is very numerous and the vehicle traffic is relatively high, so the exposure of people to the traffic related concentrations is significant. In the last years, the vehicle traffic increased especially in these areas. As a consequence, although there were implemented new techniques for controlling the emissions the urban air quality was not improved significantly. In cities with many tall buildings, placed on both sides of the street, the pollution level often does not comply with air quality standards.

2. MATERIALS AND METHODS

From all suspended particulate matters, which represent a complex mixture of very small particles and liquid drops, care is taken in particular to the PM10 fraction (aerodynamic diameter less than 10 microns). The emission sources are natural (volcanic eruptions, rocks erosion, sand storms, pollen dispersion) and anthropogenic (industrial activities, domestic combustions, power plants, vehicle traffic). It is known that in the urban areas about 80% from total quantity of PM10 is emitted by the vehicle traffic, due to wires friction on the road surface and incomplete combustions [6].

The sampling of PM10 fraction was performed according to the standardized method: *EN 12341/1999 "Air Quality. Determination of the PM10 fraction of suspended particulate matter. Reference method and field test procedure to demonstrate reference equivalence of measurement methods"* [5]. The suspended particulate matters were collected on filters by 24 hours samplings, starting every day at 00.00 o'clock, with a constant flow of 2.3 m^3/h (= 38.8 L/min), using a Tecora sampler equipped with an automatic filters changer. In order to eliminate any interference during measurements of heavy metals content in PM10, quartz filters were used.

The filters charged with PM10 were digested by pressure disintegration in acid medium, so the heavy metals traces from particulate matters were transformed in solution. The equipment used was a Milestone Microwave Digestion System and the acid medium was a nitric acid – peroxide mixture [1]. In order to eliminate any interference it is recommended to use only ultra pure reagents and PTFE vessels, perfectly clean, hermetic closed with safety vents and PTFE tops.

The solutions resulted after this acid digestion were analyzed using the atomic absorption spectroscopy [9] according to the reference method *SR EN 14902/2007 “Ambient air quality. Standard method for the measurement of Pb, Cd, As and Ni in the PM10 fraction of suspended particulate matter”* [8].

The field study was conducted for a year in a street canyon, which can be considered hot spot, by comparison with a blank area:

1. *Nicolae Balcescu Street, Pitesti* – an urban street with high vehicle traffic that can achieve frequently 60.000 transits in 24 hours, especially in the working days. Moreover, because of the tall buildings placed on both sides of the street the area is characterized by a strong effect of accumulation and keeping of pollutants – a street canyon.

2. *Calinesti village, Arges County* – a rural area, about 20 km east from Pitesti, with very low vehicle traffic and away from any industrial activities influence.

3. RESULTS AND DISCUSSIONS

3.1. HEAVY METALS THEORETICAL AIR EMISSIONS

The annual quantities of **lead** and **cadmium** emitted by the vehicle traffic were calculated using the EMEP/CORINAIR Methodology [7] (Group 7 – Road Transport), starting with following input data: daily average vehicle traffic DAT [number of motor vehicles/24 hours], average running speed ARS [Km/h] and annual carburant consumption ACC estimated for each motor vehicle class [tones/year]. Daily average vehicle traffic DAT was determined from the vehicle traffic manual counts made in three-hour intervals in different days along the year. The results are presented in the Tables 1 and 2.

Table 1

Heavy metals calculated emissions – Nicolae Balcescu Street

Motor vehicle class	Carburant	DAT [nr/24 h]	ARS [km/h]	ACC [tones/year]	Emission (g/year)	
					Pb	Cd
Cars	Gasoline	45 500	40	1245	149.5	12.45
	Diesel oil	10 800	40	265	0	2.65
Vans (<3.5 t)	Gasoline	4 200	40	172	20.6	1.72
	Diesel oil	8 300	40	305	0	3.05
Tracks	Gasoline	350	30	43	0	0.43
Buses	Diesel oil	1 400	30	215	0	2.15
TOTAL					**170.1**	**22.45**

