MODELING OF RELATIONSHIPS BETWEEN TRAFFIC PARAMETERS AND VEHICULAR LEAD AND CADMIUM DISTRIBUTION IN URBAN ROADSIDE SOILS

Saeed Samani¹, Gholamreza Shiran², Amir Taebi³, Majid Afyuni⁴, Mohammad Mehdi Abtahi⁵ and Hamidreza Pourzamani⁵

¹Zenderood Environmental Research Center, Isfahan, 8174673461, Iran
²Civil Engineering Department, Faculty of Engineering, University of Isfahan, Isfahan 8174673441, Iran
³Department of Civil Engineering, Isfahan University of Technology, Isfahan 8415683111, Iran
⁴Department of Agriculture, Isfahan University of Technology, Isfahan 8415683111, Iran
⁵Environment Research Center, Isfahan University of Medical Sciences, Isfahan 8174673461, Iran

DOI: http://dx.doi.org/10.24327/IJRSR.2017.0804.0118

ABSTRACT

Lead and cadmium are heavy metals and are regarded as traffic generated pollutants scattered in the urban environment through vehicular traffic flow. A total of 13 roads in the city of Isfahan were used for studying the roadside soil pollution amount and determination of effective traffic parameters on soil lead and cadmium amounts. Soil samples were collected and analyzed from 13 sites. An empirical statistical approach was employed for the analysis and modeling purposes. Results suggest that Lead and Cadmium mean concentrations within the distance of 50 m from road curbside are more than background values. These values are well-above the maximum acceptable concentration of heavy metal contents of agricultural soil. Regression analysis of metal concentrations in gutter soil showed that the most effective traffic parameter which affects soil metal concentrations is total traffic volume. It was also observed that Lead and Cadmium concentrations (as independent variables) decreased logarithmically as distance increased from road curbs (as dependent variable), but they decreased exponentially with increment of total traffic volume (as another dependent variable). The regression models developed in this research are used for estimation of Lead and Cadmium concentrations in urban roadside soils on the basis of the distance from road and total traffic volume. The outcomes of this research can be used for mitigation of environmental impacts of roads by using them in urban land use planning, urban design, urban transportation and road traffic management and control.

INTRODUCTION

The disease burden by a population and how that burden is distributed across sub population is important information for defining strategies to improve population health. Global found of the diseases burden from Lead have been introduced for 14 different reasons and different age groups worldwide in developed countries. When Leaded gasoline has usually been phased out, the highest environmental exposure to Lead generally affects children of lower income families. In countries where Lead is still used, Leaded gasoline will likely be a major contributor to exposure directly through air, or indirectly through food and dust of Leaded ceramics (WHO). The evidence for carcinogenicity is stronger in animals, its carcinogenicity in human has recently been questioned [1].

By increasing social needs for transportation and communication, day to day vehicular usage has been increased. There will be more than 950 million vehicles by the year 2020 in the world [2]. Automobiles are known to be the main sources of producing heavy metal pollutions in cities. These pollutions enter the environment from automobile bodies and exhaust as particles. Vehicular pollutions are distributed in roadsides by traffic flow and cause air, water and soil pollution [3, 4].

Lead and Cadmium are parts of vehicular pollutants. These pollutants, because of their poisoning characteristics and because of being dangerous for nature and human body such as blood and nerve system, have been researched by previous researchers [5, 6].

*Corresponding author: Saeed Samani
Zenderood Environmental Research Center, Isfahan, 8174673461, Iran
Lead usually enters the urban environment by using Leaded petrol. Although in recent years, Lead has been omitted from fuel and its entering the environment has been decreased, its pernicious effects still persist. Cadmium exists in automobile tires. It partially departs from vehicles and disperses with traffic flow and enters the urban environment [5, 7, 8]. Moreover different parameters affect vehicular pollution in environment, which in large scale contains conditions of road, traffic and environment.

