Pak. J. Bot., 53(5): 1611-1616, 2021. DOI: http://dx.doi.org/10.30848/PJB2021-5(5)

EXPLORATION OF STATUS AND INTENSITY OF Pb AND Cd POLLUTION IN ROADSIDE SOILS AND CEREAL GRAINS

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Abstract

Heavy metal pollution is becoming one of the major problems around the globe resulting from the increase in population, urbanization, and industrialization. Therefore, it is need of time and important to quantify the level of heavy metals especially Pb and Cd in the soils and cereals grown along the highways. Here, we explore the status and intensity of Pb and Cd pollution in roadside soils and cereals grown on these fields. A total of 500 soil and 250-grain samples were collected from the wheat and rice field located along the road from Faisalabad to Sheikupura and Sheikupura to Lahore. The outcomes depicted that the contents of Pb and Cd in the soils from the wheat fields located along Faisalabad to Sheikupura was ranged from 1.18 to 4.98 mg kg^{-1} and from 0.008 to 0.62 mg kg^{-1} respectively. Together these new data shows that the contents of both Pb and Cd in the soils from the wheat field located along the Sheikupura to Lahore road were lower than the soils from the fields along Faisalabad to Sheikupura road. The average contents of Pb and Cd recorded in the grains of wheat and rice grown along the road from Faisalabad to Sheikupura was 278 and 75.3 µg kg^{-1} respectively and 269 and 39.5 µg kg^{-1} respectively. Therefore, growing cereals in the vicinity of highways and heavy industries for longer times may cause heavy metals accumulation in the cereal grains.

Key words: Lead; Cadmium; Highways; Wheat; Rice.

Introduction

Recently, the development of the global economy has resulted in increasing the content of heavy metals in the soil and water thus deteriorating the environment (Prajapati & Meravi, 2014; Raju *et al*., 2013). Besides their natural occurrence, anthropogenic activities like mining, smelting, pesticides and fertilizer application, and waste disposal also caused the entry of heavy metals into the ecological environment. Resultantly, the mounting contents of heavy metals are damaging food quality and human health (Kachenko *et al*., 2006). Heavy metals are harmful because they tend to be bio-accumulated, meaning that over a long time the concentrations of heavy metal within a biological organism can be higher than that in the environment. Long-term exposure to the polluted dust environment would cause chronic damage through inhalation, ingestion, and dermal contact (Du *et al*., 2013). Moreover, chronic problems associated with long-term heavy metal exposures are metal lapse caused by Pb exposure; Cd has effects on the kidney, liver, and gastrointestinal tract (Willers *et al*., 2005).

Highways and intensively trafficked roads are major sources for pollutants introduced into the environment. The growing volume of worldwide traffic leads to increasing emission rates causing contamination of roadside soils (Monks *et al*., 2009). The traffic derived pollutants originate from a variety of sources including incomplete and complete fuel combustion, fuel losses, and oil leakage from hydraulic systems. Corrosion, de-icing activities and vehicle component wear and tear (tires, brakes, clutch, and engine) are also important sources of traffic emissions (McKenzie *et al*., 2009; Zereini *et al*., 2006). Another relevant pollutant source is the dust resulting from the abrasion of the road construction material itself (Thorpe & Harrison, 2008). Moreover, metals in road dust may be solubilized in road runoff, or mobilized by storm water runoff, contaminating receiving soils or water bodies (Birch & McCready, 2009; Davis & Birch, 2010; Zhao *et al*., 2010; Munksgaard & Lottermoser, 2010).

Roadside soils are important reservoirs for the direct pollution from vehicle sources, which could easily come in contact with pedestrians and people residing within the vicinity of the roads either by suspended dust or directly. The accumulation of trace metals in soils can be a secondary source of water pollution in a transformed environmental condition (Cheung *et al*., 2003). Recently, street dust and top roadside soils in urban areas are considered as indicators of trace metal contamination from atmospheric deposition (Christoforidis & Stamatis, 2009; Chen *et al*., 2010) and dust (Omar *et al*., 2007; Lu *et al*., 2009). The composition and amount of dry and wet deposition depend on many factors, such as traffic intensity (Arslan & Gizir, 2006), wind direction, wind velocity, rain events and intensity, previous dry periods, highway design, or vegetation cover (Lee *et al*., 2011).