Table 2

Heavy metals calculated emissions – Calinesti village

Motor vehicle class	Carburant	DAT [nr/24 h]	ARS [km/h]	ACC [tones/year]	Emission (g/year)	
					Pb	Cd
Cars	Gasoline	80	50	1.64	0.197	0.0164
	Diesel oil	25	50	0.50	0	0.0050
Vans (<3.5 t)	Gasoline	5	50	0.12	0.014	0.0012
	Diesel oil	10	50	0.27	0	0.0027
Tracks	Gasoline	2	40	0.18	0	0.0018
Buses	Diesel oil	2	40	0.18	0	0.0018
TOTAL					**0.211**	**0.0289**

So, vehicle traffic is really an important emission source for heavy metals, in urban area the calculated air emissions are about 10 times higher than in rural area.

3.2. EXPERIMENTAL

The samples from the two studied areas drown along 2008 were analyzed by atomic absorption spectrometry in order to determine the **lead** and **cadmium** contents. An example with these filters charged with PM10 is shown in Fig. 1.

Fig. 1 – Quartz filters charged with PM10: 7T = blank filter, 10K = filter from blank area, 10F = filter from polluted area.

Daily average values of **lead** contents in PM10 along 2008 are shown in Fig. 2.

The broken line represents the annual limit value for the human health protect according to the *Frame Directive nr.96/62/CE for the air quality evaluation and management* [2] and the *First Daughter Directive nr. 99/30/CE for the limit values for sulphur dioxide, nitrogen dioxide and oxides, particulate matters and lead in the atmospheric air* [3], both transposed by Romania in owner legislation.

In urban area the daily average values of lead content exceed frequently the 0.5 $\mu g/m^3$ limit value, especially during summer months, when vehicle traffic is higher and meteorological conditions favor the pollutant accumulation. In rural area these values are much lower and the slight increases during winter months are due to the solid combustible burning for domestic heating and the agricultural works in spring and autumn, such as stubbles burning.

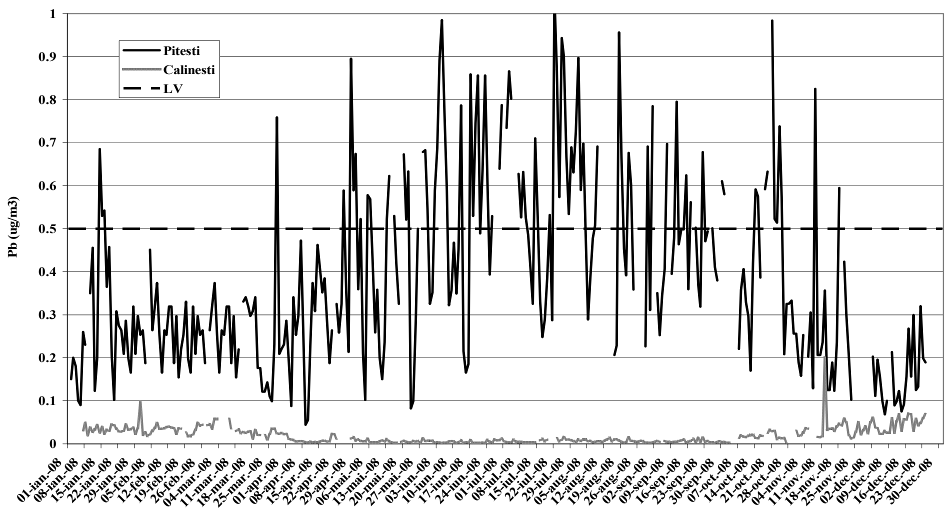

Fig. 2 – Daily averages of lead content in PM10 – 2008.

The weekly variation of lead content obtained by calculation of the average values for each week day (from Monday to Sunday) in 2008 is plotted in Fig. 3.

In urban area the lead content values were higher in working days (from Monday to Friday) relative to the week-end (Saturday and Sunday). That is why because Nicolae Balcescu street in Pitesti is not a national way, but an urban facilities street, so the vehicle traffic variation is intense influenced by the people's circulation between working places and their houses.