Road parameters related to road physics and design are: length, slope, road canyon and average height, average aspect ratio (i.e. the ratio of height of the building to width of the road), number of lanes, and the type of green cover and its height [9-11]. Traffic flow as one of the most important factors in dispersing vehicular pollution contains speed, traffic volume, traffic congestion and driver behavior in start time and movement, fleet composition ,traffic management method and traffic sign arrangement in roads [12-14]. Environmental parameters contain climatic conditions like temperature, wind direction, speed and also roadside soil characteristics [10, 12, 13].

Past research works have measured heavy metal concentrations in soil, as well as their impacts on distribution trend. Rahmani [15] through soil sampling from different distances in four highway sides in Iran illustrated that sharp decreases exit in lead concentrations as distance increases from the main road. Ward et al. [16] in Auckland New Zealand measured Lead and Cadmium concentrations in surface roadside soils in 17 sites. A gradual decrease of heavy metal concentrations has shown in the study as distance increases from roads. Lead content in soil has shown to have a definite relationship with traffic. However, this relationship has been weak for cadmium concentrations. Carlosena et al. [17] in Lacrona, Spain studied vehicular traffic effect on heavy metal concentrations and concluded that high load of Lead concentrations and low load of Cd, Cu and Zn concentration were results of traffic distributions. Garsia and Milan [18] measured Cd, Cu, Zn and Pb concentrations at two distances in eight sites experiencing different traffic flow in urban highways of Gipuzequa, Spain. Their results showed Pb and Cd concentration levels changed as distance from highway varied.

This study of vehicular pollutions and their impacts on roadside environment and also impacts of different traffic parameters on distribution amount and trend of pollution is a requirement when urban architecture, design and planning and urban traffic management are of concerns. This study investigates the roadside soil and gutter soil pollution because of Lead and Cadmium. During the course of this research, the impacts of different traffic parameters on the distribution of pollution will be studied and finally the trend of Lead and Cadmium distributions as function of distance and traffic parameters will be analyzed and then modeled.

**MATERIALS AND METHODS**

Thirteen sites along various roads of varying traffic volumes in the built up areas of Isfahan were selected. Table (1) lists the selected sites and Figure (1) depicts locations of sampling sites in Isfahan. Criteria for the selection of sites were: a) a minimum of 150 m distance from bus stations (terminal) and b) away from any vertical barrier or constraints to prevent trapping from circulation. Most roads in Isfahan are divided and the traffic flows in two directions. Gutters are open drainage channels adjacent to the road stretched along both sides. These gutters have soil apron and concrete wall as well as plants growing in these places.

Soil samples were collected from depth of 0-5 cm and distance of 0.5, 1, and 2 m from all roadsides and distances of 4, 6, 8, 10, 15, 20, 30, 40, and 50 m from sites number 10 to 13. Figure (2) presents typical cross sections of roads along sites number 10 to 13. Sampling was carried out using linear soil sampling method. In doing so, samples were taken at a distance of 25 cm from a line parallel to road axis and then mixed. Standard Methods /Techniques [19] were adapted as the basis of sample extraction and measurement of Pb and Cd concentration. These include Atomic Absorption Spectroscopy (AAS) in the sites and laboratories. Data and information were collected on the total traffic volume, daily traffic volume, total (accumulated) traffic volume, total traffic volume to directional road width, total traffic volume to total capacity, vehicular speed and street aspect ratio. Their definitions and calculation methods are as follows: Average annual daily traffic (AADT) is defined as the yearly traffic volume divided by 365. AADT has been used by many researchers in order to compare concentrations in various roads [15-18]. Average daily traffic in year and yearly traffic volume in studied roads were defined from existing data of transportation research center of Sharif University of Technology [20]. Road ages also were defined from their construction documents. On the basis of the vehicular possession coefficients, Isfahan population and age of each road, annual traffic volume in different years for roads were estimated. Information on the construction year of road extraction was extracted from the data base of Isfahan Highway Department and Municipality of Isfahan. Total traffic volume for each road was estimated up to the years 2013. The total traffic volume in all studied roads was about 52 to 520 million vehicles. Total traffic volume was assumed as an effective parameter on extinction of cumulative Lead concentration on the roads under study.
Total capacity is the maximum number of vehicles that can pass through a point on a road per unit time in a year in both or all directions under the prevailing condition of road and the traffic. Total traffic volume is the demand or number of vehicles that pass through a given point on a road per unit time in both directions. The ratio of (Volume/Capacity) or (V/C) shows the extent to which volume of a road is approaches capacity. It also presents the degree of saturation of a road. Such a ratio has been sought to be another influencing parameter in the amount vehicular heavy metal pollution [10]. Total capacity values were calculated by EMME/2 software. This parameter shows relative value of using roads in their usage age.