By keeping in mind the harmful effects of heavy metals, it is necessary to evaluate the level and distribution of heavy metals especially Pb and Cd in roadside soils and crops grown on those soils. Therefore, the current survey study was undertaken to investigate the level and intensity of Pb and Cd in soils along and away from the highways. The contents of the said heavy metals were also quantified in the grain of rice and wheat grown in those fields.

Materials and Methods

The current survey study was conducted at Soil Chemistry Section, Institute of Soil & Environmental Chemistry, Ayub Agriculture Research Institute, Faisalabad, Pakistan for exploring the status of Pb and Cd in soils and cereals (wheat and rice) grown around Faisalabad to Sheikupura and Sheikupura to Lahore road.

Soil and grain samples were collected from wheat and rice fields along and away from GT road from Faisalabad to Sheikupura and Sheikupura to Lahore. The fields at a distance of 2 to 10 m from the main road were designated as fields along the road while the fields at a distance from 10 to 50 m were designated as field away from the GT road. The soils in the immediate vicinity of the road (~1 m) were not included to avoid the risk of sampling recently disturbed soil from road construction and upgrades (Werkenthin *et al*., 2014). Soil samples were collected from the upper (0-15 cm) and lower (15-30 cm) soil layer at field capacity with soil auger both from wheat and rice fields located along and away from the road. From the selected fields soil samples were collected randomly from various locations and the sub-samples were homogenized to form a composite sample. The collected samples were brought to the laboratory in plastic bags for further processing and analysis. Likewise, wheat and rice grains samples were taken from the same fields chosen for soil samples collection. Total of 500 soil and 250-grain samples were collected. All chemicals used in the analysis of Pb and Cd for soil and grain samples were of analytical grade with the purity of ≥99%. Soil samples were air dried and sieved using a 2 mm sieve. These samples were sealed in zip lock polyethylene bags and stored at ambient laboratory conditions (22±2°C) in the dark until analyzed. Similarly, grain samples were oven dried and ground before analysis.

Analytical methods: The Pb and Cd contents in soil samples were estimated by following DTPA extraction method. Briefly, about 10 g dried soil sample was mixed with 20 mL of DTPA (diethylene triamine penta acetic acid) extracting solution at pH 7.3 and kept on a reciprocal shaker at 120 rpm for 2 h. The aliquot was centrifuged at 5000 rpm for 5 min and supernatants were collected for heavy metal determination (Lindsay and Norvell, 1978). The grain samples were digested using concentrated nitric acid and perchloric acid (Anon., 2005). The contents of Pb and Cd were analyzed using Atomic Absorption Spectrophotometer (AA-7000, Shimadzu, Japan). Sigma plot software (version 12.5, Sigma, Inc.) was used for plotting and data analyses.

Quality assurance and control: The chemicals used in the current study were purchased from Merck Chemical Germany. Double distilled water was used for solution preparation and washing of glass wares. Standard solution for each metal was prepared from their stock solution of concentration 1000 ppm in order to calibrate the instrument. The accuracy and precision of the analysis were investigated through repeated analysis against SRM2709 for soil and NIST standard reference material for plant heavy metals analysis.

Results and Discussion

Pb and Cd in soil: The maximum Pb contents ranged from 1.18 to 4.98 mg kg^{-1} with average value of 3.21 mg kg^{-1} in upper soil layer of wheat fields situated along the GT road from Sheikupura to Lahore, while the contents were a bit lower in wheat fields located away from the same road (1.14-4.68; average, 3.01 mg kg^{-1}) (Fig. 1). Furthermore, the concentration of Pb in soil samples taken from the wheat fields located along and away from the Faisalabad to Sheikupura road was higher than the contents in the soil of the fields located along and away from the Sheikupura to Lahore road. The contents of Cd in the upper and lower depth of soils along the Faisalabad to Sheikupura road were ranged from 0.008 to 0.62 mg kg^{-1} and 0.006 to 0.60 mg kg^{-1} respectively (Fig. 2). While the range of Cd contents in the upper and lower depth of soil from wheat fields located along the Faisalabad to Sheikupura road was from 0.002 to 0.28 mg kg^{-1} and 0.001 to 0.19 mg kg^{-1} respectively.

