Contents list available http://www.kinnaird.edu.pk/

Journal of Natural and Applied Sciences Pakistan

Journal homepage: http://jnasp.kinnaird.edu.pk/

ENVIRONMENTAL POLLUTION AND HEALTH RISK ASSESSMENT OF HEAVY METALS DUE TO CONSTRUCTION OF ORANGE LINE ROUTE, LAHORE-PAKISTAN

Aamir Ali[1*], Muhammad Mansoor[1,2], Waqas Chohan[1], Muhammad Ayaz Afridi[1]

[1]Geological Survey of Pakistan, Lahore-54782, Pakistan.

[2]Department of Chemistry, University of Engineering and Technology, Lahore-54890, Pakistan.

Article Info

*Corresponding Author
Email: aamirnaqvi80@gmail.com

Abstract

Heavy metals such as Lead, Cobalt, Copper and Iron along the track of orange line metro train were investigated. Twenty-six soil samples were collected for four metal analysis. These metals were extracted from soil samples by acid digestion and diluted for the metal analysis using Atomic Absorption Spectrophotometer (AAS). The results showed that Iron was present in excess, followed by Lead, Cobalt and Copper. The high concentration of these four heavy metals along the orange train route indicates the contaminated soil, which is a serious threat for the residents of surrounding areas.

Keywords
Environmental Pollution, Health Risk, Heavy Metals, Orange Line.

1. Introduction

Urban soil is contaminated with various metals due to their long-lasting nature. Urban soils are a sink of heavy metals and toxic pollutants from diverse sources like industrial effluents, coal and petroleum combustion, vehicle exhausts and disposal of untreated municipal waste. The heavy metals in the soil cause pollution and have become a serious concern in all over the world, including Pakistan (Khan *et al*, 2011).

Metals either exist as a separate entity or bonded with other soil components. Soil components may have inorganic metal compounds like phosphates and carbonates, free metal ions or soluble metals, and attached metals to silicate minerals. They do not pose pollution compared with the metals that present as separate entities

or those that exist in high quantity (Pan *et al,* 2016). Soil and sediment analyses have been used to assess the level of heavy metal pollution and resulting health issues associated with industrial effluents, sewage discharge and lubricants disposal (Wu *et al,* 2015). Toxicity of heavy metals can lead to serious illness and death even at very low concentrations. Although, some heavy metals, in very low concentration, are indispensable for the human body and plants for normal growth and reproduction. Some of the essential elements are Cu, Fe, Zn, Mo, Mn, Co and Ni, but they become harmful when their concentration is limited (Ranet *et al,* 2016).

Since pre-history, lead has been known to human beings and is widely used in auto motors, paint, and ceramic and petrol as an anti-knocking agent. It can damage the central nervous system, hepatic, hematopoietic and renal systems. It can also cause vomiting, encephalopathy, delirium, lethargy, coma and convulsions (Flora *et al,* 2012). Cobalt has applications in the industrial sector like jet engines, magnetic bars, grinding and cutting tools. Cobalt is emitted from power generation plants is bound to tiny particles, but airborne soil has mostly big particles compared to those released from plants. These particles can settle or be washed out by rain. Copper can cause exhaustion, brain fog, depression and adrenal burnouts and some are linked to numbness of emotions, schizophrenia, Alzheimer's and even cancer (Stern, 2010). Iron is a cardinal nutrient to make hemoglobin. The normal human body has 3-5 grams of iron. Excessive iron accumulation in this organ is linked to hepatocellular cancer development. However, the toxicity of iron is to produce radicals, which damages body cells and tissues (Brissotet *et al,* 2012).

Contaminated soil with heavy metals is a primary source of human exposure to toxic elements. These metals can affect the human body by eating contaminated food, water or inhalation of dust. Continued consumption of contaminated food over a long time may lead to persistent accumulation of heavy metals in the kidney and liver, which results in the disturbance of vital organs like kidney, liver, cardiovascular and bone disorders (Qing *et al,* 2015). Suspended dust particles that succeed in crossing the nose filter reach the bronchi and bronchioles. These particles get trapped in Mucus. Then, cilia, tiny hairs on the air tube walls, move this Mucus up to the throat where it is coughed out or swallowed. These air sacs are very critically important, as the exchange of oxygen and CO_2 takes place here. Particles are engulfed by macrophages and taken up to air tubes where cilia do the work to kick out unwanted guests (Wei *et al,* 2015). Total vehicle registration in Lahore has increased from 70,342 on 30th June, 1980 to more than 1.17 million by 30^{th} April 2007 with an annual increase of 10 % on average (Sajjad *et al,* 2009).

