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Original Research

Assessment of Heavy Metals Accumulation in the Soil and the Cultivated Crops along a Highway in Lucknow City, Uttar Pradesh

Snigdha Singh*

School of Environment and Sustainable Development, Central University of Gujarat, Sector-30, Gandhinagar, 382030, Gujarat, India.

Abstract

Development of transport facilities unconsciously affects the natural resources and biodiversity. Non-point sources of traffic related pollution has become a major concern as they are more difficult to be defined or controlled as compared to the point sources. The environmental pollution of heavy metals from the automobiles has attained much consideration in the recent past. The present research was conducted to study the levels of chromium, lead, cadmium and nickel in the roadside farmland soil and crops cultivated there. Soil samples were collected from a farmland at distances of 0, 50, 100 and 1000 mtrs from the road edge. The concentration of the heavy metals in the soil samples and the crops (Pigeon pea, Wheat, Mustard) has shown a decreasing trend with the increase in the distance from the road edge, thus indicating their relation to the traffic and the automotive emissions. Deposition of these heavy metals in the environment and the crops in particular could pose health risk to humans through food chain contamination.

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***Corresponding Author:**
Snigdha Singh
E-mail:
sngdhasingh@gmail.com

INTRODUCTION

The risk posed by heavy metals to food safety and the environment are of great concern to governments and society in many countries. Heavy metal pollution in agricultural soils is becoming serious with the rapid industrialization and urbanization in developing countries (Wei and Yang 2010; Zhang *et al*., 2012) Roads are known as the second largest non-point source of creating pollution in urban environment (Saeedi *et al*., 2009; Fakayode and Olu-Owolabi, 2003). Emissions of heavy metals from road operations cause many environmental problems such as air pollution, water and soil pollution and thus lead to human health impairment. The environmental pollution of heavy metals from automobile emissions has attained much attention in the recent past due to their long-term accumulation. Several studies have proved that roadside environment get polluted by heavy metals released during different operations of the road transport (Matthews and Samuel, 2013). Traffic activities are one of the major sources leading to heavy metal contamination in roadside soils due to their long-term accumulation. More importantly, the roadside farmland soil is associated with the food chain and public health. The mechanisms of heavy metal emission from vehicles consist of fuel consumption, engine oil consumption, tire wear, brake wear, and road abrasion (Markus and McBratney, 1996; Wilcke, *et al*., 1998; Winther and Slentø, 2010). Engine oil consumption is responsible for the largest emission for Cd, tire wear contributes the most important emission for Zn, and brake wear is the most important source of emissions for Cu and Pb (Winther and Slentø, 2010).Though the use of unleaded gasoline has caused a subsequent reduction in fuel emissions of Pb, it may still occur in exhaust gas and come from worn metal alloys in the engine. At low doses some heavy metals are essential micronutrients for plants, but in higher doses, they may cause metabolic disorders and growth inhabitation in most plant species (Zhang *et al*., 2012; Sinha *et al*., 2005). Cd and Pb, even at extremely low concentrations, are toxic and lead to many diseases, including increased risk of cancer (Willers *et al*., 2005). Cd emission is mainly from lubricating oil consumption and tire wear. Zn comes from tire wear and galvanized parts such as fuel tanks (Falahi-Ardakani, 1984). Brake wear is the most important source for Cu and Pb emissions. Pb comes also from exhaust gas and worn metal alloys in the engine. Through the atmospheric deposit or road runoff, heavy metals can be transported into the roadside soils (Nabulo *et al*., 2006; Viard, 2004) where the roadside grasses absorb these heavy-metal elements from the soils through their roots.

Considering the above facts, the present study aims to examine the effect of soil contamination due to vehicular exhausts along the highway and on the crops (pigeon pea, wheat and mustard)grown in the associated soil.