In each road, by measuring the speed of two types of dominant vehicles in different hours of day, mean speed was defined. The vehicular mean speed on the vicinity of study sites varied between 30 and 76 kilometers per hour (km.h$^{-1}$). Previous studies have confirmed the influence of street aspect ratio on traffic generated air pollutants distribution. Aspect ratio is defined as the mean height of building along streets to the mean width of streets. Linaritakis (1987) has modeled CO pollution concentrations using data on streets of central London. Models developed based on traffic load was setting and geometry of streets located in central basin districts where high building are set on both sides of roads are known as "Street Canyon models" [21]. Zero height denotes to area where there is no building along streets.

RESULTS
Statistical characteristics of total Lead and Cadmium in street soils up to 50 meters from kerb and background soil are presented in Table (2).

| sampling site number | site name | location | construction year |
|----------------------|-----------|----------|-------------------|
| 1                    | Chahar Bagh Paeen | 100 meters north of Takhti Junction west bound | 1937 |
| 2                    | Forouqi   | 500 meters west of Shohada junction south bound | 1941 |
| 3                    | Bozorgmehr | 200 meters north of Bozorgmehr Square west bound | 1961 |
| 4                    | Ahmad Abad | 150 meters west of Mehregan street south bound | 1937 |
| 5                    | Kashani   | 30 meters south of Halal Ahmar east bound | 1941 |
| 6                    | Mohtasham Kashani | 400 meters west of Shariati square north bound | 1981 |
| 7                    | Forougi   | 500 meters west of Shohada junction south bound | 1941 |
| 8                    | Kamal Esmaeili | 200 meters east of Ferdosi junction north bound | 1951 |
| 9                    | Chahar Bagh Bala | 300 meters south of Shariati east bound | 1956 |
| 10                   | Sajad     | 200 meters south of Apadana junction west bound | 1966 |
| 11                   | Imam Khomeini | 150 meters south of Khane Esfahan street east bound | 1961 |
| 12                   | Imam Khomeini | 1 km north of Ghalamestan park west bound | 1961 |
| 13                   | Razmandegan | 500 meters west of Robat north bound | 1991 |

Table 1 Selected streets and sampling sites

Table 2 Statistical characteristics of total Lead and Cadmium in street soils of up to 50 m from curb and background soil

| statistical parameters | gutter Pb | Cd | distance up to 50(m) Pb | Cd | background Pb | Cd |
|------------------------|-----------|----|-------------------------|----|---------------|----|
| samples number         | 19        | 19 | 19                      | 19 | 40            | 40 |
| mean/(mg.kg$^{-1}$)    | 220.86    | 2.94 | 126.82                  | 2.41 | 28.91        | 2.02 |
| median/(mg.kg$^{-1}$)  | 186.34    | 3   | 86.85                   | 2.4 | 25            | 1.8 |
| standard deviation/(mg.kg$^{-1}$) | 12.52 | 0.31 | 8.77                     | 0.37 | 1.87         | 0.15 |
| minimum/(mg.kg$^{-1}$) | 65.05     | 2.4 | 35.78                   | 1.8 | 7.3           | 0.6 |
| maximum/(mg.kg$^{-1}$) | 481.35    | 3.4 | 325.26                  | 3.4 | 57.8          | 2.7 |
| domain/(mg.kg$^{-1}$)  | 416.3     | 1   | 289.48                  | 1.6 | 50.5          | 2.1 |

The statistical difference of Lead and Cadmium mean concentrations are investigated by t-student test in significant level of 5% (reliable level 95%) in Table (3).

Table (4) shows results of t-paired test for comparison of Pb and Cd concentrations in soil in different distances.