The content of Pb in upper layer soil of rice fields located along and away from Sheikupura to Lahore road was ranged from 1.29 to 4.23 mg kg^{-1} and 1.13 to 4.03 mg kg^{-1} respectively (Fig. 3). Whereas, the average concentration in soil of rice fields located along and away from the Faisalabad to Sheikupura road was 3.87 and 2.85 mg kg^{-1} respectively. Moreover, the average contents of Cd in the upper and lower depth of soil of rice fields located along the road from Sheikupura to Lahore were 0.17 and 0.13 mg kg^{-1} respectively with a range from 0.04-0.76 mg kg^{-1} and 0.03-0.38 mg kg^{-1} respectively (Fig. 4). While the average contents of Cd in upper soil depth of rice field located along and away from the Faisalabad to Sheikupura were 0.047 mg kg^{-1} and 0.040 mg kg^{-1} respectively.

Soils are deliberated to be the ultimate sink for heavy metals released into the environment from various anthropogenic sources. The discharged heavy metals can accumulate in the top soils; however, their availability in the soil strongly relies on their source (Lu *et al*., 2009; Sridhara *et al*., 2008). Furthermore, for direct pollution from vehicle sources, roadside soils are important reservoirs. Therefore, the current study was undertaken to explore the distribution pattern of Pb and Cd in the soils and grain of wheat and rice grown in the vicinity of GT road from Faisalabad to Sheikupura and Sheikupura to Lahore. Pb and Cd were detected in measurable contents in the soils from the fields located along and away from the GT road (Figs. 1, 2, 3 and 4). Moreover, it was seen that the contents of studied metals were higher in soils located along the road compared with the soils from the fields situated away from the road. Higher Pb and Cd contents in a soil samples taken from the fields located along the road; was may be due to their entry through runoff of rainwater to the soils located in the close vicinity of the road (Gunawardana *et al*., 2014; Liang *et al*., 2016).

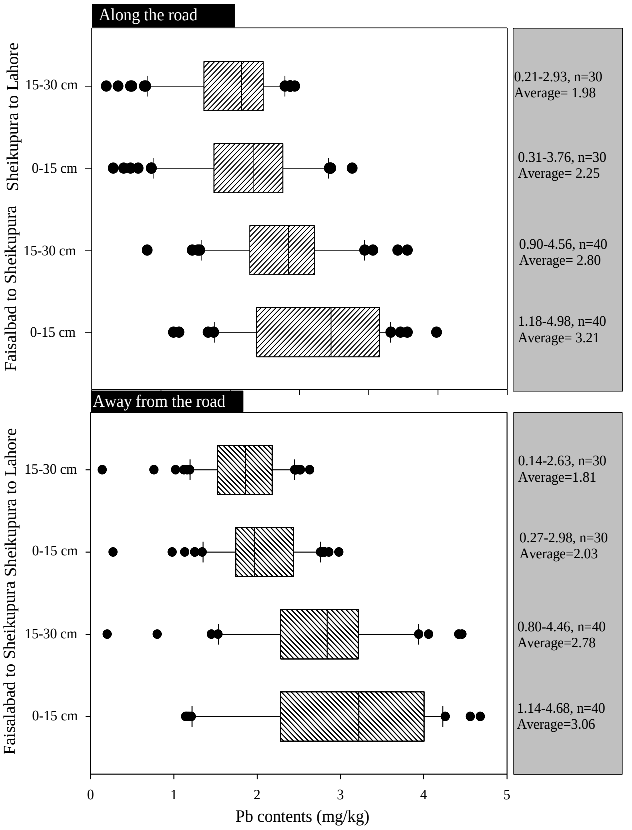

Fig. 1. Contents of Pb in soil samples (on dry weight basis) taken from wheat fields along and away from GT road from Faisalabad to Sheikupura and Sheikupura to Lahore.