This record is alarming for the environmental and the government authorities. With a

population of nearly twenty million and increasing vehicles, Lahore city is becoming polluted day by day. These vehicles emit not only toxic gases but are also responsible for the heavy metal contamination in the air and soil.

The main objectives of this study are to establish geochemical baseline values and assess the pollution status of different heavy metals. The pollution status of heavy metals in urban soils was evaluated based on comparing heavy metals concentration in soils.

2. Materials and Methods

2.1 Sampling Area

Sampling locations along the metro train stations are shown in Figure 1. This Orange Line Metro Train (OLMT) project was the country's first metro train, mostly elevated line and underground at one point. It will cost 1.6 billion USD and connect Thokar Niaz-Beg (Raiwind Road) with Dera Gujran (Ring Road) via Multan Chungi, Chauburji, Railway Station and G.T. Road. 2.5 lac passengers per day would be benefited from this project (Rizvi, 2015). This project is associated with many health effects like noise, air and soil pollution. This impact could be temporary and permanent to the environment.

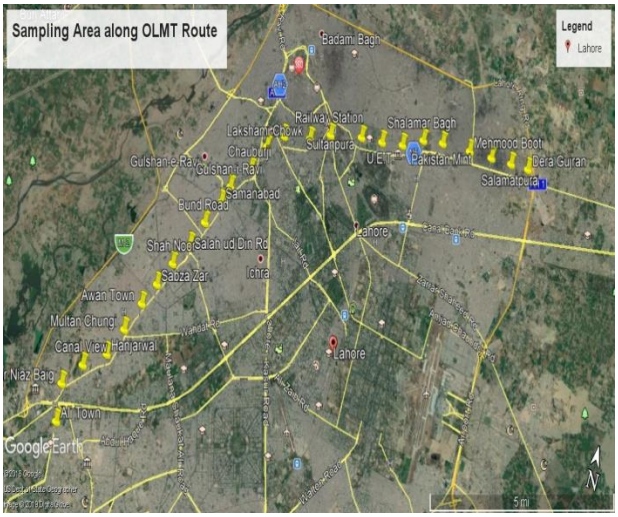

Figure 1: Sampling area

2.2 Sampling

Orange Line has 26 stations, and from each station, three samples were collected randomly. Hence, 98 samples from 26 stations were collected, and the mean value of the results was taken. Polythene bags were used to collect soil samples with the help of a plastic spatula. Each bag was marked with the name of the station.

2.3 Sample Treatment

10 grams of each sample was kept in an air oven to remove moisture at 80˚C temperature for 4 hours. So, that accurate weighing of the samples could be done. It was made sure that samples were completely dried.

Soil samples were sieved to collect fine dust free from large sand particles and stones. For this purpose, USA (ASTM) standard testing sieve No. 18 was used.

Aqua Regia was prepared by mixing HCl and HNO_3 in a volumetric ratio of 3:1 for the digestion of soil. A fuming chamber was used to avoid inhalation of toxic fumes during

preparation. Proper PPE's were used to make sure of personal safety.

For metal extraction, 0.4 g of dried soil sample was taken in a beaker and 10 mL of Aqua Regia HCl:HNO_3 (3:1) was added to the sample. Samples were put on a heating plate in the fume hood at 80 ^{0}C until complete digestion.

Digested samples were added with 15 mL of dilute HCl to ease the solvation process and then filtered by using Whatmann's filter no. 40. The filtrate volume was made up to 25 mL by adding deionized water and later collected in labeled plastic bottles for analysis.

2.3 Standard Solutions

Standard solutions for each metal were prepared from 1000 ppm stock solution by diluting with DM water.

2.4 Analysis of Flame Atomic Absorption Spectrophotometer

Several methods and instruments can be used for the quantitative analysis of heavy metals, but Flame Atomic Absorption Spectrometer (Varian AA240) was used here. Blanks were prepared by adding Aqua Regia to de-mineralized water. Standard solutions of different concentrations were run to prepare the calibration curve, and then samples were run for each metal.