In Figure (3) relative frequent distribution (probability) of total Lead in roadside soil has been presented. The distribution curve of Lead in background soil is also shown in the Figure (3).

In Figure (4) presents relative frequency of total Cadmium in roadside surface soil of Isfahan. This figure also shows background distribution for Cadmium in soil.

![Relative frequent distribution of total Lead concentration in Isfahan urban roadsides](image1.png)

![Relative frequent distribution of total Cadmium concentration in Isfahan urban roadsides](image2.png)
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Table 3: t-test for comparison of Lead and Cadmium concentration in gutter soil and soil until 50 m with background concentrations

| situation          | number of observations | mean/(mg.kg⁻¹) | standard deviation/(mg.kg⁻¹) | degree of freedom | t_cal | t_crit |
|--------------------|------------------------|----------------|-----------------------------|-------------------|-------|--------|
| background         | 40                     | 28.91          | 10.87                       | -                 | -    | -      |
| gutter soil        | 19                     | 220.86         | 12.52                       | 57                | 18.73 | 2      |
| soil until 50/m    | 40                     | 126.82         | 12.77                       | 78                | 6.28  | 1.66   |
| Cadmium            |                        |                |                             |                   |       |        |
| background         | 40                     | 2.02           | 0.55                        | -                 | -    | -      |
| gutter soil        | 19                     | 2.94           | 0.31                        | 57                | 2.2   | 2      |
| soil until 50/m    | 40                     | 2.41           | 0.37                        | 78                | 2.2   | 1.66   |

Table 4: Results of t-paired test for comparison of Pb and Cd concentrations at different distances traffic lanes

| parameter                  | distance 1 versus 8/(m) | distance 1 versus 15/(m) | distance 1 versus 50/(m) | distance 8 versus 15/(m) | distance 8 versus 50/(m) | distance 15 versus 50/(m) |
|----------------------------|-------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------------|
| Lead mean/(mg.kg⁻¹)       | 211.42-120.35           | 211.42-104.9             | 211.42-58.7              | 120.35-104.9             | 120.35-58.7              | 104.9-58.7                |
| observations              | 4                       | 4                        | 4                         | 4                        | 4                         | 4                          |
| df                        | 3                       | 3                        | 3                         | 3                        | 3                         | 3                          |
| t_cal                     | 2.81                    | 2.64                     | 2.58                      | 1.72                     | 2.30                     | 2.40                      |
| t_crit                    | 2.353                   | 2.353                    | 2.353                     | 2.353                    | 2.353                    | 2.353                     |
| significant level         | 0.05                    | 0.05                     | 0.05                      | 0.05                     | 0.05                     | 0.05                      |
| probability               | 0.021                   | 0.027                    | 0.030                     | 0.120                    | 0.05                     | 0.04                      |
| Cadmium mean/(mg.kg⁻¹)    | 2.7-2.4                 | 2.7-2.35                 | 2.7-2.1                   | 2.4-2.35                 | 2.4-2.1                  | 2.35-2.1                  |
| observations              | 4                       | 4                        | 4                         | 4                        | 4                         | 4                          |
| df                        | 3                       | 3                        | 3                         | 3                        | 3                         | 3                          |
| t_cal                     | 2.6                     | 4.03                     | 3.137                     | 1.055                    | 3.48                     | 2.05                      |
| t_crit                    | 2.353                   | 2.353                    | 2.353                     | 2.353                    | 2.353                    | 2.353                     |
| significant level         | 0.05                    | 0.05                     | 0.05                      | 0.05                     | 0.05                     | 0.05                      |
| probability               | 0.029                   | 0.003                    | 0.012                     | 0.319                    | 0.007                    | 0.071                     |

Fig 5: Normalized total Pb concentrations in road side soils of sampling sites of 10 to 13 versus Distance from road curbs

Fig 6: Normalized total Cd concentrations in road side soils of sampling sites of 10 to 13 versus Distance from road curbs

