Kuwait J. Sci. **44 (2)** pp. 121-128, 2017

Correlation analysis of toxic metals on motorway and national highway

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Absract

Research study evaluating levels of toxic metals along roads, which are polluted with dust from exhaust smoke and sand dust is timely. Five (5) each sampling sites were strategically selected along motorway M-3 and national highway N-5 in Pakistan. The sites were designated as M-3a, M-3b, M-3c, M-3d, M-3e and N-5a, N-5b, N-5c, N-5d and N-5e respectively. In each location, dust was accumulated 24 hours within two consecutive months in petri plates encrusted with polystyrene foam, which was kept 15 m away from roads as reference control and its corresponding road side dust deposit as test. The lead (Pb^{2+}) and cadmium (Cd^{2+}) contents were estimated using atomic absorption spectrophotometer (AAS). The results showed high Pb^{2+} concentration along M-3 and N-5 road side dust deposit, compared to controls. High Cd^{2+} contents were also recorded in road side deposit at M-3e and M-3d, compared to controls at 15 m away from the roads. Although high levels of these toxic metals were detected in the road sides sand deposit compared to controls, the controls may be considered to also harbor reasonable concentration of the metals. The correlation co-efficient between the metal contents and traffic density proved that Pb^{2+} & Cd^{2+} were constantly totting up from vehicular exhaust dust. The findings may therefore indicate that settlers along these roads are at high risk of toxicity from these metals.

Keywords: Cadmium; correlation; dust; environmental pollution; lead.

1. Introduction

In the process of urbanization, due to traffic load, fuel gases (particularly PbO_2) emit and mix well with dust. This high dust deposition rate is constantly affecting the infrastructure (buildings and roads etc.) and it also causes environmental problems to communities (Mehmood & Khan, 2005). Even though, transportation facilitates the socio-economic status of a country, load of heavy vehicles on the roads also release carcinogenic air pollutants to the atmosphere (Sarwar & Muhammad, 2014). The unstable metallic elements from vehicular and industrial emissions are constantly entering the environment from point and nonpoint sources (Ahmed & Ishiga, 2006). According to literature, the correlation coefficient for lead and zinc is 0.578, for lead and cadmium is 0.506 and for cadmium and zinc is 0.573. The said pollutants mainly originating from vehicular as well as industrial emissions enter into the atmosphere (Abdel-Latif & Saleh, 2014). Although Pb^{2+} pollution was phased out from motor vehicles under Clean Air Act (1992), still Pb^{2+} emission occurs from some industries in United States of America (Clean Air Act USA, 1992). This metal causes neurological disorders among children, learning deficits with low IQ as well as cardio-cerebral and cardiovascular diseases in adults (Dufault *et al.,* 2009). Although controlled within USA by the local government, this pollutant has caused a global concern. This pollutant has also contributed to climate change since last five years. Anthropogenic activities pose potential threats to community and ecosystems (Karl *et al*., 2009). Keeping all this in view, an experimental study on dust generated by traffic pollution has been carried out in Pakistan. The findings proved that Pb^{2+} is a key source of air pollution and it has perilous effects on children (Roman *et al*., 2013; Gen *et al*., 2014). While some metals are quite beneficial at optimum concentration to crops, others may be toxic even at trace levels (Adams & Lamoureux, 2005). The high concentration of Pb^{2+}, Cd^{2+}, Cu^{2+} and Zn^{2+} cause lethal effects to biodiversity

(Adams & Lamoureux, 2005). The Pb^{2+} concentration from different polluted localities of Adana city were reported as maximum, minimum and mean values (0.26, 0.056 and 0.183 mg kg^{-1} respectively) (Khairy *et al*., 2011). The Pb^{2+} content of soil was found to be the highest and directly correlated to high traffic density. The measured correlation R^2= 0.996 to 0.999 for Pb^{2+} and Cd^{2+} showed good linear relationship with concentration of total suspended particles (Awan *et al*., 2011).