MATERIALS AND METHODS

Study Area

The area selected for the study is the Lucknow-Raebareily National Highway (NH-24B). It runs within the state of Uttar Pradesh, India, that links the state capital Lucknow to Allahabad and is 185 km long. The climate of the region is humid subtropical with cool dry winters from mid November to February and dry hot summers from late March to June with an average rainfall of 896.2 millimeters (35.28 in).

Sampling of Soil and Crop Samples

For the present study soil and crop samples were collected from the agricultural field situated adjacent to the Lucknow-Raebareily highway near Mohanlal ganj area, Lucknow. Three crops namely pigeon pea (*Cajanus cajan*); wheat (*Triticum sp.*); mustard (*Brassica juncea*) and their associated soils were collected at distances of 0, 50, 100 and 1000m from the edge of the road. The 1000m site was considered as the reference site. The samples were collected in triplicates. The samples were brought to the laboratory following the standard procedures and then air dried, mixed, ground and sieved through a 2-mm sieve to remove coarse particles and stored for further analysis.

Preparation of the Sample for Analysis

The plant samples collected for analysis were washed in fresh running water to eliminate adhering dust particles and were finally washed with deionized water. The clean plant samples were air dried and placed in an electric oven at 65 ^{0}C for 72 hrs. The dried samples were then homogenized by grinding using ceramic coated grinder and used for metal analysis. The soil samples were spread on plastic trays and allowed to dry at ambient temperature for about 4-5 days. The dried soil samples were ground with a ceramic coated grinder and sieved.

Analysis of the Samples

One gram air dried plant or soil sample was weighed into 50ml volumetric flask, followed by the addition of 10ml mixture of analytical grade acids (HNO_3:$HClO_4$ in the ratio 1:3). The digestion was performed at a temperature of about 60 to 100^{0}C. After cooling, the solution was made up to a final volume with distilled water. The metal concentrations were determined by using anatomic Absorption Spectrophotometer. Soil pH and EC were determined using a soil-water ratio 1:2.5 (w/v) through a pH meter and EC meter respectively. Soil organic matter was determined using the Walkley-Black wet oxidation method (1934), nitrite by Stevens and Oaks, (1973) method, Nitrate estimation through Catalado method.

RESULTS AND DISCUSSION

Physicochemical Properties of Roadside Soil

The results indicated that all soil samples were slightly acidic to neutral (pH range was 6.47 - 7.04 with an average value of 6.86). The electrical conductivity values were also slightly higher than that of the control (0.10), indicating the input of some soluble electrolytes to the roadside soil due to various traffic related activities.

Table 1: Physicochemical properties of roadside soil of the sampling site.

Parameters	Value
pH *(range)*	6.47 – 7.04
EC *(dsm$^{-1)}$*	0.35
Organic Carbon *(%)*	1.98
Organic Matter	3.40
Nitrate (µg g^{-1})	79.75
Nitrite (µg g^{-1})	63.50
Phosphate *(µg g^{-1})*	0.735

Values are mean of triplicates

Heavy Metal Concentration in Roadside Farmland Soil and Crops

The heavy metal concentrations in the roadside soil are furnished in table 2. The concentration of the metals were found in the order Cr > Ni > Pb > Cd. A steady decline in the concentration of the metals with respect to the distance from the road has been observed in the study. Cd has not followed the pattern. The same order of heavy metal contents was found in the crops at the same sampling points.

Lead: Concentration of lead in crops and soil samples collected from roadside appeared to be in the spatial pattern of distribution with the order of 0 m>50m> 100m>1000m. It is thus obvious from the results that the lead contamination is majorly caused by the traffic activities along the road. Pb is one of the major heavy metals and is considered as an environmental pollutant (Sharma and Dubey 2005). It is considered as a general protoplasmic poison which accumulates and is slow acting. The main vehicular source of Pb is the exhaust fumes of the automobiles, chimneys of the factories etc. (Eick *et al*.,1999). Lead level in the roadside soil averaged about 15.08 µg g^{-1} with a concentration of 19.90 µg g^{-1} at 0 m distance, whereas at a distance of 1000 m, it was 10.05 µg g^{-1}. The mean Pb level in pigeon pea was found to be 2.87 µg g^{-1}, in the wheat plant 3.36 µg g^{-1}. The mean value of lead content in the mustard was observed to be 2.37 µg g^{-1}.