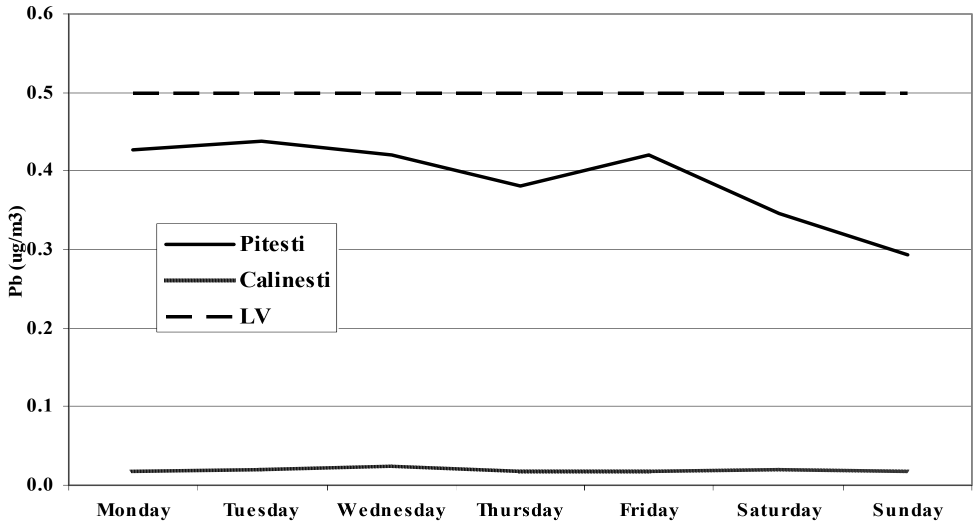

Fig. 3 – Daily averages of lead content in PM10 – weekly variation.

Contrariwise, in rural area the lead content hasn't a weekly variation, the values being about constant along the whole week. This fact is due to the absence of vehicle traffic, the principal activities being domestic and agricultural.

The annual average values for lead content are presented in Table 3.

Table 3

The annual average of lead contents

Area	Nicolae Balcescu Street, Pitesti	Calinesti Village, Arges	Annual limit value according to legislation
Value (μg/m^3)	0.3841	0.0190	0.5

So, in 2008 the annual average of lead contents in PM10 comply with air quality standards in the both areas, but the value obtained in urban area is about 20 times higher than in rural area, and that is certainty due to the vehicle traffic.

Daily average values of **cadmium** contents in PM10 along the 2008 year are shown in Fig. 4.

The broken line represents the annual limit value for human health protect according to the *Frame Directive nr.96/62/CE for the air quality evaluation and management* [2] and the *Forth Daughter Directive nr.2004/107/EC for the evaluation of arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in the ambient air* [4], both transposed in Romanian legislation.