This study was designed to evaluate the established metal pollution, emanating from mobile bodies and its relation to traffic density along the roads linking many districts. The pollution status of these areas remained unattended due to irregular infrastructure and scarcity of regular air monitoring. The inhabitants of these thickly populated areas are using vehicles and as a result, heavy traffic density is always experienced on both roads. The methodology used has been briefly discussed here.

2. Material and methods

2.1 Study area

The study was conducted along two busy roads namely Motorway M-3 and National Highway N-5 linking many districts of Faisalabad, Gujranwala and Sheikhupura. The main industrial sectors are also located along these roads. It is a busy area used as residential and industrial sites. Thirty three (33) industrial units are located along these roads.

2.2 Work design and sample collection

Five (5) strategic locations on each road were identified as sites for trapping dust particles and 15 m away from roadsides as reference control. The controls receive no dust, as they are further apart from the main roads. Their corresponding sand dust was collected at the road sides as test for two months, on regular basis**.**

The sites along Motorway M-3 were designed as follows:

M-3a – Kamalpur sorgaha road

M-3b – M. C. Drain

M-3c - Nahar Barnala Jhang

M-3d – Hojan town

M-3e – Pindi Bhattian,

The sites along National Highway N-5were designated as follows:

N-5a – Sitara valley

N-5b – ZIS textile

N-5c – Chuk No.6 Saudagarpur

N-5d – Bhalipur bhara panwa stop

N-5e - Bhikki

2.3 Sample digestion and analysis

The composite samples (0.1g) were drawn in triplicates and digested using the method for consecutive two months (Florence & Batley, 1977). The digested samples were analyzed for Pb^{2+} and Cd^{2+} contents using atomic absorption spectrophotometer (Perkin Elmer Germany). The vehicle records adopted in the method were obtained from Express Highway Authority (Amusan *et al*., 2003; Zhang *et al*., 2012).

2.4 Statistical analysis

The data were subjected under paired *t*-test using CoHort Statistics software. The level of significance was 0.05.

3. Result and discussion

3.1 Lead (Pb^{2+}) distribution

The distribution of Pb^{2+}on road with distance along M-3 and N-5 is depicted in Figure 1 and Figure 2 respectively.

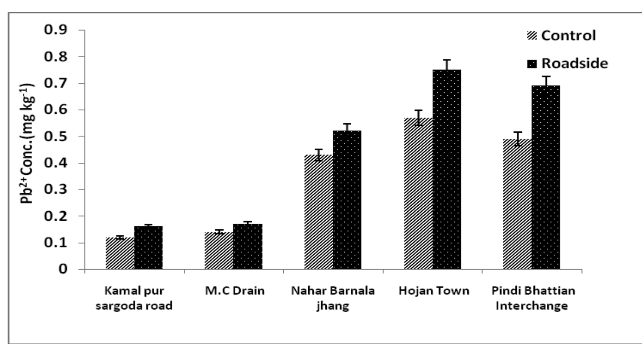

Fig. 1. Concentration of Pb^{2+} in dust of five selected sites of Motorway (M-3).

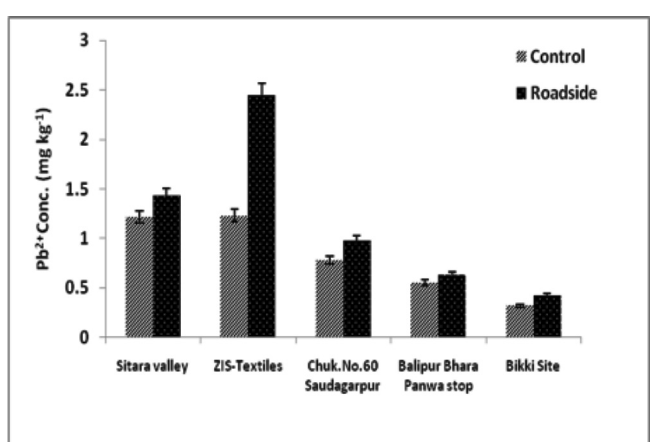

Fig. 2. Concentration of Pb^{2+} in dust of five selected sites of National Highway (N-5).