Chromium: The concentration of chromium has also followed the same trend as of lead. According to Al-Khashman (2004), the Chromium in roadside soil is associated with the chrome plating of some motor vehicle parts. The chromium level in the soil was observed in a range of 43.54 µg g^{-1} to 12.54 µg g^{-1} at a distance of 0 m and 1000 m respectively. The mean Cr levels in pigeon pea, wheat and mustard were observed to be 44.13 µg g^{-1}, 21.94 µg g^{-1} and 21.24 µg g^{-1}, respectively (Table 2).

Nickel: The concentrations of Ni showed a decreasing trend as the distance increased from the road edge in both and soil and crops (Figure 2 and 6). This decrease in the Ni levels with distance from the road indicated that vehicular emission played a significant role in the levels of Ni on the roadside crops and soil. Word *et al*., (1977) reported that motor vehicle traffic is responsible for the buildup of Cd and Ni in soils and vegetations along a motorway in New Zealand. The mean Ni content in the crops and soil varied significantly from site to site (Table 2 and 3). Nickel content in soil ranged from 40.20 µg g^{-1} to 20.17 µg g^{-1} at a distance of 0 m and 1000 m respectively. The mean Ni levels in pigeon pea, wheat and mustard were observed to be 30.85 µg g^{-1}, 23.63 µg g^{-1} and 22.46 µg g^{-1}, respectively.

Cadmium: Cadmium is dispersed in natural environment through human activities as well as natural rock mineralization process thus plants can easily absorb Cd from soil and transport to the shoot system. Cadmium induces complex changes in plants genetically, biochemically and physiologically. Our analysis for Cd in the roadside crops and soil showed that there was significant difference between polluted and control area. Cadmium level in roadside soil averaged about 2.93 µg g^{-1} with a maximum of 4.3 µg g^{-1} at 0 m and was the lowest among the four metals examined, whereas at a distance of 1000 m from the road it was 0.92 µg g^{-1}. The mean Cd level observed in *Pigeon pea* was 0.16 µg g^{-1}, in wheat, 2.25 µg g^{-1} and in mustard was 1.95 µg g^{-1}. Cd level in the roadside crops decreased with increase in distance from the main road as similar to other metals but for soil, the pattern was irregular. It was observed that the Cd level in soil was found to be independent of distance from road. This indicates that Cd level may also be influenced by the parent soil material of the region. These metals were emitted from the exhaust as well as from wear and tear of vehicles as particulates and could have deposited along the roadside soils. The sources of cadmium in the urban areas are much less well defined than those of Pb, but metal plating and tire rubber were considered the likely sources of Cd (Hewitt and Rashed 1988). Cadmium and Zinc are found in lubricating oils as part of many additives. It was reported that the cadmium level in car tires is in the range of 20 µg g^{-1} to 90 µg g^{-1} as associated Cd contamination in the process of vulcanization (Ward *et al.,* 1977). In the absence of any major industry in the sampling sites, the levels of Cd could be due to lubricating oils and/or old tires, that are frequently used, and the rough surfaces of the roads which increase the wearing of tires.

Similar results have been reported by others where concentration of heavy metals in plants and soils increased nearer to the roadside and decreased with distance from roadside (Word *et al*., 1977; Fergusson 1991; Sithole *et al*., 1993).The accumulation of Pb and Cd above tolerable levels takes place up to a distance of approximately 33m (Rodriguez *et al*., 1982). This suggests that edible crops for human or animal consumption should be restricted within strips of this width on both sides of heavily traveled roads. Most of the effects of Pb discharge from automobiles are confined within a zone 33m wide, measured from the road edge (Motto *et al*., 1970). A more conservative value of 100m on either side of road edges have been suggested by some other studies (Ward *et al*., 1975).