3. Results

After digestion with Aqua Regia, the soil samples were analyzed on AAS (Varian AA240) to estimate the concentration of four heavy metals such as Pb, Fe, Cu, and Co. Each sample was analyzed in triplicate, and the mean value with the positive error are shown in Table 1

Table 1: Heavy metals concentration in soil samples collected from the study area

Sr. No.	Station Name	Lead	SD.	Iron	SD.	Copper	SD.	Cobalt	SD.
1	Ali Town	89	26.89	4596.9	232.37	BDL	-	BDL	-
2	Thokar Niaz Beg	269	63.11	3997.5	532.07	7.5	3.27	BDL	-
3	Canal View	119	11.89	4206.3	427.67	BDL	-	BDL	-
4	Hanjarwal	161	9.11	3713.8	673.92	BDL	-	BDL	-
5	Wahdat Road	159	8.11	4760.0	150.82	BDL	-	BDL	-
6	Awan Town	69	36.89	5027.5	17.07	BDL	-	BDL	-
7	Sabza Zar	125	8.89	4436.3	312.67	BDL	-	BDL	-
8	Shah Noor	134	4.39	4908.1	76.77	BDL	-	BDL	-
9	Salah ud Din Road	104	19.39	4574.4	243.62	BDL	-	BDL	-
10	Bund Road	113	14.89	4453.8	303.92	6.25	3.90	BDL	-

11	Saman Abad	134	4.39	4557.5	252.07	BDL	-	BDL	-
12	Gulshan-e-Ravi	84	29.39	4790.6	135.52	BDL	-	BDL	-
13	Chauburji	120	11.39	5032.5	14.57	BDL	-	BDL	-
14	Lake Road	138	2.39	4933.1	64.27	BDL	-	BDL	-
15	G.P.O.	145	1.11	4536	262.82	BDL	-	BDL	-
16	Lakshami	153	5.11	4082.5	489.57	BDL	-	BDL	-
17	Railway Station	277	67.11	6179.4	558.88	9.38	2.33	BDL	-
18	Sultan Pura	153	5.11	6203.1	570.73	12.5	0.77	BDL	-
19	U.E.T.	103	19.89	5938.1	438.23	10	2.02	BDL	-
20	Baghban Pura	141	0.89	6040	489.18	16.88	1.42	3.75	2.86
21	Shalamar Bagh	234	45.61	6067.5	502.93	10.63	1.71	5.00	2.23
22	Pakistan Mint	266	61.61	7500	1219.18	28.13	7.04	16.88	3.71
23	Mehmood Booti	224	40.61	7193.8	1066.08	20.00	2.98	8.13	0.67
24	Islam Park	211	34.11	6385.6	661.98	18.75	2.35	10.63	0.58
25	Salamat Pura	55	43.89	6167.5	552.93	BDL	-	7.5	0.98
26	Dera Gujran	49	46.89	6356.3	647.33	17.5	1.73	14.38	2.46

Table 1 summarizes the results obtained for each heavy metal of the samples collected from 26 sites along the route of OLMT. The Pb concentrations ranged from 49 – 277 mg/Kg, Fe concentrations ranged from 3713.8 – 7500 mg/Kg, Cu concentrations ranged from 6.25 – 28.13 mg/Kg, and Co concentrations ranged from 3.75 – 16.88 mg/Kg.

3.1 Statistical Analysis

Table 2 represents minimum value, maximum value, arithmetic mean, and median for each trace element and intervention guidelines, dictated by Dutch, USA and European Union environment agencies. Based on the obtained results, maximum Pb, Fe, Cu and Co values were 277.0, 7500.0, 28.13 and 16.88 mg/kg. Maximum values of Copper and Cobalt were below the International Environmental Protection Authority. However, maximum values of Lead and Iron were higher than International guidelines. Mean concentrations of the analyzed trace elements in OLMT soils were 142.78, 5061.63, 14.04 and 9.47 mg/kg, respectively (Table 2).

Table 1: Descriptive statistics of heavy metal concentrations (mg/kg) in the soil and related International guideline values

	Lead	**Iron**	**Copper**	**Cobalt**
Maximum Value	277	7500	28.13	16.88
Minimum Value	49	3713.80	6.25	3.75
Arithmetic Mean	142.78	5061.63	14.04	9.47
Median	136	4920.6	12.5	2.23
Dutch Soil Quality Guidelines (Target Value)	85	-	36	-
Dutch Soil Quality Guidelines (Intervention Value) (Qing *et al,* 2015)	530	-	190	-
USEPA Soil Quality Guidelines (SSL)	150	5500	-	2.3
European Union Soil Quality Guidelines (Tóth *et al,* 2016)	100	-	50	100
% Sample which exceeded Dutch target value	88.46	-	0	-
% Sample which exceeded Dutch intervention value	0	-	0	-
% Sample which exceeded USEPA (SSL) guidelines	38.46	38.46	-	11.54
% Sample which exceeded EEU guidelines	80.80	-	0	0

Pollution indexes (PIs) of heavy metals in soil samples of OLMT, Lahore, were calculated using soil environment quality standards of European Union, USEPA, Dutch quality guidelines for the protection of environmental and human health. The formula for calculating the pollution index is Equation.

$$\boldsymbol{PI = \frac{Ci}{Si}}$$

Where PI is the pollution index of heavy metal *i*, C*i* is the actual concentration of element *i* in soils (mg/kg), S*i* is the soil quality standard or reference value of element *i* (mg/kg). Grouping of PIs of heavy metals is listed in Table 3

.

