Modeling of lead and cadmium density in the soil of urban roadside using traffic parameters

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ABSTRACT

Lead and cadmium are heavy metal pollutants released by vehicles which are propagated into the urban environment by traffic flow. To study roadside soil pollution and to determine the traffic parameters affecting levels of read and cadmium in soil, Isfahan was selected for a case study. In this city, soil samples were collected from 13 roadside sites and traffic parameters were determined. The traffic parameters studied include total traffic volume, total traffic volume to road oriented width, total traffic volume total traffic capacity, speed, and aspect ratio. Average lead and cadmium concentration in soil at distances from 0 to 50 meters from the road edge were found to be higher than background values, thus failing to meet maximum acceptable agricultural soil standards. The regression analysis of concentrations in stream soils versus selected traffic parameters showed that the total traffic volume was the parameter with the highest impact on soil metal content. Also, it was observed that lead and cadmium concentration (as dependent variables) decreased logarithmically with increasing distance (as one of the independent variables) while each of the lead and cadmium concentration increased linearly and exponentially, respectively, with increasing total traffic volume (as another independent variable). The regression models developed in this study can be used for predicting lead and cadmium levels in roadside soil in terms of distance from road edge and total traffic volume. The results obtained obtained from this study may be used in urban traffic control, transportation management, urban design and architecture, and urban land use planning.

Keywords: ***Urban environment, traffic pollution, traffic demand model, lead and cadmium distribution, roadside soil pollution.***

By increasing the society's requirement for transportation and communication, using vehicles specially personal vehicles increases daily, so that in the base of the prediction there will be about 950 million vehicles in 2020 all over the world. Basically, the vehicles are the main resource of heavy metal pollution production which entering environment in the form of ingredients in the cities. The vehicles pollution distributes at the rode margins via traffic flow, so the soil and plants polluted in that area.

Considering the physical and chemical characteristics of earth, there are diverse compositions of heavy metals in very limited quantities in the particles and primary layers of earth and considering its texture and environmental conditions the process of accumulation and colony of the particles are accordingly affected [2]. Lead and cadmium are those automotive pollutants that due to high level of toxicity for nature and human race and cause of blood, neurological and bone diseases have been mostly focused on by the scientists and researchers [3,4]. Lead is usually produced due to burning lead containing benzene fuels in urban environments. In the recent years, by omission of lead from benzene fuels, there has been a drastic drop in the level of lead accumulation in urban areas but still the previous colony remains in such environments. Cadmium exists in automobile tires and car depreciation and traffic diffusion enters the urban environments[3]. Different parameters affect the diffusion of automotive pollutants in the environment and in large scales they include parameters of streets, traffic and the environment. Street parameters, including the physical and architectural condition of the roads are inclusive of the length, slope, width, and lie expectancy, average height, clip, and the life expectancy of surrounding buildings, width of side walks, number of lanes, the type of greenery coverage and the height of the plants surrounding the streets, the shades and the average sight [3,6]. The traffic flow stimulates the air around the road that carries the heavy metal pollutants. Considering that the air flow is usually is perpendicular to the street axis, in contact with any of the above mentioned physical factors, it takes and different position and eventually affects the process of pollutant diffusion in the side roads. The traffic flow, which is the most important factor affecting the diffusion of automotive pollutants includes different factors such as speed, traffic volume and density of the flow and other factors such as the behavior of the drivers at the time of starting and driving, type of fleet, traffic management methodology, and the clip of driving signs in the streets [7,8,9].

Environmental parameters of climate including temperature, rainfall, wind direction and speed and the characteristics of the earth covering the sides of the roads [6, 7, 8].