Table 2: Heavy metal concentrations in roadside soil collected at different distances

Sample	Heavy metal concentration (µg g^{-1})			
	Cr	**Pb**	**Cd**	**Ni**
0 m	43.54	19.90	4.3	40.20
50 m	35.98	17.3	2.7	33.5
100 m	27.54	13.08	3.8	27.94
1000 m	12.54	10.05	0.92	20.17

Values are mean of triplicates

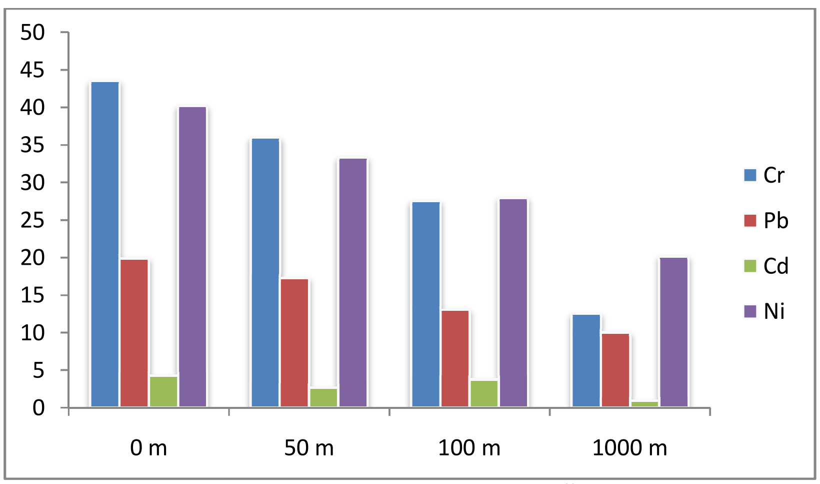

Figure 2: Heavy metal contents in the soil at different distances

Table 2: Heavy metal concentration (µg g^{-1}) in the crops

	Pigeon Pea				Wheat				Mustard			
	Cr	**Pb**	**Cd**	**Ni**	**Cr**	**Pb**	**Cd**	**Ni**	**Cr**	**Pb**	**Cd**	**Ni**
0 m	79.96	3.58	0.18	49	35.9	4.6	3.1	31.13	32.12	3.2	2.6	30.19
50 m	57	3.1	0.18	26.3	29.4	3.9	1.9	27.35	25.72	2.9	1.8	25.9
100 m	22.21	3.1	0.15	26.2	17.32	2.75	2.1	20.75	19.25	2.3	2.1	19.8
1000 m	17.35	1.71	0.13	21.9	5.17	2.19	1.92	15.32	7.9	1.1	1.32	13.98