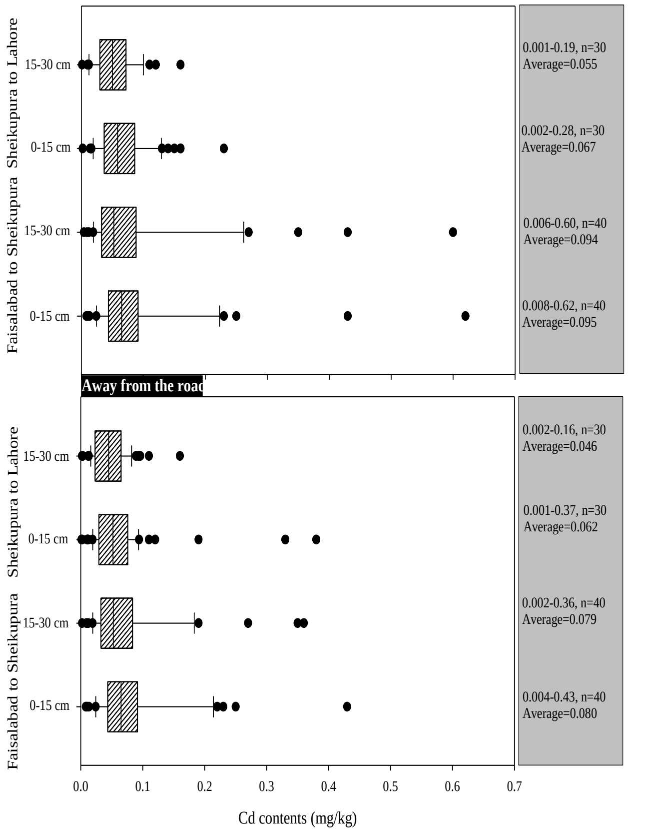

Fig. 2. Contents of Cd in soil samples (on dry weight basis) taken from wheat fields along and away from GT road from Faisalabad to Sheikupura and Sheikupura to Lahore.

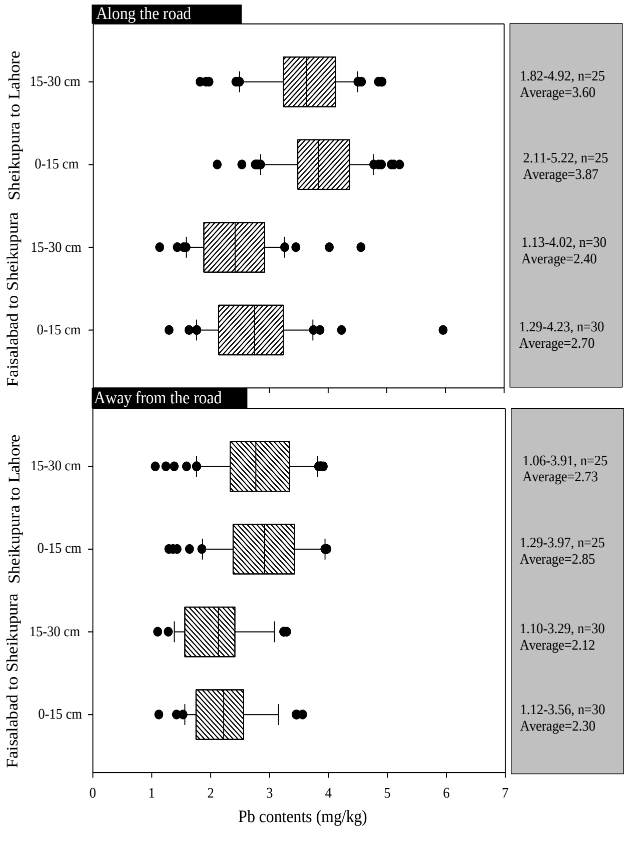

Fig. 3. Contents of Pb in soil samples (on dry weight basis) taken from rice fields along and away from GT road from Faisalabad to Sheikupura and Sheikupura to Lahore.