Researches have been conducted in evaluating the pollution of the earth around the streets considering the heavy metals specifically lead and cadmium and the relation of pollution density with the traffic factors. In these studies, the density of metal in the soil and its proximity considering different traffic factors have been considered. Rahmani, considering the samples of soils taken from different distances of four expressways in Iran has shown the decreasing level of lead density by increase of distance from expressways. Ward et al [10], in Oakland New Zealand have evaluated the density of heavy metals of cadmium and lead in the skin deep soil of the street sides in 17 sites. The results show gradual drop in the density of heavy metals in the earth due to increasing distance from the streets and the level of lead is almost significantly related to the traffic but this relation in cadmium has been very weak. Carlosna et al [11], in Lacrona Spain, studied the automotive traffic effect over the metal density in the earth around couple of streets and decided that lead, cadmium, copper and zinc follow a similar behavior under the traffic diffusion. Garcia and Milan [12] have studied the density of cadmium, copper, ferrus, manganese, lead and zinc in eight different geographical situations in the earth covering the margins of expressways and their ling to traffic flow in the Guipozcua of Spain and decided that the distance affects the density of lead, zinc and cadmium.

Study of automotive pollutants and the way they affect the pollution of the environment across the roads and the traffic factors affecting the level and process of diffusion of such pollutants is required in defining the architecture and the city map and traffic management. Such studies have been conducted in most other countries [13] but the results can not be confidently applied in Iran due to the different architecture and street plans and the level of traffic in different cities of Iran. Hence, the cause of this research is to evaluate the level of earth pollution by lead and cadmium in the road margins and waterways in the streets and also the effect of different traffic factors over the level of pollution and eventually defining the diffusion process of lead and cadmium pollutants based on traffic and distance factors.

2. Elements and methodology

13 sites of high traffic volume cities of different and relatively old streets in Isfahan were chosen which shown in table 2. The criteria to choose the streets was their relative distance of almost 150 meters from the first automobile concentration centers such as bus and taxi stations, and intersections; however there has not been any barrier for pollutant diffusion near these sites for a long time. The street plan in Isfahan includes water ways along the two sides of the streets and these waters ways have dusty grounds and concrete sides and trees are planted. Soil samples were taken from the 0 to 50 centimiters depth of the waterways of the sites to 50 meters distance from the sites 10 to 13. In other sites, due to construction activities it was not possible to provide samples of soil in 50 meters distance. The criterion to choose the sample sites was the recommendations and results offered in other similar researches conducted all over the world [10,17]. Sampling methodology has been lineal where three similar samples were provided in two parallel axis of the street from a unique central point with 25 centimeters distance from one another and the samples have been mixed. The samples gathered were extracted in the laboratory and the density of total lead and cadmium were evaluated by spectroscope of atom absorption. The phases of extraction and evaluation of lead and cadmium density in the laboratory have been standard [14].

Generally the traffic inputs include: average annual traffic level, annual traffic volume, total traffic volume (during exploitation), proximity of total traffic to traffic capacity, proximity of total traffic volume over the width of the street, annual average speed of the cars and the site. The definitions for each of the above parameters include: Average daily traffic per year is calculated by dividing the volume of annual traffic over the number of days per year. These parameters have been adopted by many scientists for the evaluation of the density of pollutants in the streets [10,11,12].

To define the average daily traffic per year and annual traffic volume of these streets the following have been done:

1. For all sites (except Mohtasham Kashani Street) the statistics of 2000 collected by the collage of transportation of Sanati Sharif University have been used.
2. The statistics of 1987 collcted by the average daily traffic of Mohtasham Kashani during 2005 has been defined through census and then traffic volume was calculated.