Values are mean of triplicates

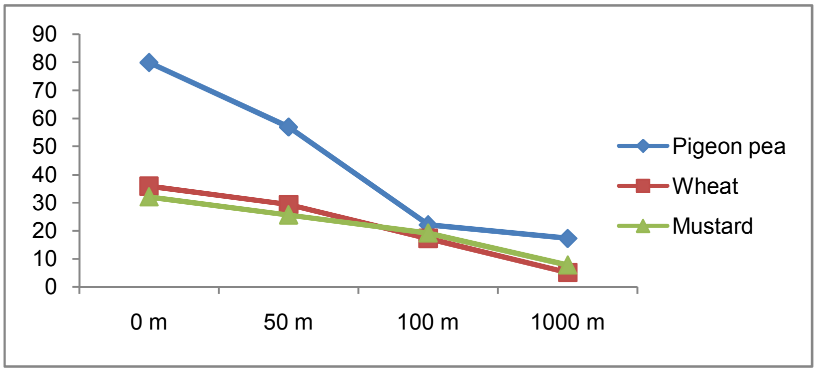

Figure 3: Cr content in different plants at varying distances from the road

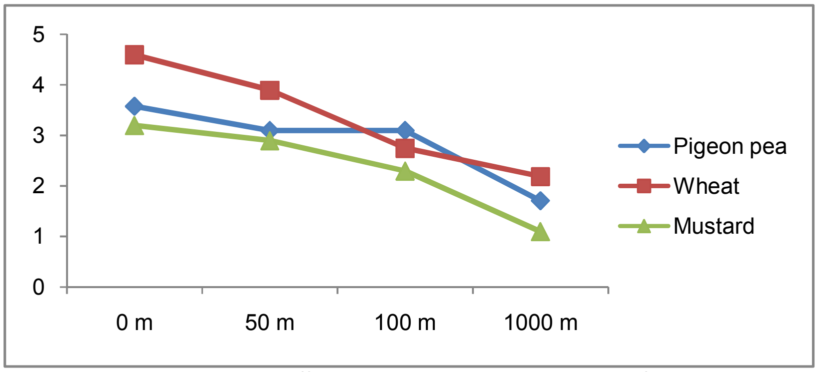

Figure 4: Pb content in different plants at varying distances from the road

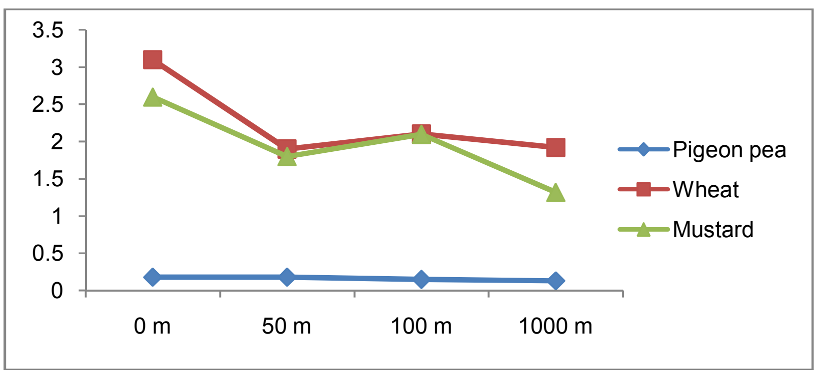

Figure 5: Cd content in different plants at varying distances from the road

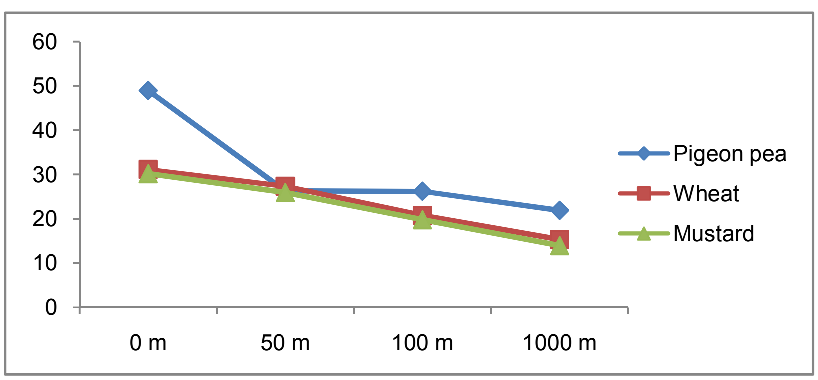

Figure 6: Ni content in different plants at varying distances from the road

Transfer Factor

Trace metal concentration in the extracts of soils and plants were calculated on the basis of dry weight. The transfer factor (TF) was calculated as: TF = C plant/C soil, where C plant and C soil represent the heavy metal concentrations in samples of soil and plant respectively. It is the ratio of contaminant concentration in the plant parts to the concentration in the dry soil (Chojnackaa *et al*., 2005; Upasona *et al*., 2015). The transfer factor of the metals were calculated and presented in table 3.