The Pb^{2+}concentration in the road side dust deposit was found to be high compared to control at M-3e Interchange (28%), followed by M-3a (25%) and M-3d (24%). While lesser concentration of Pb^{2+} (17%) was recorded in M-3b and M-3c (Figure 1), the highest Pb^{2+} concentration (2.44mg kg^{-1}) was detected in road side dust deposits of N-5b, compared to its corresponding control (1.23mgkg^{-1}). The dust samples of all sites at N-5 (Figure 2) showed significant increase ($P<0.05$) in Pb^{2+} concentration compared to their corresponding controls. The high percentage (49%) of Pb^{2+} was calculated for N-5b, while 17% was recorded for N-5d. Pb^{2+}concentrations of 14%, 20% and 23% were recorded at N-5a, N-5c and N-5e respectively.

The results indicate that high Pb^{2+} concentration at M-3 and N-5 was accumulated due to emission of gases from exhaust of brick furnaces situated near these roads. The toxic pollutants suspend in the air and settle with the passage of time on ground. Though factories are the key contributors for accumulation of the Pb^{2+} in the environment, Pb^{2+} contents in dust due to exhaust from vehicles may also have contributed to the high amount of Pb^{2+} in samples collected from N-5. The findings of this study are similar to the work of Arslan & Gizir, 2006, that established median values for Pb^{2+} (1.83 mg kg^{-1}) in street dust of Mercin, Turkey. The findings of this work are justified with another experimental analysis (Jing *et al*., 2014), which indicated high quantity of accumulated Pb^{2+}in deposited dust and absorption in plants. All these findings also indicated that metals detected in road side deposits were from vehicular smoke and they contaminated the surrounding air (Clarke *et al*., 2010). In another study, heavy metals like chromium (Cr^{3+}), zinc (Zn^{2+}), lead (Pb^{2+}) and cadmium (Cd^{2+}) were found in suspended particles emitting from vehicles; the values reported were 0.066, 0.506, 0.079 and 0.003 mg kg^{-1} respectively in Kolkata, India (Karar *et al*., 2006). Industrial dust caused metal pollution in soil and air, which indirectly alters the form and functional metabolism of plants (Peng *et al*., 2010). The findings of this research work are in conformity with the reports of various groups of scientists as given above and the inhabitants are therefore at risk of the toxic effects of these metals.

Metal content from dust samples analyzed at major roads indicated that this dust contained high levels of heavy metals, particularly Pb^{2+} ranging from 66 mg kg^{-1} to 105 mg kg^{-1} (Tanushree *et al*., 2011). The metals mixing into air from thermal power plants were reported to contain Zn^{2+} and Pb^{2+} with respective values of 0.317 mg kg^{-1} and 0.002 mg kg^{-1} in ash dust samples (Syla *et al*., 2008). According to MEPA (2005), the percentage fraction for Pb^{2+} (2.15%) and Cd^{2+} (0.02%) noticed in particulate matter (PM) in USA were within permissive limits. High metal concentration was reported in ground surface water emitting from metallurgical industries and positive association existed between metal concentration and effluent of industries (Mehmood *et al*., 2013). In another study, metals Cr^{3+}, Pb^{2+} and Zn^{2+} analyzed in urban dust samples from five different locations at the road of Aba city (Nigeria) revealed respective mean concentrations of 0.03, 0.07864 and 0.3122 mg kg^{-1} per day with positive correlation between metals and pH of rhizosphere (Akhionbare, 2011). High concentration of Fe^{2+}, Pb^{2+} and Zn^{2+} recorded in indoor dust had been reported to possess significant correlation with traffic density in urban town (Figueroa *et al*., 2007).