Table 2: Contamination categories based on PI values

PI value	Pollution category
PI ≤ 1	Low contamination
1 < PI ≤ 3	Moderate contamination
PI >3	High contamination

Table 3: Pollution indexes for Pb, Fe, Cu and Co

Sr. No.	Station Name	Lead (EEU) 100 mg/kg	Iron (USEPA) 5500 mg/kg	Copper (EEU) 50 mg/kg	Cobalt (USEPA) 2.3 mg/kg
		Pollution Indexes (PIs)			
1	Ali Town	0.89	0.84	0	0
2	Thokar Niaz Beg	2.69	0.73	0.15	0
3	Canal View	1.19	0.76	0	0
4	Hanjarwal	1.61	0.68	0	0
5	Wahdat Road	1.59	0.87	0	0
6	Awan Town	0.69	0.91	0	0
7	Sabza Zar	1.25	0.81	0	0
8	Shah Noor	1.34	0.89	0	0
9	Salah ud Din Road	1.04	0.83	0	0
10	Bund Road	1.13	0.81	0.12	0
11	Saman Abad	1.34	0.83	0	0
12	Gulshan-e-Ravi	0.84	0.87	0	0
13	Chauburji	1.20	0.92	0	0
14	Lake Road	1.38	0.90	0	0
15	G.P.O.	1.45	0.82	0	0
16	Lakshami	1.53	0.74	0	0
17	Railway Station	2.77	1.12	0.19	0
18	Sultan Pura	1.53	1.13	0.50	0
19	U.E.T.	1.03	1.08	0.20	0
20	Baghban Pura	1.41	1.10	0.34	1.63
21	Shalamar Bagh	2.34	1.10	0.21	2.17

22	Pakistan Mint	2.66	1.36	0.56	7.34
23	Mehmood Booti	2.24	1.31	0.40	3.53
24	Islam Park	2.11	1.16	0.38	4.62
25	Salamat Pura	0.55	1.12	0	3.26
26	Dera Gujran	0.49	1.15	0.35	6.25

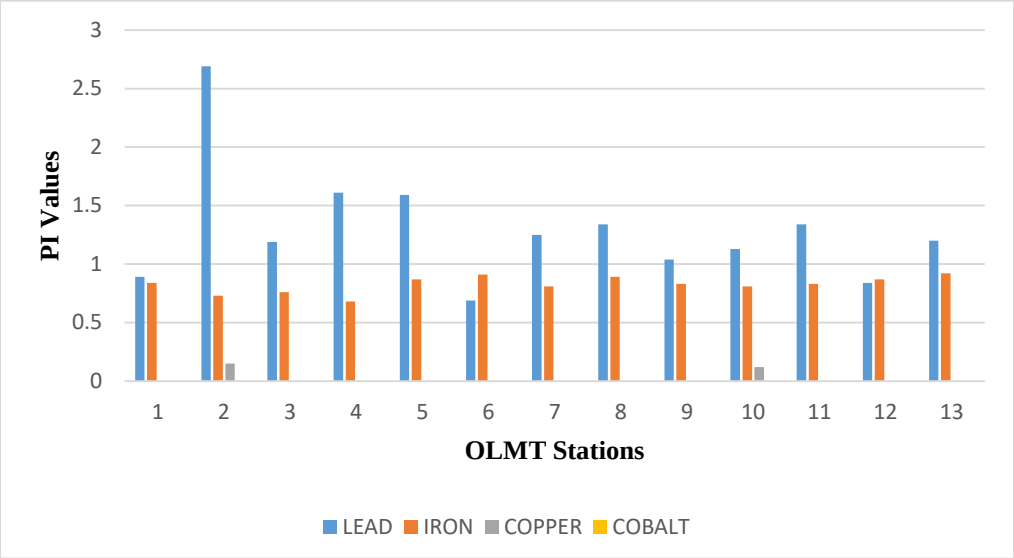

Figure 2: Pollution indexes of heavy metals (1-13 stations)