Table 3*:* Transfer factor of metals in crops of roadside crops

Crops	Cr	Pb	Cd	Ni
Pigeon pea	1.47	0.19	0.05	1.01
Wheat	0.73	0.22	0.76	0.77
Mustard	0.71	0.15	0.66	0.73

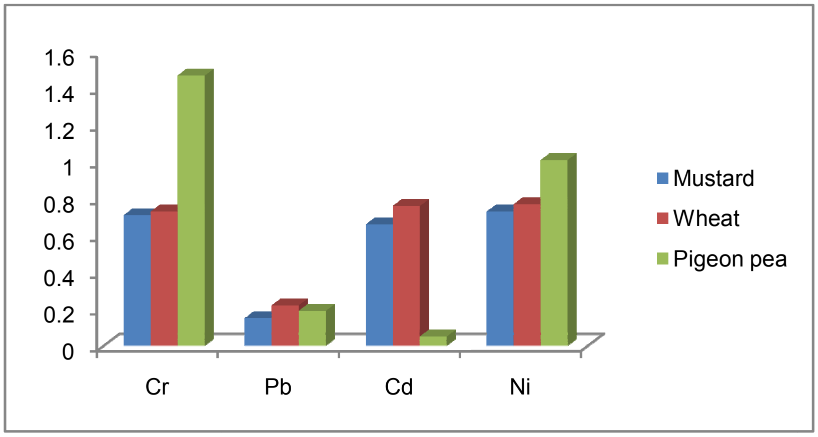

Figure 7*:* Transfer factor

CONCLUSIONS

In the present study, the heavy metal contents at the same distance from the road were found in the following order*:* Cr > Ni > Pb > Cd*.* The same trend *(*Cr > Ni > Pb > Cd*)* was also observed for the crops*.* With regard to the distances from road the order of heavy metal contents was 0 m > 50 m > 100 m > 1000 m*.* Examining the Cr, Pb, Cd, and Ni content of roadside soil, it can be concluded that the concentration decreases with increasing distance from the road edge, except Cd*.* The soils near the highway have a long-term contamination of heavy metals from transport*.* We could observe that the vehicular exhausts and the traffic density are leading to the accumulation of these heavy metals in the soil that can give rise to serious environmental hazards in future*.* The excessive uptake of certain minerals by food crops from contaminated soils might have detrimental effects on food safety and quality, thus imparting detrimental impacts on human health*.*

Conflict of Interest

None declared.

REFERENCES

Al-Khashman O.A. (2004). Heavy metal distribution in dust, street dust and soil from the work place in Karak Industrial Estate, Jordan. *Atmospheric Environment* 38: 6803-6812.

Chojnackaa, K., Chojnackib, A., Gorecka, H. and Gorecki, H. (2005). Bioavailability of heavy metals from polluted soils to plants. *Science of the Total Environment* 337: 175-182.

Eick, M.J., Peak, J.D., Brady, P.V. and Pesek, J.D. (1999). Kinetics of lead adsorption and desorption of gooethite: residence time effect. *Journal of Soil Science* 164: 28-39

Fakayode S.O. and Olu-Owolabi B. I. (2003). Heavy metal contamination of roadside topsoil in Osogbo, Nigeria: its relationship to traffic density and proximity to highways. *Environmental Geology* 44: 150-157.

Falahi-Ardakani, A. (1984). Contamination of environment with heavy metals emitted from automotives. *Ecotoxicology and Environmental Safety* 8: 152-161

Fergusson, J.E. (1991). The heavy elements: Chemistry, Environmental Impact and health effects. Oxford, Pergamon Press.

Hewitt, C.N. and Rashed, M. (1988). Heavy metals in motorway runoff waters. Proceedings of the International Conference on Chemicals in the Environment, Lisbon

Markus, J.A. and McBratney A.B. (1996). An urban soil study: Heavy metals in Glebe, Australia. *Australian Journal of Soil Research* 34: 453-465.