3.2 Correlation analysis

Correlation studies were conducted between Pb^{2+} in dust at roadside and control along traffic density at M-3 and N-5. The correlation coefficient values (R^2 =0.189) for dust samples of M-3, indicated positive weak association (Figure 3), which means traffic density contributed positively for enhancing the Pb^{2+} in dust.

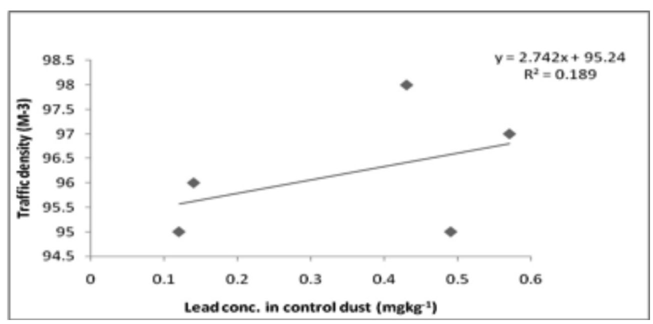

Fig. 3. The correlation between traffic density and Pb^{2+} conc. in control dust on Motorway (M-3).

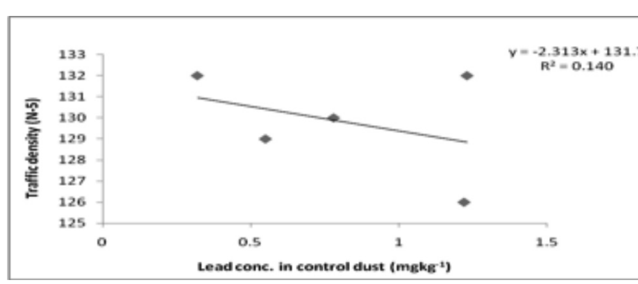

Fig. 4. The correlation between traffic density and Pb^{2+}conc. in control dust on National Highway, (N-5).

The co-efficient of determination (R^2=0.108) indicates that a weak association (Figure 4) was found between traffic density and Pb^{2+} concentration, while the (R^2=0.140) for N-5 dust samples taken as control depicted that Pb^{2+} in dust was not strongly associated with traffic density (Figures 5 & 6).

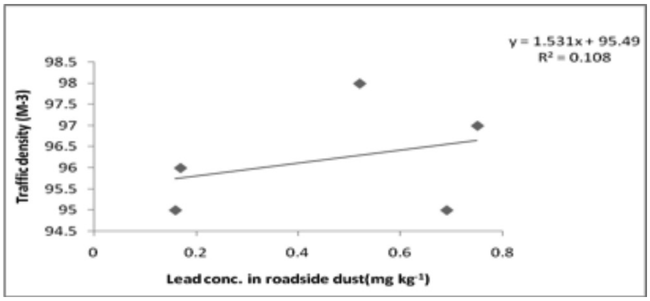

Fig. 5. The correlation between traffic density and Pb^{2+} conc. in dust on Motorway (M-3).

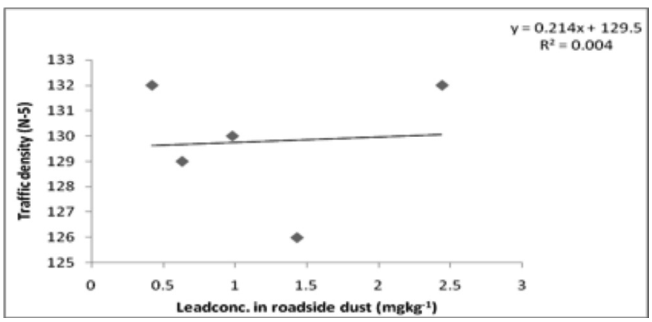

Fig. 6. Correlation between traffic density and Pb^{2+} conc. in roadside dust on National Highway (N-5).