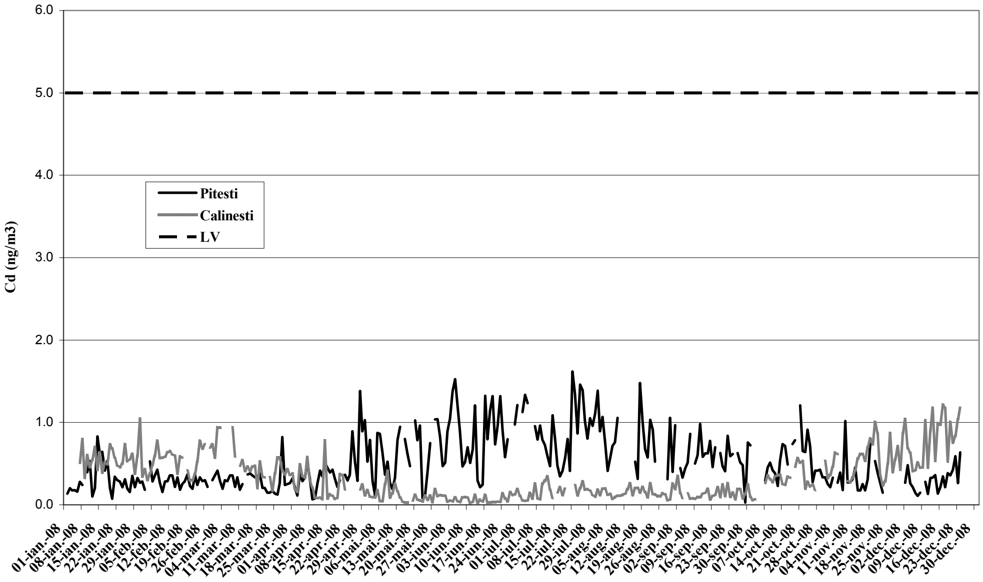

Fig. 4 – The variation of daily average cadmium content in PM10 – 2008.

In urban area the daily average values of cadmium content don't exceed the limit value, but slight higher during summer months, when the vehicle traffic is higher and the meteorological conditions favor the pollutant accumulation.

In rural area the obtained values are much lower and the slight increases during winter months are due to the solid combustible combustion used for domestic heating and the agricultural works in spring and autumn.

The weekly variation of cadmium content in the two studied areas is shown in Fig. 5.

It can be observed that, unlike lead content weekly variation, the cadmium content values are about constantly along the whole week, in the both studied areas. That is why because the cadmium content in air is not intense influenced by the vehicle traffic, the last being not a major emission source for this heavy metal.

The annual average values for cadmium content are presented in the Table 4.

So, in 2008 the annual average of cadmium contents in PM10 comply with air quality standards in the both areas, but the value obtained in urban area is about 1.5 times higher than in rural area, and that is equally due to the vehicle traffic and industrial activities.

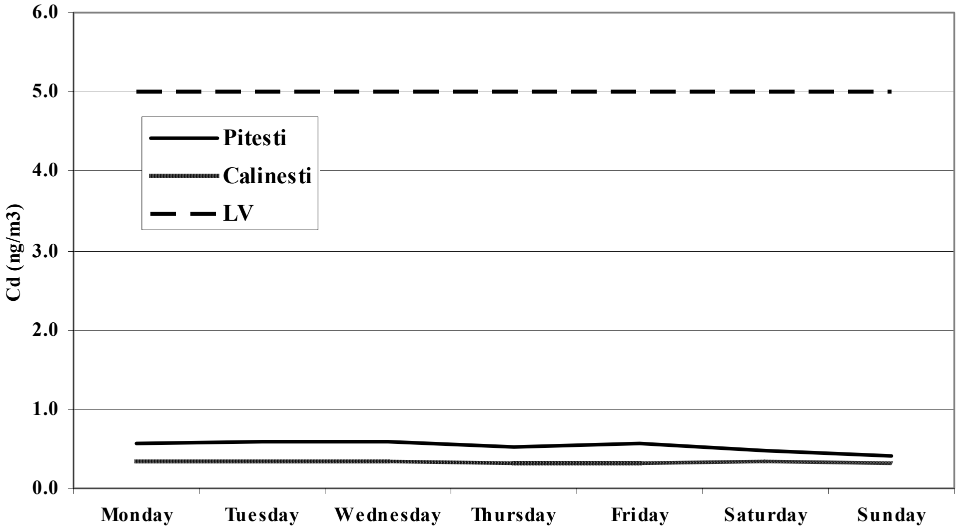

Fig. 5 – Daily averages of cadmium content in PM10 – weekly variation.

Table 4

The annual average of cadmium contents

Area	Nicolae Balcescu Street, Pitesti	Calinesti Village, Arges	Annual limit value according to legislation
Value (ng/m^3)	0.5253	0.3296	5

4. SUMARY AND CONCLUSIONS

It is known that vehicle traffic is the most important source for carbon monoxide CO, pollutant emitted by vehicle engines during theirs running. So, in order to prove the relation between vehicle traffic and heavy metals content in PM10, the correlations between different pollutants were plotted in Figs. 6–11.