Matthews-Amune., Omono Christiana and Samuel, K. (2013). Investigation of heavy metal levels in roadside agricultural soil and plant samples in Adogo, Nigeria. Academia *Journal of Environmental Sciences* 1(2): 031-035.

Motto, H.L., Daines, H.R., ChilKo, D.M. and Motto, K.C. (1970). Lead in soils and plants: its relation to traffic volume and proximity to highways. *Environmental Science and Technology* 4: 231-237.

Nabulo, G., Oryem-Origa, H. and Diamond, M. (2006). Assessment of lead, cadmium, and zinc contamination of roadside soils, surface films, and vegetables in Kampala City, Uganda. *Environmental Research* 101: 42-52.

Rodriguez-Flores, M. and E. Rodriguez-Castellon. (1982). Lead and Cadmium levels in soil and plants near highways and their correlation with traffic density. *Environmental Pollution. Series B* 4: 281-290.

Saeedi, M., Hosseinzadeh, M., Jamshidi, A., Pajooheshfar S. (2009). Assessment of heavy metals contamination and leaching characteristics in highway side soils, Iran. *Environmental Monitoring and Assessment* 151: 231-241

Sharma, P. and Dubey, R.S. (2005). Lead toxicity in plants. *Brazilian Journal of Plant Physiology* 17:35-52

Sinha, S., Pandey, K., Gupta, A. and Bhatt, K. (2005). Accumulation of metals in vegetables and crops grown in the area irrigated with river water. Bulletin of *Environmental Contamination and Toxicology* 74: 210-218

Sithole, S.D., Moyo, N. and Macheka, J. (1993). An assessment of lead pollution of vehicle emissions along selected roadways in Harare (Zimbabwe). International *Journal of Environmental Analytical Chemistry* 53: 1-12.

Upasonadevi., Raza Rafiqul Hoque and Kali Prasad Sarma (2015). Accumulation of trace metals in soil and trees by the highway passing through an ecological heritage area. *Journal of Environmental Research and Development* 9: 605-612.

Viard, B., Pihan, F., Promeyrat, S. and Pihan, J.C. (2004). Integrated assessment of heavy metal (Pb, Zn, Cd) highway pollution: Bioaccumulation in soil, Graminaceae and land snails. *Chemosphere* 55: 1349-1359.

Ward, N.I., Brooks, R.R., Roberts, E. and Boswell, C. (1977). Heavy metal pollution from automotive emissions and its effects on roadside soil and pasture species in New Zealand. *Environmental Science and Technology* 11: 917-920.

Ward, N.I., Reeves, R.D. and Brooks, R.R. (1975). Lead in soil and vegetation along a New Zealand State highway with low traffic volume. *Environmental Pollution* 9: 243-251.

Wei, B. and Yang, L. (2010). A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. *Microchemical Journal* 94: 99-107.

Wilcke, W., Silke M., Nualsri, K. and Wolfgang, Z. (1998). Urban soil contamination in Bangkok: Heavy metal and aluminium portioning in topsoils. *Geoderma* 86: 211-228.

Willers, S., Gerhardsson, L. and Lundh, T. (2005). Environmental tobacco smoke (ETS) exposure in children with asthma-relation between lead and cadmium, and nicotine concentrations in urine. *Respiratory Medicine* 99: 1521-1527.

Winther, M. and Slentø E. (2010). Heavy Metal Emissions for Danish Road Transport. National Environmental Research Institute, Aarhus University; Aarhus, Denmark.

Word, N.I., Brooks, R.R. and Roberts, E. (1977). Heavy-metal pollution from automotive emissions and its effect on roadside soils and pasture species in New Zealand. *Environmental Science and Technology* 11: 917-920.

Zhang Fan., Yan Xuedong., Chen Zeng., Man Zhang., Lochan Prasad Devkota and Tandong Yao (2012). Relationship between Heavy Metal Concentrations in Soils and Grasses of Roadside Farmland in Nepal. *International Journal of Environmental Research and Public Health* 9: 3209-3226.