3. The traffic volume for 1987 for sites No 1, 3, 6, 7, and 9 were calculated based on referrance inputs {18}.
4. The construction year of each street has been identified through a local newspaper in Isfahan named Akhgar, which was later renamed as Isfahan newspaper, published since 1928. The coefficient of car ownership and Isfahan population has been used to evaluate the volume of annual traffic during different years of exploitation for sites 2, 10, 11, and 12. Using the above inputs, the coefficients of annual traffic volume of all sites during the years including the statistics have been evaluated then the annual traffic volume of each street during different years of exploitation has been estimated. Finally, the passing traffic volume of each street with the total annual traffic volume since the date of construction was assess in 2002. 2002 was the date when lead was omitted from benzene fuels which is the main source of pollutant diffusion in Iran. The valley of traffic volume changes in all sites studied constitutes 52 to 520 million different vehicles. The total traffic volume which is in fact the cumulative volume of traffic was estimated since it affects the density of lead pollutant in the earth of the street margins. The total volume refers to the capacity of streets for transport of vehicles during the exploitation life of each street. The total traffic capacity divided to the total traffic volume (V/C where V is te total traffic volume and C is traffic capacity) where the potential factors affecting the density of heavy metal automotive pollutants. The C volume can be calculated by EMME/2 software. This parameter defines the approximate exploitation of the streets during the years. In each street, the average speed of the automobiles has been calculated by comparison of two dominating automobile speed. The valley of average speed changes in different sites has been 30 to 76 Km/h. [15] ratio has been one of the potential parameters affecting the diffusion of automotive pollutants that has been calculated by division of the average height of surrounding buildings in each site over their distance from the extended line in the middle of the streets showing the direction of car movements up to the side walk. This parameter has been used to estimate the pollutnats in the street strips in different studies [16]. Zero height means no buildings exist around the streets. The streets and surrounding buildings and the strips they make are referred to as street strips. The width of the lane of each

side of the street is called direction width which allows us to estimate the effect of traffic volume from each lane of the street.

3- Results and Recommendations

Table 2 is the statistical specification of lead and cadmium density in the waterways along the streets to the distance of 50 meters and the base earth in Isfahan city. The base of calculation has been level of lead and cadmium accumulation in the soil of bald and untamed areas outside Isfahan. Also table 2 shows that the average of metal accumulation in the waterways up to 50 meters is higher than the baseline. Table 3 the difference of lead and cadmium density of the samples and the ground sample has been identified by using t test methodology in 5% level (95 percent confidence level). In this comparison, unilateral potential has been considered considering that it is expected that the level of lead and cadmium density estimated to be equal or more than the ground sample. In test t, estimated t (tcal) is more than t in crisis (tcri) and shows the efficient difference of the two samples.
Table 3 indicates that the average of lead density at all times has a significant different with the ground sample at 5%. Accordingly the total lead density in the sample earth has been affected by pollutant sources and since the samples are all collected from urban areas, human elements are the reason of diffusion of pollutants into the soil. The level of cadmium density of earth in the waterways has also a significant difference with the ground sample and is affected by external factors. Considering that these observations includes the earth of the streets, one can conclude that the traffic flow causes the pollution which is also proved by many other researches [5,8,10,11]. conducted in this regard. Since the waterways usually have plan coverage and trees are planted, it is useful to compare the soil of these areas with the standard agricultural soil. In Iran, standards for level of heavy metal density has not been defined from agricultural purposes, for comparison, standards of Britain and Australia have been used were the MAC for lead is 100 and for Cadmium is accordingly 1 and 5 milligram per kilogram. Table 2 indicates that the average lead density of the waterways soil to 50 meters is above the maximum standard level and cadmium is also above the standard level of Britain. This emphasizes that in creating greenery along the streets, soil pollution and heavy metal density has to be considered and precautions have to be taken. Table 4 indicates the traffic inputs including total traffic volume till 2002, average annual daily traffic in 2002, total traffic volume per total traffic capacity,

total traffic volume per street lane width, average speech in 2005 and sight level in the sites studied in this research. The evaluation of lead and cadmium density of inputs in 50 meters for the sites 10 to 13 shows that the process of change drops by increase of distance and comparison of different samples against the density inputs in distance it was concluded that the logarithm model is the best model to define these changes. As defined in table 5, the results of comparison of lead density at 5% level, site 10 compared to sites 11 and 12 has been calculated with the high t level and has a significant difference of t crisis of bilateral possibility.
Also site 13 compared to sites 11 and 12 has a t of higher than t critic level. The result of comparing the cadmium density also shows that site 10 compared to sites 11 and 13 has higher t critic level and site 11 compared to 13 has a higher t than the t crisis. It can be concluded that the difference between the sites are significant and obviously the difference is due to various traffic patterns in the sites.