This rising level was due to construction, geography of infrastructure (buildings) and types of emission from running vehicles. Mostly vehicles are CNG based and that is why low concentration of Pb^{2+} was found in the dust collected from both roads. The metal pollution might have gathered slowly and steadily in the air over decades. Some other factors, particularly gases and industrial emission may also have contributed to addition of Pb^{2+} in dust, while at N-5 dust samples had less association with Pb^{2+} accumulation. Number of vehicles did not significantly interact with the Pb^{2+} accumulation in dust. In fact, industrial dust and vehicular smoke simultaneously contributed to Pb^{2+} accumulation in dust. Literature also showed similar reports that dust had negative impact on vegetative growth and metabolism of *Ziziphusspina christi* and *Syzygium cumini,* which were growing on roadsides (Hegazi & Al-Kaydi, 2010). Positive correlation was found among different metals at high traffic areas; more the vehicles, higher the concentration of metals reported (Bada &Oyegbami, 2012). In literature, the concentration of Pb^{2+} and Cd^{2+} recorded at traffic signals was 145.95 mg kg^{-1} and 0.08 mg kg^{-1} respectively (Junaid *et al*., 2011).

3.3 Cadmium (Cd^{2+}) distribution

An increasing trend was observed in Cd^{2+} concentration on both roadsides of M-3 and N-5. The percentage of Cd^{2+} was 50% higher in roadside samples collected from both roads, compared to their controls placed 15 m away from the sample site. The maximum Cd^{2+} concentration (0.03 mg kg^{-1}) was recorded in dust samples of M-3e interchange, while minimum was at M-3c (Figure 7). However, maximum value was calculated in dust samples of N-5c (0.03 mg kg^{-1}) and minimum (0.01 mg kg^{-1}) was in valley N-5a (Figure 8).

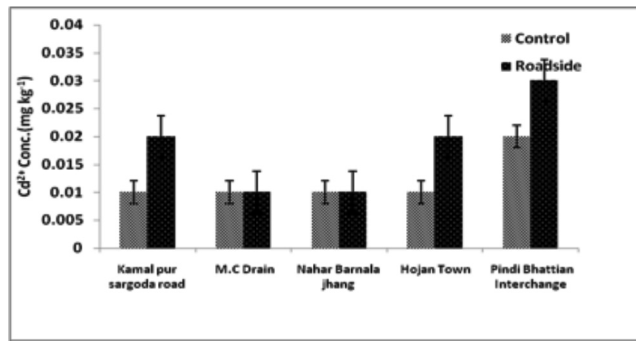

Fig. 7. Concentration of Cadmium (Cd^{2+}) in dust of five selected sites of Motorway (M-3).

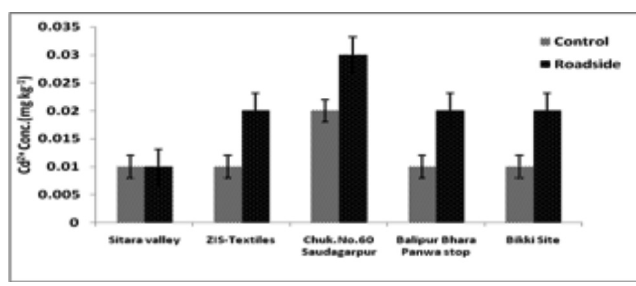

Fig. 8. Concentration of Cadmium (Cd^{2+}) in dust of five selected sites of National Highway, (N-5).

Comparing the values to literature, the recorded values for heavy metals in dust samples of Jordan city indicated Zn^{2+} concentration to be highest, while Cd^{2+} the lowest (Jaradat *et al*., 2004). The low concentration was also observed for Cd^{2+} (0.59 mg kg^{-1} to 1.33 mg kg^{-1}) in street dust samples of Nigeria (Shinggu *et al*., 2007) compared to collect from outdoor. Generally, the finding of this research work is similar to study conducted on main roads of Lahore (Pakistan), which revealed that the degree of heavy metal contamination from automobile exhaust decreased with increase in distance from roads and was less contaminated with Cd^{2+} (Ahmad *et al*., 2006; Lamme *et al*., 2006; Rashed, 2008).