First, in Fig. 6 it can see a very good correlation between the quantities of particulate matter – PM10 fraction and the CO concentrations measured in Nicolae Balcescu Street, Pitesti. That is why because in the urban areas the vehicle traffic is considered to be a major emission source for PM10, about 80% from total quantity being due to this activity.

But then, Fig. 7 shows a very poor correlation between the same two pollutants in Calinesti village, because in this area there are another PM10 emission sources, like solid combustible burning, agricultural activities.

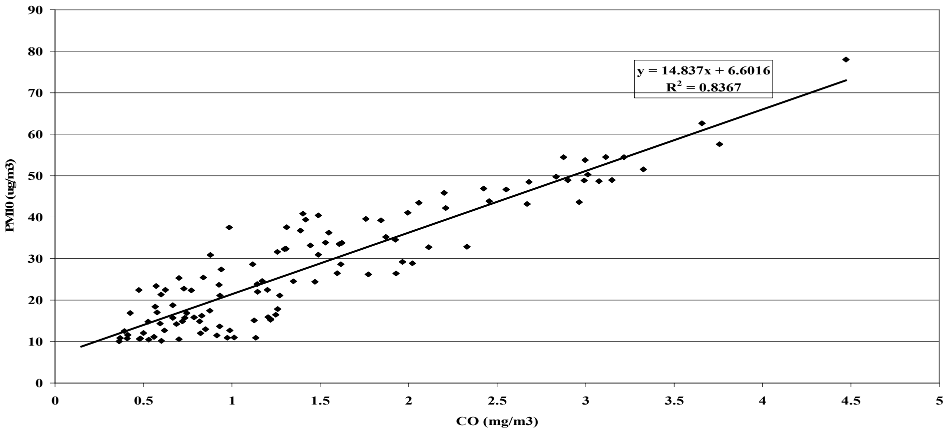

Fig. 6 – The correlation between PM10 and CO measured concentrations in urban area.

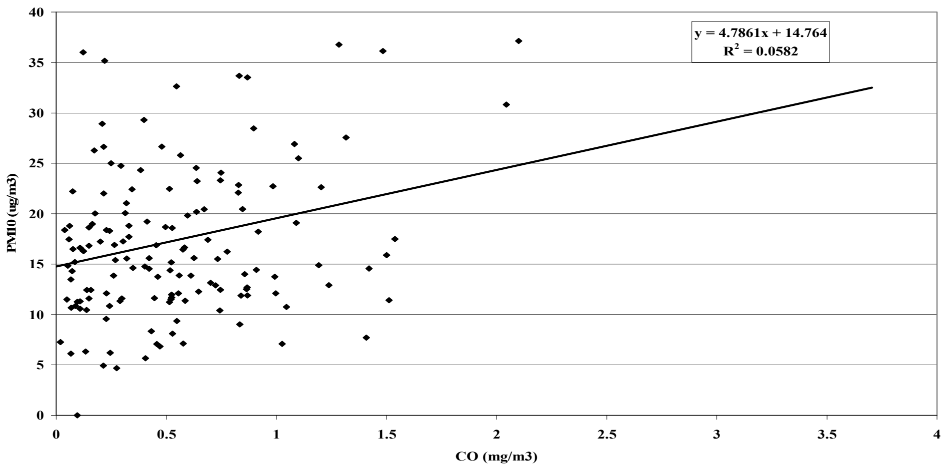

Fig. 7 – The correlation between PM10 and CO measured concentrations in rural area.

Then, in Fig. 8 it can see a relatively good correlation between the lead contents in PM10 and the CO concentrations measured in the urban area, so vehicle traffic is a major emission source for lead, too. Contrariwise, in the rural area was proven a poor correlation between these two pollutants (see Fig. 9), due to others emission sources.

Finally, Figs. 10–11 show poor correlations between the cadmium contents in PM10 and the CO measured concentrations obtained in both areas, so vehicle traffic is a minor emission source for cadmium and it is possible to be another cadmium source around, such as industrial activities, respectively solid combustible burning.