Table 1: *Soil sampling and traffic studies specifications.*

Number of site	Name of Site	Position	Streets build year
1	Chahar bagh st.	100 meter before chahar rah takhti	1936
2	Foroghi st.	500 meter before shohada square	1940
3	Bozorgmehr st.	200 meter before bozorgmehr square	1960
4	Ahmadabad st.	150 meter before mehregan st.	1936
5	Kashani st.	30 meter before helalahmar building	1940
6	Moshtagh aval st.	500 meter before khajo square	1975
7	Kamal esmail	200 meter before ferdosi building	1950
8	Chahar bagh bala st.	300 meter before shariati st.	1955
9	Sajad st.	200 meter after abshar aval st.	1965
10	Mohtashame kashani st	400 meter after chaharrah shariati	1980
11	Emam Khomeini st.	150 meter before khaneh esfehan	1960
12	Emam Khomeini st.	1 km befor ghalamestan park	1960
13	Razmandegan st.	100 meter after robat st.	1990

Table 2 : *The statistic specification of lead and cadmium density at water way soil, the streets margin soil to 50 meter distance and earth soil.*

Statistic parameters	Unit	Water way soil		Street margie soil		earth soil	
		Cd	Pb	Cd	Pb	Cd	Pb
Number of sample	Mg/kg	19	19	40	40	40	40
Mean	Mg/kg	220.82	2.94	126.82	2.41	28.91	2.02
Median	Mg/kg	186.34	3	86.85	2.4	28.65	1.8
Deviation variance	Mg/kg	112.52	0.31	82.77	0.37	10.87	0.55
Minimum	Mg/kg	65.05	2.4	35.78	1.8	7.3	0.6
maximum	Mg/kg	481.35	3.4	325.26	3.4	57.8	2.7
amplitudeIn regards to	Mg/kg	416.30	1	289.48	1.6	50.5	2.1

Table 3 : *Test for comparing the lead and cadmium density averages at waterway soil and the streets margin soil to so meter distance whit earth soil.*

Samples position	Number of observation	Mean , mg/kg	Deviation variance mg/kg	Degrees of freedom	Tcal	tcri
Earth soil	40	28.91	10.87			
Water way soil	19	22086	112.52	57	18.73	2.00
Margin soil	40	126.82	82.77	78	6.28	1.66
Cadmium						
Earth soil	40	2.02	0.55			
Water way soil	19	2.94	0.31	57	2.20	2.00
Margin soil	40	2.41	0.37	78	2.20	1.66

Table 4 : *The using traffic data for each site.*

Number of site	Name of site	Total traffic volume up to 20002 (veh)	Avery daily traffic volume in 20002 (veh/day)	Total traffic volume divided to total capacity up to 2002	Total traffic volume divided to the street width (veh/m)	Avery speed in 2005 (km/h)	Sight ratio
1	Cahar bagh paeen	323277305	31583	0.473	8710723.98	30.2	0.129
2	Foroghi	48657845	5470	0.121	11701274.02	30.3	0.3
3	Bozorgmehr	38803251	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	Moshtagh aval	119352995	18304	0.328	7976695.902	52.2	0.514
7	Kamal esmaiel	285227027	20759	0.638	28787951.13	43	0.106
8	Chahar baghe bala	247895679	23970	0.311	31040260.08	43.3	0.214
9	Sajad	222501183	25358	0.243	34029190	53	0.067
10	Razmandegan	68052132	10600	0.184	18649612.12	54	0
11	Imam khomeni (khaneh Esfahan)	295864488	34230	0.192	21133177.71	54	0
12	Imam khomeni (ghalamestan)	255499686	29560	0.187	43881081.08	75.8	0
13	Mohtasham kashani	72299009	26205	0.50	32538749/94	54	0