3.4 Correlation study

The Cd^{2+} concentration was correlated with control and roadside dust samples at M-3 and N-5. The highest coefficient of determination (R^2=0.411) was found for roadside dust samples relative to respective control (R^2=0.264). The low R^2 indicated that more association existed between Cd^{2+} accumulations (Figures 9 and 10).

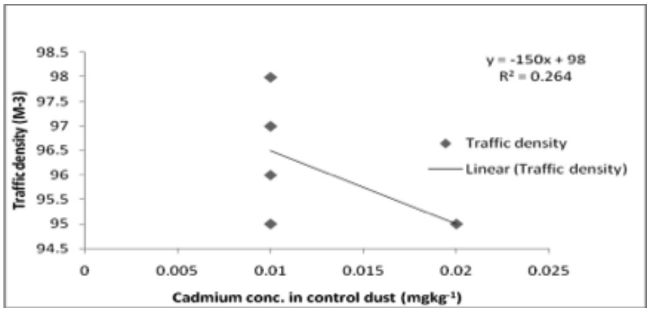

Fig. 9. The correlation between traffic density and Cd^{2+} conc. in control dust on Motorway (M-3).

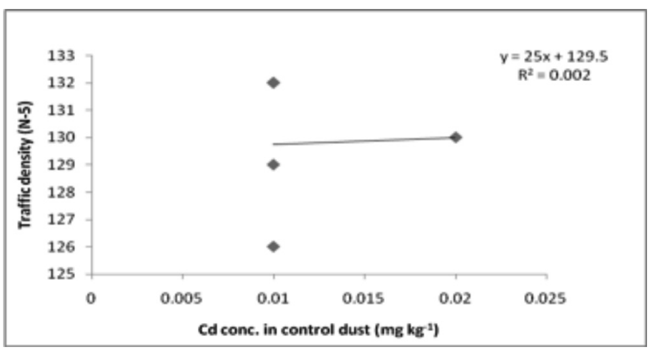

Fig. 10. The correlation between traffic density and Cd^{2+} conc. in control dust on National Highway, (N-5).

Similar trend was noticed on N-5 regarding the Cd^{2+} concentration (Figures 11 and 12). Less association for Cd^{2+} was observed in dust samples and traffic density. The factorial analysis among pine needles, metals and traffic density has proven that high concentration of Cu^{2+}, Pb^{2+}, Cd^{2+} and Zn^{2+} were closely associated with traffic. It has been reported that some neighboring sources play a key role in metal pollution (Bosco *et al*., 2005), while the highest air born metal correlated with the traffic volume (Zereini *et al*., 2005).

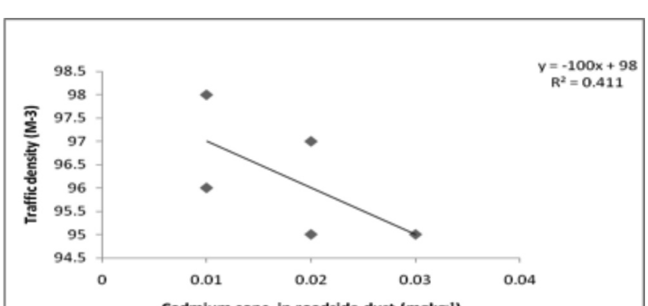

Fig. 11. The correlation between traffic density and Cd^{2+} conc. in roadside dust on Motorway, (M-3).