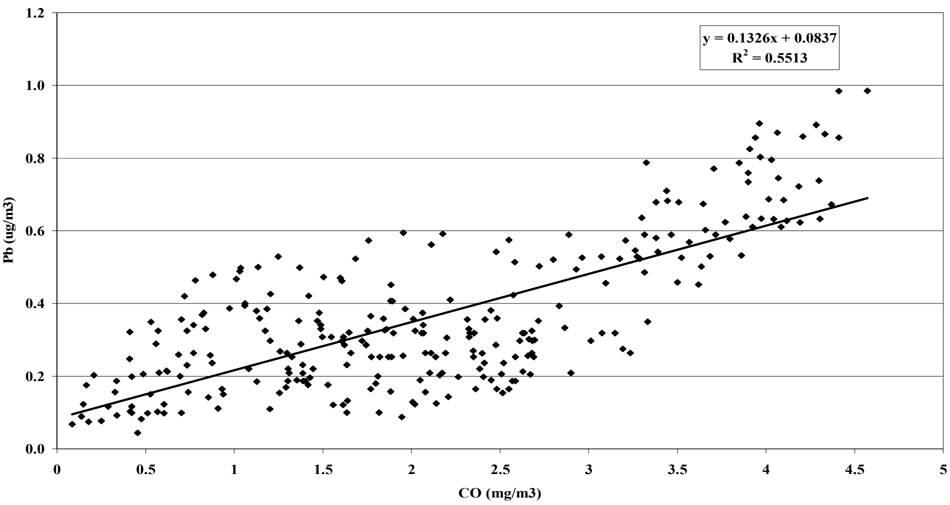

Fig. 8 – The correlation between lead and CO measured concentrations in urban area.

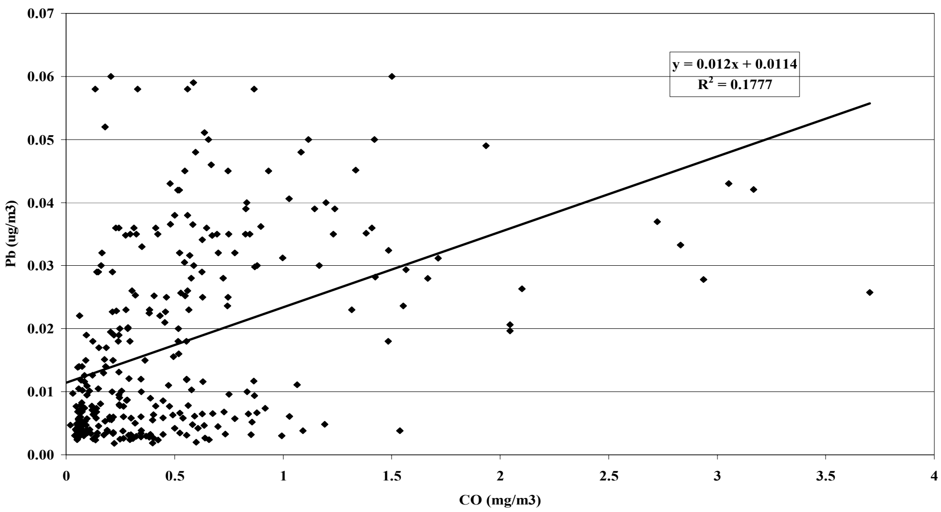

Fig. 9 – The correlation between lead and CO measured concentrations in rural area.