Table 5: Traffic data used for modeling

| site number | site name                     | cumulative traffic volume/veh/day | daily traffic volume/veh/d | total traffic volume to total capacity | total traffic volume to directional road width/veh/m | speed/(km/h) | street aspect ratio |
|-------------|-------------------------------|----------------------------------|--------------------------|----------------------------------------|-----------------------------------------------|--------------|--------------------|
| 1           | Chahar bagh paeen             | 323277305                        | 31583                    | 0.0475                                  | 8710723.98                                   | 30.2         | 0.129              |
| 2           | Forougi                       | 48657845                         | 5470                     | 0.121                                  | 11701274.02                                  | 30.3         | 0.3                |
| 3           | Bozorgmehr                    | 388003251                        | 39686                    | 0.318                                  | 7561348                                     | 54.3         | 0.144              |
| 4           | Ahmad abad                    | 152576141                        | 12325                    | 0.429                                  | 20601961.39                                  | 33.8         | 0.198              |
| 5           | Kashani                       | 520619999                        | 32303                    | 0.390                                  | 24067541.65                                  | 45.4         | 0.24               |
| 6           | Moshtag aval                  | 119352995                        | 18304                    | 0.328                                  | 7976695.90                                  | 52.2         | 0.514              |
| 7           | Kamal esmaeel                 | 285227027                        | 20759                    | 0.638                                  | 28787951.13                                 | 43           | 0.106              |
| 8           | Chahar bagh bala              | 247895679                        | 23970                    | 0.311                                  | 31040260.08                                 | 43.3         | 0.214              |
| 9           | Sajad                         | 222501183                        | 25358                    | 0.243                                  | 34029190                                    | 53           | 0.067              |
| 10          | Mohtasham kashani             | 68052132                        | 106500                   | 0.184                                  | 18649612.12                                 | 54           | 0                  |
| 11          | Imam Khomeini                 | 68052132                        | 34230                    | 0.192                                  | 21133177.71                                 | 54           | 0                  |
| 12          | Imam Khomeini                 | 255499686                       | 29560                    | 0.187                                  | 43881081.08                                 | 75.8         | 0                  |
| 13          | Razmandegan                   | 72299009                       | 26205                    | 0.50                                   | 32538749.94                                 | 54           | 0                  |

Notes: a) Before the year 2010; b) Year of 2013
With respect to the fact that surveying of heavy metal distribution trend resulted from vehicular factors in roadside soil is one of the research goals, normalized concentrations in versus distances are plotted in Figures (5) and (6). Table (5) shows traffic data, used for modeling which were total traffic volume, daily traffic volume, total traffic volume to directional road width, total traffic volume to total capacity, speed, and aspect ratio.

Table (6) shows the results of "t" paired student test for comparing Pb and Cd mean concentrations in the soil of different sites.

Table 6 Results of t-paired test for comparison of Pb and Cd concentrations in different sites

| sites number   | Pb       | Cd       |
|----------------|----------|----------|
| parameter      | 10 versus 11 | 10 versus 12 | 10 versus 13 | 10 versus 14 | 10 versus 15 | 10 versus 16 | 10 versus 17 | 10 versus 18 | 10 versus 19 | 10 versus 20 | 10 versus 21 | 10 versus 22 | 10 versus 23 | 10 versus 24 | 10 versus 25 |
| mean           | 74.9-181.9 | 74.79-184.1 | 74.79-65.92 | 181.89-184.1 | 181.89-65.92 | 184.1-65.92 | 181.89-184.1 | 181.89-65.92 | 184.1-65.92 | 181.89-184.1 | 181.89-65.92 | 184.1-65.92 | 181.89-184.1 | 181.89-65.92 | 184.1-65.92 |
| observations   | 10-10     | 9-9      | 8-8       | 9-9        | 9-9        | 9-9       | 9-9        | 9-9        | 9-9        | 9-9        | 9-9        | 9-9        | 9-9        | 9-9        | 9-9        |
| df            | 6.032     | 6.032    | 6.032    | 6.032     | 6.032     | 6.032     | 6.032     | 6.032     | 6.032     | 6.032     | 6.032     | 6.032     | 6.032     | 6.032     | 6.032     |
| $t_{cal}$    | 2.262     | 2.262    | 2.262    | 2.262     | 2.262     | 2.262     | 2.262     | 2.262     | 2.262     | 2.262     | 2.262     | 2.262     | 2.262     | 2.262     | 2.262     |
| significant level | 0.05     | 0.05    | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     |
| probability   | 0.001>   | 0.001>  | 0.001>  | 0.001>   | 0.001>   | 0.001>   | 0.001>   | 0.001>   | 0.001>   | 0.001>   | 0.001>   | 0.001>   | 0.001>   | 0.001>   | 0.001>   |