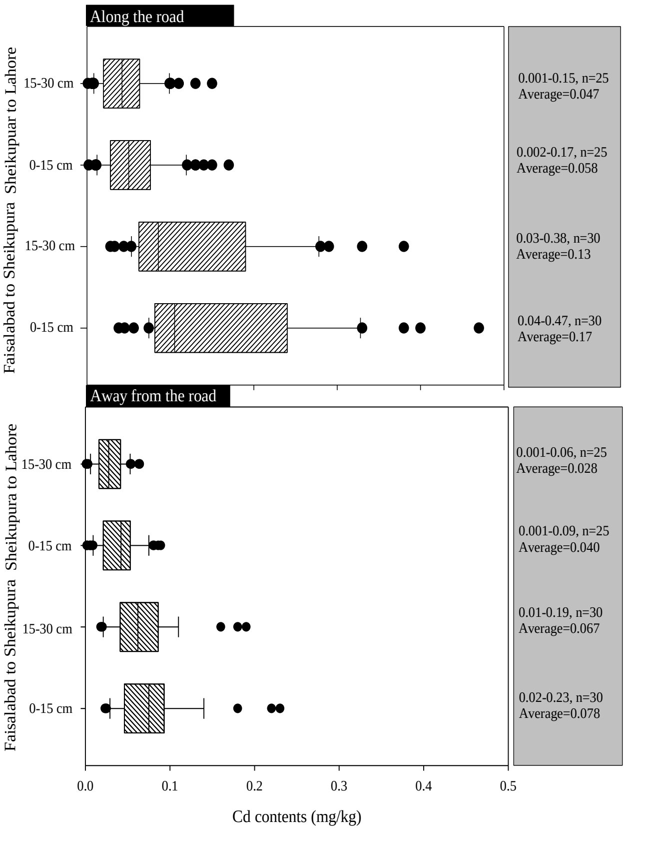

Fig. 4. Contents of Cd in soil samples (on dry weight basis) taken from rice fields along and away from GT road from Faisalabad to Sheikupura and Sheikupura to Lahore.

Table 1. Permissible limits for lead and cadmium for soil and grain.

Heavy metal	Pb (mg/kg)	Cd (mg/kg)	Reference
Soil DTPA	13.0	0.31	Mclean *et al*., (1987) Soltanpur (1985)
Soil total	300	3.00	WHO, 2007
Plant	5.0	0.20	WHO, 2007

Likewise, the higher contents of heavy metals in the soil samples taken from the fields located along and away from the Faisalabad to Sheikupura road than the soil samples taken from the fields located along and away from the Sheikupura to Lahore road was may be due to higher intensity of industries along the formerly mentioned roads. Moreover, the contents of both heavy metals were below the permissible limits (Table 1). Islam *et al*., (2016) conducted a study for the determination of heavy metals in the soils and vegetables grown on the fields along the highways. They found that the contents in the soils and vegetables samples were within the permissible limits as observed in this study. Recently, Inelova *et al*., (2021) collected soil and plant samples from for evaluating heavy metals contents and observed that the contents of heavy metals in soil samples were below the permissible limits like the current study.

Pb and Cd in grain: The Pb contents in wheat grain samples taken from the fields along the Faisalabad to Sheikupura road was ranged from 77-615 ppb with average value of 278 ppb (Fig. 5) while the grain samples taken from the fields located away from the formerly mentioned road was in the range of 56 to 456 ppb. A similar trend of Pb contents in wheat grain was observed for samples taken from fields located along the road from Sheikupura to Lahore. However, the contents of Pb in grain samples taken from fields along and away from the Sheikupura to Lahore road were lower than the contents recorded in grain samples taken from wheat fields located along and away from Faisalabad to Sheikupura road. The highest contents of Cd (ranged from 26.8 to 131 ppb) were recorded in wheat grain samples taken from the fields located along the Faisalabad to Sheikupura road (Fig. 5) while the maximum and average Cd contents in grain samples taken from the fields located along the Sheikupura to Lahore were 94.5 ppb and 44.5 ppb respectively.

Similarly, the Pb and Cd contents in rice grain samples taken from the fields located along the Faisalabad to Sheikupura road were ranged from 84 to 414 ppb and 10.5 to 79 ppb respectively with average values of 269 ppb and 39.5 ppb respectively (Fig. 6). The contents of both Pb and Cd in grain samples taken from the fields located away from the same road were lower than the contents in grain samples collected from the fields located along the road. Likewise, the sequence of both Pb and Cd contents was the same for grain samples taken from the fields located along and away from the Sheikupura to Lahore road. However, the contents of Pb and Cd in rice grain samples taken from fields located along and away from Faisalabad to Sheikupura road were lesser than the contents in grain samples taken from fields situated along and away from the Sheikupura to Lahore road.