Table 5 : *The results of double teat for comparing the averages of lead and cadmium density in various sites.*

parameter	10 against 11		10 against 12		10 against 13		11 against 12		11 against 13		12 against 13	
Mean	74.79	181.89	74.79	184.1	74.79	65.92	181.89	184.1	181.89	65.92	184.1	65.92
Observation	10	10	10	10	9	9	10	10	9	9	9	9
Df	9		9		8		9		8		8	
t_{cal}	6.032		4.550		0.559		0.170		5.858		4.908	
t_{cri}	2.262		2.262		2.306		2.262		2.306		2.306	
Significant level	0.05		0.05		0.05		0.05		0.05		0.05	
Probability	<0.001		<0.001		0.591		0.869		<0.001		<0.001	
Cadmium												
Mean	2.36	2.7	2.36	2.44	2.36	2.11	2.7	2.44	2.7	2.11	2.44	2.11
Observation	10	10	10	10	9	9	10	10	9	9	9	9
Df	9		9		8		9		8		8	
t_{cal}	6.530		0.497		8		1.816		10		1.664	
t_{cri}	2.262		2.262		2.306		2.262		2.306		2.306	
Significant level	0.05		0.05		0.05		0.05		0.05		0.05	
Probability	<0.001		0.631		<0.001		0.103		<0.001		0.135	

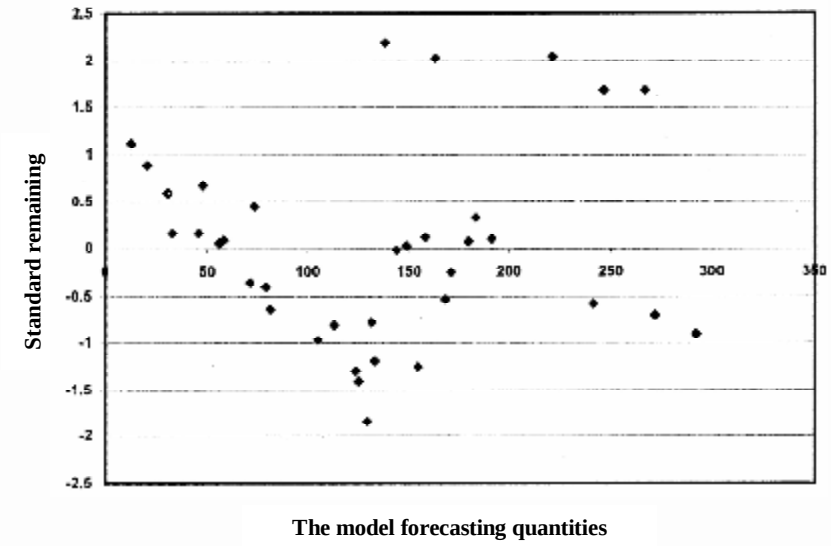

Figure 1 : *Remaining dispersion against the model for casted quantities for total lead.*

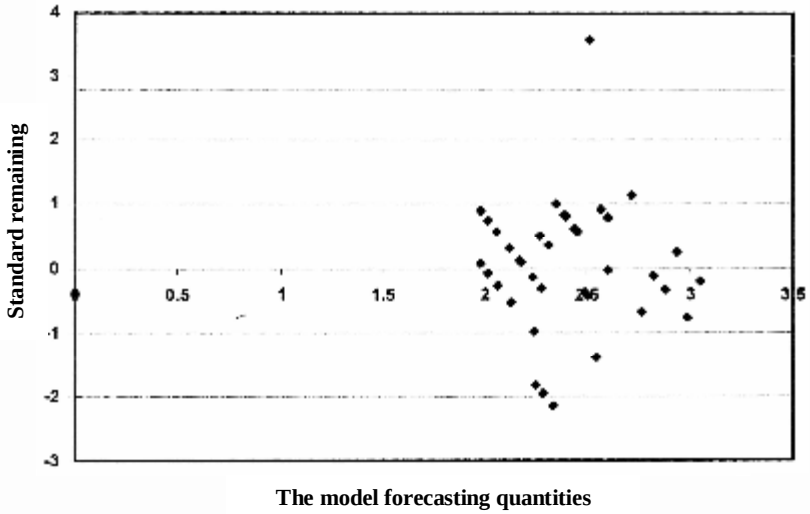

Figure 2 : *Remaining dispersion against the model for casted quantities for total cadmium.*