Comparison of Figures (3) and (4) shows that Lead is outer than Cadmium from their related background distribution. As a result of planting trees in gutter soil, it is required to use agricultural soil standard for its health measurement. The British and Australian standards were used for Pb is 100 and for Cd is land 5 mg.kg$^{-1}$, respectively. As seen in Table (2), the mean concentration of Pb in gutter soil up to 50 m is greater than maximum allowable concentration. In the case of Cd, mean concentration exceeded the British standard. Such comparison reveals that more attention should be paid to roadside plantation and soil pollution.

DISCUSSION

Background Lead and Cadmium concentrations are those measured in remote areas of Isfahan regions which were lesser exposed by anthropogenic activities. As shown in Table (2), mean concentrations of metals in the soils of streets and up to distance of 50 m are greater than the background values. Lead distribution in roadside surface soil is more dispersed when compared with lead distribution in background soil. As shown in this Figure 4, cadmium distribution in surface has an outward distribution from its background distribution.
concentration on that site. These values are always between 0 to 1. Using these curves and regarding their amounts, it is more possible to study and compare distribution trend of concentrations.

Figures (5) and (6) show that distribution trends are in wave manner. Wave summits are the same in all sites. This phenomenon relates to size of produced particles by vehicles and happens in the result of traffic flow speed and rotary flow of air near the roads.

Each wave moves to the extent that its movement energy dissipates and concentrations reach background concentrations or any obstacles near the road. Moreover heavy metal distribution is that concentrations in 5 m are less than 1 m from road (Figures 5 and 6). This phenomenon refers (is related to) to road architecture and curb heights (Figure 2) and rotary flow of air. Comparison of Figures (5) and (6) shows that wave manner distribution trend for Pb concentrations is more apparent than Cd concentrations which relates to differences of their particle sizes and weights. Plotting Pb and Cd concentrations versus distances for sites 10 to 13 show that distributions decrease with the increment in distance. In addition to this, the logarithmic models are the best. As Table (6) presents, results of comparison at significant level of 5 percent shows that site 10 versus 11 and 12 with regard to its calculated t and critical t in two tailed test has a significant difference. Also site 13 versus sites 11 and 12 has t(calc) more than t(cal). Results for Cd show that site 10 versus sites 11 and 13 have t(calc) more than t(cal) and site 11 versus site 13 has t(calc) more than t(cal). So, it can be concluded that differences between sites are significant and it is clear that this difference relates to various traffic parameters in these sites.

Regression analysis suggests traffic related parameters have influenced heavy metal concentrations and their distribution in road side soil. From fitting different regression models to Pb and Cd concentration data in gutters of all sites versus each one of traffic parametersstatute in Table (5), metal concentrations have a good correlation with the total traffic volume. Linear and exponential models explain the relationship between Lead and Cadmium and the explanatory variables well, respectively. Analysis shows a weak correlation between the Pb and Cd concentrations and the explanatory variable V/C (ratio of total traffic volume to capacity). Moreover, we found a weak relationship between daily traffic volume and concentrations of Pb and Cd, which is the opposite of what was found by other researchers [16-18]. Insignificant correlation between the metal concentration and daily traffic volume can be attributed to the short term nature of daily traffic volume when compared to the cumulative traffic volume. No significant correlation was found between the metal concentration and vehicles speed and street aspect ratio. One may conclude that parameters such as street aspect ratio, vehicles speed and daily traffic volume influence the distribution pattern of gaseous pollutants. Because of this, in this research, a significant relationship was seen between total traffic volume and metal concentration in soil.