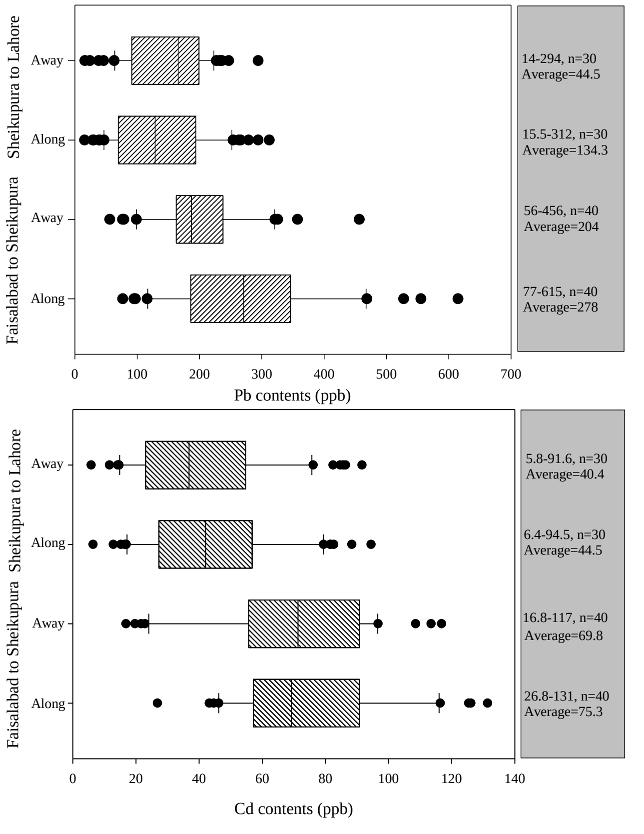

Fig. 5. Contents of Pb and Cd in wheat grain grown along and away from GT road from Faisalabad to Sheikupura and Sheikupura to Lahore.

The contents of heavy metals accumulated in the crops depend upon their availability in the soil as well as the type of plants. The vegetables tend to accumulate higher contents of heavy metals compared with the cereals (Islam *et al*., 2016). Likewise, the lower contents of Pb and Cd were observed in the wheat and rice grain samples in the current study. Among cereals, wheat grain tends to accumulate more metals compared with rice grain. Moreover, it was found that the contents in the grains also decrease with increase in distance from the road. Like the findings of the present study Jankowski *et al*., (2014) investigated the contents of lead and cadmium in two species of grasses grown along the highways. They reported that the contents of both metals were well below the safe limits and they further found that the contents decrease with increase in distance from the highway. Furthermore, the contents of Pb and Cd observed in the current study were far lower than the already reported contents (Filipek-Mazur *et al*., 2007; Jankowski *et al*., 2014). Higher contents of heavy metals were also reported in vegetables by Liu *et al*., (2006) and Islam *et al*., (2016). Therefore, the findings of the current study clearly depicted that the cereals grown along the studied roads were safe to consume as food owing to their fewer contents of both Pb and Cd than the permissible limits.

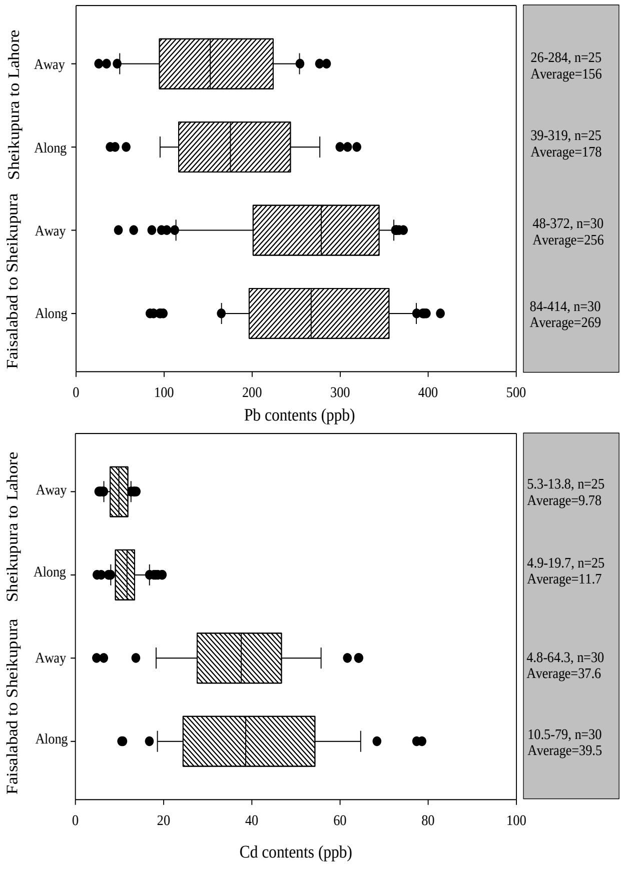

Fig. 6. Contents of Pb and Cd in rice grain grown along and away from GT road from Faisalabad to Sheikupura and Sheikupura to Lahore.