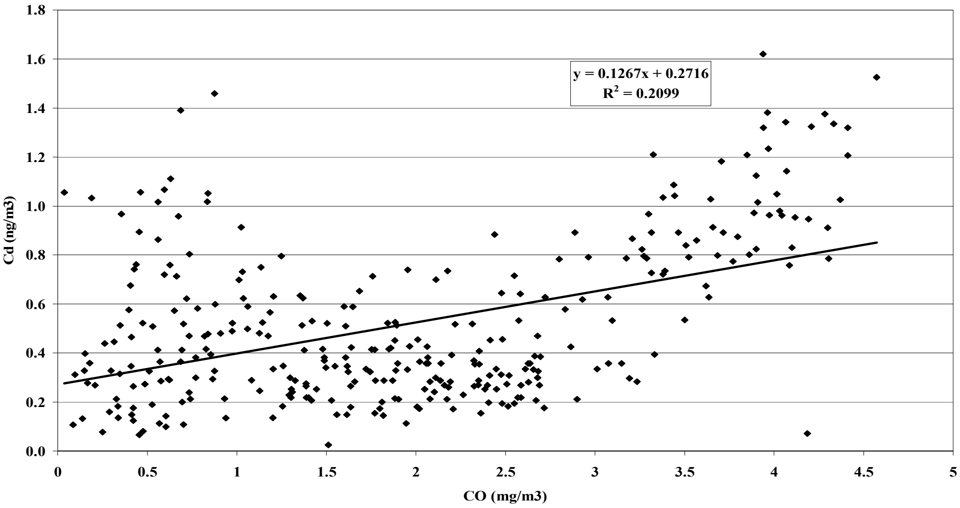

Fig. 10 – The correlation between cadmium and CO measured concentrations in urban area.

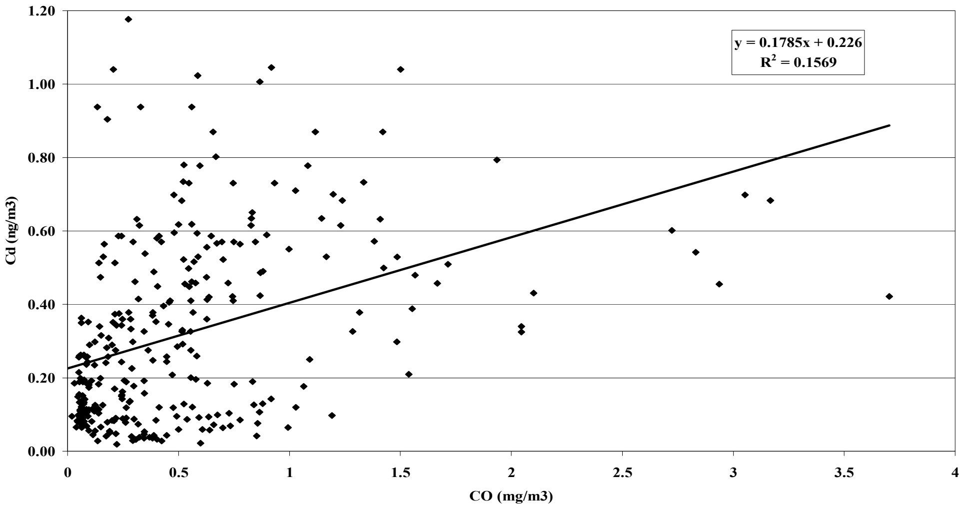

Fig. 11 – The correlation between cadmium and CO measured concentrations in rural area.

Conclusively, as a result of this study there are the following conclusions:

The annual average of lead content in PM10 particulate matter is about 20 times higher in urban area than in rural area (blank), relative to cadmium content that is only 2 times higher. This fact is certainty due to the vehicle traffic that emits much more lead than cadmium.

From weekly variation in urban area were proven that during the working days the lead content in the air is much higher than during the week-end. This is another prove for the influence of vehicle traffic to the heavy metals content (especially lead), taking into account the traffic affluence from Mondays to Fridays, when the people leave for and from offices and homes.

In rural area both lead and cadmium content in the air is approximately constant in all week days. However, in this area, it was found an increase of heavy metals content, both lead and cadmium, during november-march months, due to the solid combustible burning for domestic heating and spring and autumn agricultural works.

Moreover, the correlations between lead contents, carbon monoxide and PM10 prove the high influence of vehicle traffic to the heavy metals contents, especially lead.

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