It has been proven by now that traffic affects the diffusion and density of heavy metals around roads, the methodology and level of this impact can be identified through regression analysis. Comparison of different regression patterns against the lead and cadmium density inputs around the waterways of the sites against any of the traffic factors indicated in table 4, it can be observed that density of metals is efficiently surpassed by traffic volume and the best pattern for lead is linear patter (with coefficient of

regression 0/73) and cadmium 9with coefficient of regression 0/69) as a model. Although in [6] the proximity of total traffic volume over the total traffic capacity is used as the effective factor over the process of diffusion, but in this research no proper relation between total lead density and this parameter was not identified. Despite the fact that many scientists [10,17]. Have used the parameter of daily traffic volume to compare the sites, this research has observed very weak relation between this factor and the metal density and considering that daily traffic volume is a short term quantity, this is reasonable. Also, no proper proximity was traced between the density of the metals and speed and sight parameters of traffic. It can be concluded that traffic parameters of daily traffic volume, speed and sight are factors that affect gas pollutants with smaller particle size which can bee easily disseminated by air but they can have less effect over heavy metals with bigger and heavier particles and sink very quickly. On the contrary, considering that the density of lead and cadmium is cumulative in earth and it happens during long term exploitation of the streets, those parameters that include wider time lines are significantly effective. In this research a meaningful relation between the level of total traffic volume and density of metals in the soil was observed. The patterns obtained regarding the change of density compared to the distance and density compared to the total traffic volume, to create general patterns, different models have been used in combination where the variables have been lead and cadmium density and independent variable of total traffic volume and distance and finally the below patterns have been identified considering their higher level of unity (with the coefficient of 0/8) and simplicity:

1. CPb = 120/83 + 4/92*10-7V-35/39InD
2. CCd=2/25+0/29 e3E-9*V-0/16 InD

CCd indicates the total lead density and CPb Indi Cates the total cadmium density where:

The total cadmium and lead density has been calculated on mg/Kg of dry soil, distance over D based on meter and total traffic volume over V based on the number of vehicles over. The standardized difference have been estimated by the division of the anticipated volumes by the observed ones over the square root of the difference and all have an average of zero and unique deviation and while appearing between 2 and -2 are the best pattern of regression to be chosen. Comparison of the standardized differences with the anticipated ones of 1 and 2, it is observed that in lead and cadmium almost all differences are between 2 and 2 and almost all have a

positive and negative deviation of 1.96. Hence it can be concluded that the regression pattern offered is credible.

4- Conclusion

The following can be concluded of this research :

- The average of lead and cadmium density in the waterways and earth up to 50 meters, is higher than the ground sample and even higher than the standards of agricultural soil in other countries.
- The average of lead and cadmium density in different sites has a meaningful difference which is resulted from various traffic patterns.
- The density of lead and cadmium in the earth around the streets is more linked to the traffic parameter of "total traffic volume" rather than other traffic parameters (daily traffic volume per year, traffic volume over the street width, dight, average speed and traffic volume in lane).
- In general, the comparison of the density of heavy metals in the earth around the roads and its link with the traffic parameters, those parameters with longer effects are more influential.
- The density of lead and cadmium of the margins of the streets has a logarithm decrease with the distance.
- The level of lead density in the soil of the waterways has a linear increase and the density of the cadmium in the waterways has a modal increase compared to the traffic volume.
- The patterns offered in this research (1 and 2) with relative proximity estimate the density of lead and cadmium to 50 meters on an ancillary basis up to the edge of the street and traffic volume.
- The result of this research can be adopted in the management of urban area usage. For instance, the results can be useful in defining the width of the sidewalks, identification of proper locations for sensitive installations such as hospitals, kindergartens and defining the height of the edges of the streets.

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