Conclusions

The current survey study was conducted for the evaluation of status and contents of Pb and Cd in the soils and cereals grown on the fields situated along the highways. The results perceived that the contents of both Pb and Cd were well below safe limits (13 mg/kg and 0.31 mg/kg for Pb and Cd respectively). Moreover, the content in soils decreases with increase in distance from the main road. Likewise, both wheat and rice grains were observed to have lower contents than the permissible limits (5 ppm and 0.20 ppm for Pb and Cd respectively), therefore were safe for consumption. However, long term cultivation of the cereals especially on the fields located in the neighborhood of the main road may cause heavy metals contamination.

Acknowledgement

For the accomplishment of this manuscript, we acknowledge the Agriculture Department, Government of Punjab, Pakistan for its financial assistance. There was no involvement of this funding agency in conduction of experiment and writing of this manuscript. We are also highly thankful to Institute of Soil Chemistry & Environment Sciences, Ayub Agricultural Research Institute, Faisalabad for facilitating us to carry out this research work.

References

Anonymous. 2005. Official methods of analysis. Association of official analytical chemists international. Maryland, USA.

Arslan, H. and A.M. Gizir. 2006. Heavy-metal content of roadside soil in Mersin, Turkey. *Fresenius Environ. Bull.*, 15: 15-20.

Birch, G.F. and S. McCready. 2009. Catchment condition as a major control on the quality of receiving basin sediments (Sydney Harbour, Australia). *Sci. Total Environ.*, 407: 2820-35.

Chen, X., X. Xia, Y. Zhao and P. Zhang. 2010. Heavy metal concentrations in roadside soils and correlation with urban traffic in Beijing, China. *J. Hazard Mat.*, 181: 640-646.

Cheung, K.C., B.H.T. Poon, C.Y. Lan and M.H. Wong. 2003. Assessment of metal and nutrient concentrations in river water and sediment collected from the cities in the Pearl River Delta, South China. *Chemosphere*, 52: 1431-1440.

Christoforidis, A. and N. Stamatis. 2009. Heavy metal contamination in street dust and roadside soil along the major national road in Kavala's region, Greece. *Geoderma*, 151: 257-263.

Davis, B. and G. Birch. 2010. Comparison of heavy metal loads in storm water runoff from major and minor urban roads using pollutant yield rating curves. *Environ. Pollut*, 158: 2541-2545.

Du, Y., B. Gao, H. Zhou, X. Ju, H. Hao and S. Yin. 2013. Health risk assessment of heavy metals in road dusts in urban Parks of Beijing, China. *Procedia Environ. Sci.*, 18: 299-309.

Filipek-Mazur, B., K. Gondek and K. Mazur. 2007. The impact of traffic pollution along the national road no 4 Bochnia-Sędziszów Małopolski) on the content of trace elements in soil and in meadow sward. *Zesz. Prob. Post. Nauk. Rol.*, 520: 31-27. (In Polish)

Gunawardana, C., P. Egodawatta and A. Goonetilleke. 2014. Role of particle size and composition in metal adsorption by solids deposited on urban road surfaces. *Environ. Pollut.*, 184: 44-53.

Inelova, Z., A. Nurzhanova, G. Yerubayeva, A. Mengtay, L. Djansugurova and B. Bekmanov. 2021. Heavy metal contents in plants of phytocenoses of the point of besqaynar, kyzylkairat and Taukaraturyk. *Pak. J. Bot*., 53(2): 511-516.

Islam, M.J., M.S. Rahman, M.A. Al Mamun, F. Farhana, M. Shamsuzzoha, M.H. Rahman, M. Akhtar and M.A. Hanif. 2016. Assessment of heavy metals in roadside soil, water and vegetables of the Dinajpur-Rangpur highway in Bangladesh *J. Chem. Biol. Phy. Sci. Sec*., 6(2): 237-247.

Jankowski, K., J. Jankowska, G.A. Ciepiela, J. Sosnowski, B. Wiśniewska-Kadźajan, R. Kolczarek and J. Deska. 2014. Lead and cadmium content in some grasses along expressway areas. *J. Elem. S*., 119-128.

Kachenko, A.G. and B. Singh. 2006. Heavy metals contamination in vegetables grown in urban and metal smelter contaminated sites in Australia. *Water, Air, and Soil Pollution*, 169: 101-123.