The cumulative nature of Pb and Cd concentrations in soil may also explain both operational and prolonged vehicular volume. To model the changes in metal pollution concentrations of Pb and Cd, various mathematical expressions were tested. Such models examined the relationship between the dependent variables Pb and Cd and explanation variables of total traffic volumes and the distance between the curbside and points where samples were taken.

Models (1) and (2), below, are statistically the most meaningful models resulting from the research analysis (determination coefficient of 0.8).

\[
C_{Pb} = 120.83 + (4.92 \times 10^{-7} \times V) - (35.39 \times \ln D) \quad (1)
\]

\[
C_{Cd} = 2.25 + (0.29 \times e^{3E-9} \times V) - (0.16 \times \ln D) \quad (2)
\]

Where: \(C_{Pb}\) is total Pb concentration as milligram to kilogram dried soil, \(C_{Cd}\) is total Cd concentration as milligram to kilogram dried soil, V is total traffic volume as number of vehicles, and D is distances as meter.

As pointed, total traffic volume is not used as independent variable in calculating the metal concentrations in other researches. Therefore, to verify the results, a statistical method standardized residual was used. Standardized residuals are calculated from dividing differences of predicted values and observed values to mean squares of residuals; and they have a mean equal to zero and a standard deviation equal to one and when placed between 2 and -2 show that the selected model is suitable for regression.

As shown in Figures (7) and (8), almost all the residuals placed between 2 and -2 and scattered data has no specific pattern for Pb and Cd. Therefore, regression models presented in model (1) and (2) have a suitable validation.

These are taken from samples using mean concentrations of background samples. One way probability has been employed in this statistical comparison. This is because it is expected that measured Pb and Cd concentrations are greater than background values. In t-student test, the difference between samples will be significant if calculated t (t(calc)) is more than critical t (t(cal)). As presented in Table (3), Pb concentrations in all locations have significant difference at significant level 5% with background concentrations. Based on this, total Pb concentrations in sample soil are affected by pollution sources and because of their being in cities, they are anthropogenic. Cd concentrations in gutter soil have significant difference with background values and have affected by external factors. With regard to the fact that these samples are related to road side soils, it can be concluded that traffic flow has caused the roadside to be polluted. This finding is in line with the work of other researchers’ [15-18].

CONCLUSIONS

From the review of literature on the related area of heavy metal concentrations and statistical analyses undertaken, the following conclusions can be drawn:

- All of the sites specially gutter soils and soils within 50 m from curbs had Pb and Cd mean concentrations higher than background level and standards of agricultural soil in many countries.
- Statistically, there was a significant difference between Pb and Cd mean concentrations in distances within 50 m of road curb and background level. This difference is
related to the effects of traffic and transportation parameters on roadside soil pollution.  
- The significant discrepancy observed between Pb and Cd mean concentrations in different sites can be attributed to the difference shown in their traffic parameters.  
- Pb and Cd concentrations in road side soil exhibited more relationship with total traffic volume compared to other traffic parameters.  
- Traffic parameters with longer effect such as total traffic volume, (accumulated) traffic volume, total traffic volume to directional road width, and total traffic volume to total capacity, showed a greater impact on relationship of soil heavy metal concentrations with traffic parameter.  
- By increasing distance, Pb and Cd concentrations in roadside soil decrease logarithmically.  
- Pb and Cd concentrations of gutter soils increase linearly and exponentially with increment of total traffic volume, respectively.  
- The models (models 1 and 2) developed in this research are capable of predicting Pb and Cd concentrations in soil within a distance of 50 m as a function of distance from road side and total traffic volume.

Acknowledgements
This article was the result of M.S dissertation approved by the Isfahan University of technology (IUT). The authors wish to acknowledge to Vice Chancellor of Research at IUT for the financial support Research Project.

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How to cite this article:
Saeed Samani et al.2017, Modeling of Relationships Between Traffic Parameters And Vehicular Lead And Cadmium Distribution In Urban Roadside Soils. Int J Recent Sci Res. 8(4), pp. 16280-16286.  
DOI: http://dx.doi.org/10.24327/ijrsrc.2017.0804.0118  

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