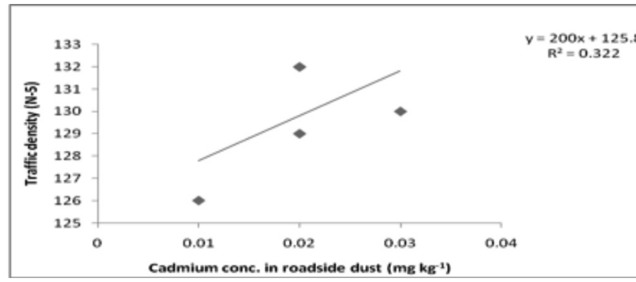

Fig. 12. Correlation between traffic density and Cd^{2+} conc. in roadside dust on National Highway, (N-5).

It seemed that long term exposure of Cd^{2+} emitting from friction of automobile parts cause structural injuries to plants growing along the roadsides. The dust particles released from point or non-point sources settled down with the direction of wind may cause hazardous effect to living biota (Hussain *et al*., 2008; Nawazish *et al*., 2012). The Cd^{2+} was weakly associated with traffic density. One reason was Cd^{2+} released from wearing and tearing of tires of vehicles entered the dust. In another study, positive correlation was found between metals in the dust and traffic density, where coefficient value was found to be 0.32 (Alhassan *et al*., 2012).

4. Conclusion

It is important that metals entering dust from different sources shall be monitored and managed periodically, in order to mitigate the pollution threats from the atmosphere. It also is a dire need to identify the detoxifiers or metal recyclers, so that metal loving organisms can purify our agro ecosystem and take preventive measures to avoid health hazards.

5. Acknowledgment

I am highly grateful to my teachers, lab fellows and Higher Education Commission (HEC), Islamabad for giving me indigenous scholarship and financial support during my Ph.D.studies

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Submitted **:** 09/09/2015
Revised **:** 09/02/2016
Accepted **:** 15/02/2016

تحليل الارتباط للمعادن السامة على الطريق السريع والطريق القومي السريع

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خلاصة

دراسة بحثية تُقدر مستويات المعادن السامة عبر الطرق، والتي تكون ملوثة بالغبار الناتج من دخان العوادم والأتربة الرملية. تم اختيار خمس (5) مواقع عينات بشكل استراتيجي لكل من الطريق السريع M-3 والطريق القومي السريع N-5 في باكستان. تم تخصيص المواقع كـ M-3a, M-3b, M-3c, M-3d, M-3e و N-5a, N-5b, N-5c, N-5d and N-5e على التوالي. في كل موقع، تم تجميع الغبار على مدار 24 ساعة خلال شهرين متتاليين على ألواح بيتري (Petri plates) مغطاة برغوة بوليسترين، في كل موقع تم وضع أحد الألواح على بُعد 15 م من الطريق السريع كمرجعية محكومة ولوح آخر مناظر على جانب الطريق للحصول على مشاهدة للاختبار. تم تقدير محتويات الرصاص (Pb_{2+}) والكادميوم (Cd_{2+}) باستخدام مطيافية الامتصاص الذري (atomic absorption spectrophotometer) (AAS). وأظهرت النتائج تركيز عالي من الرصاص في المشاهدات المأخوذة على محاذاة الطرق M-3 و N-5، مقارنةً بالمشاهدات المحكومة. كذلك تم تسجيل محتويات عالية من الكادميوم في المشاهدات المأخوذة على محاذاة الطرق M-3e و M-3d، مقارنةً بالمشاهدات المحكومة. بالرغم من اكتشاف مستويات عالية من هذه المعادن السامة في المشاهدات المأخوذة على محاذاة الطرق مقارنةً بالمشاهدات المحكومة، قد نعتبر كذلك أن المشاهدات المحكومة تحتوي على تركيز معقول من المعادن. معامل الارتباط بين محتويات المعدن والكثافة المرورية أثبت أن كلاً من الرصاص Pb_{2+} والكادميوم Cd_{2+} قد تجمعا بشكل مستمر من غبار عوادم السيارات. ولذلك قد تشير النتائج أن المقيمين على طول هذه الطرق معرضون لمخاطر جسيمة من سموم تلك المعادن.