Lee, J.Y., H. Kim Y. Kim and M.Y. Han. 2011. Characteristics of the event mean concentration (EMC) from rainfall runoff on an urban highway. *Environ. Pollut*, 159(4): 884-888.

Liang, L., L. An, L. Yang, L. Zhang, G. Zhang and Y. Guan. 2016. Polycyclic aromatic hydrocarbons associated with road deposited solid and their ecological risk: implications for road storm water reuse. *Sci. Total Environ.*, 563-564: 190-198.

Lindsay, W.L. and W.A. Norvell. 1978. Development of a DTPA soil test for Zn, Fe, Mn and Cu. *S. Sci. Soc. Amer. J.*, 42: 421-428.

Liu, W.H., J.Z. Zhao, Z.Y. Ouyang, L. Soderlund and G.H. Liu. 2006. Impacts of sewage irrigation on heavy metals distribution and contamination. *Environ. Int*., 31: 805-812.

Lu, X., L. Wang, K. Lei, J. Huang and Y. Zhai. 2009. Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW China. *J. Hazard Mat.*, 161: 1058-1062.

Maclean, K.S., A.R. Robinson and H.M. MacConnel. 1987. The effect of heavy metal and sewage sludge on the heavy metal contents of soil and plant tissues. Commun. *Soil Sci. & Plant Anal.*, 18: 1303-1316.

McKenzie, E.R., J.E. Money, P.G. Green and T.M. Young. 2009. Metals associated with storm water – relevant brake and tire samples. *Sci. Total Environ.*, 407(22): 5855-5860.

Monks, P.S., C. Granier, S. Fuzzi, A. Stohl, M.L. Williams and H. Akimoto. 2009. Atmospheric composition change-global and regional air quality. *Atmos Environ.*, 43: 5268-350.

Munksgaard, N.C. and B.G. Lottermoser. 2010. Mobility and potential bioavailability of traffic-derived trace metals in a 'wet-dry' tropical region, Northern Australia. *Environ Earth Sci*, 60: 1447-1458.

Omar, N.Y.M.J., M.R. Bin-Abas, N.A. Rahman, N.M. Tahir, A.I. Rushdi and B.R.T. Simoneit. 2007. Levels and distributions of organic source tracers in air and roadside dust particles of Kuala Lumpur, Malaysia. *Environ. Geol.*, 52: 1485-1500.

Prajapati, S.K. and N. Meravi. 2014. Heavy metal speciation of soil and Calotropisprocera from thermal power plant area. *Proceed. Int. Acad. Ecol. & Environ. Sci.*, 4 (2): 68-71.

Raju, K.V., R.K. Somashekar and K.L. Prakash. 2013. Spatio-temporal variation of heavy metals in Cauvery River basin. *Proceed. Int. Acad. Ecol. & Environ. Sci.*, 3(1): 59-75.

Soltanpour, P.N. 1985. Use of ammonium bicarbonate- DTPA soil test to evaluate elemental availability and toxicity. *J. Plant Nutr.*, 8: 323-338.

Sridhara, C.N.S., C.T. Kamala and S.R.D. Samuel. 2008. Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. *Ecotox. Environ. Safety*, 69: 513-524.

Thorpe, A. and R.M. Harrison. 2008. Sources and properties of non-exhaust particulate matter from road traffic: a review. *Sci. Total Environ.*, 400: 270-282.

Werkenthin, M., B. Kluge and G.Wessolek. 2014. Metals in European roadside soils and soil solution -a review. *Environ. Pollut*, 189: 98-110.

WHO. 2007. WHO Expert standards program codex Alimentation Commission. Geneva, Switzerland. Available online http://www.who.int [Accessed10/09/2012].

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

Zereini, F. and F. Alt. 2006. Palladium Emission in the Environment. Springer-Verlag, Berlin. Heidelberg. http://dx.doi.org/10.1007/3-540-29220-9. ISBN: 978-3-540-29219-7; E-ISBN: 978-3-540-29220-3.

Zhao, H., X. Li, X. Wang and D. Tian. 2010. Grain size distribution of road-deposited sediment and its contribution to heavy metal pollution in urban runoff in Beijing, China. *J. Hazard Mater.*, 183: 203-210.

(Received for publication 12 July 2019)