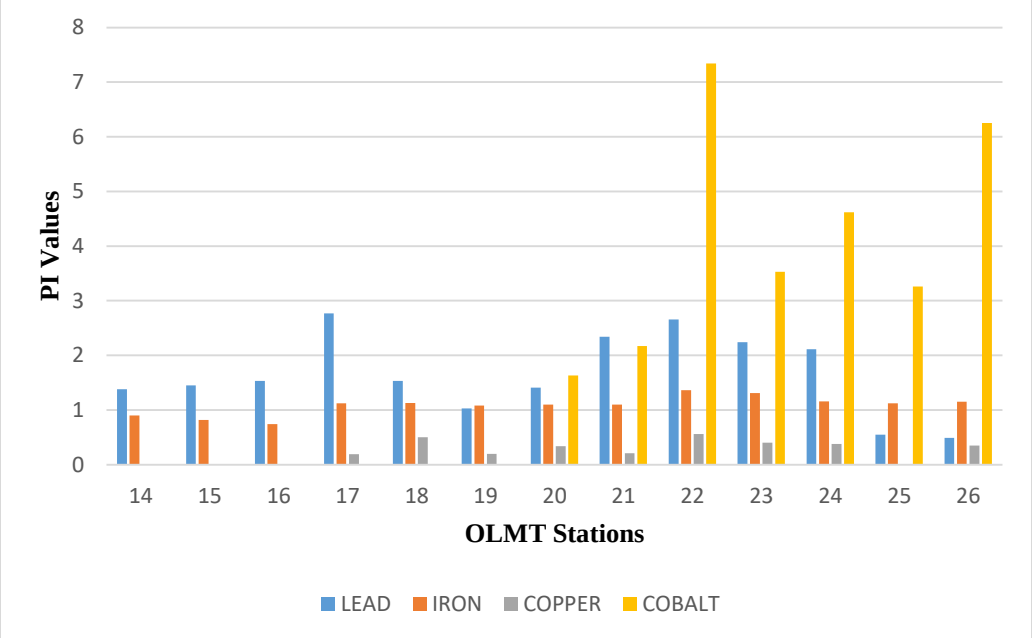

Figure 3: Pollution indexes of heavy metals (14-26 stations)

4. Discussion

The Pb content varies from 49 to 277 mg/kg. The observed values are higher than the USEPA, EEU and Dutch guidelines. Maximum contamination was observed at Railway station, Thokar Niaz Beg, Pakistan Mint, Shalamar Bagh, Mehmood Booti and Islam Park OLMT's stations with lead values of 277, 269, 266, 234, 224 and 211 mg/kg, respectively. Minimum contamination was observed at Dera Gujran, Salamatpura, Awan Town and Ali Town OLMT's stations with lead values of 49, 55, 69, 89 mg/kg, respectively. According to Dutch soil quality guidelines (target value), 88.46% of samples were exceeded in limit, and according to USEPA (Soil Screening Level) and EU soil quality guidelines, 38.46% and 80.80% of soil samples were exceeded in limits as shown in Table 2.

Pollution indexes for Lead, as shown in Table 4, shows that five soil samples have low contamination and 21 soil samples have moderate contamination. However, there was no sample found at high contamination risk.

Iron was found to be in high concentrations in most soil samples. Maximum contamination was observed at Pakistan Mint, Islam Park, Dera Gujran, Sultanpura, Railway Station, and Salamatpura with iron values of 7500, 6385.6, 6356.3, 6203.1, 6179.4 and 6167.5 mg/kg, respectively. Minimum contamination was observed at Hanjarwal, Thokar Niaz Beg and Canal View OLMT's stations with iron values of 3713.8, 3997.5 and 4206.3 mg/kg, respectively.

According to USEPA (SSLs), 38.46% of soil samples were found to exceed in limits are 5500 mg/kg, as shown in Table 2. Pollution Indexes for Iron, in Table 4, show that 16 soil samples have PI values less than 1, which shows low contamination and 10 samples have PI values less than three but higher than 1, which indicates moderate contamination.

The observed values of the Cu content did not exceed the threshold value prescribed by EEU soil quality guideline i.e., 50 mg/kg. Out of 26, 15 soil samples were below the detection limit. Only 11 samples were observed with Cu content ranging from 6.25 to 28.13 mg/kg. Maximum contamination was found in the soil samples of Pakistan Mint, Mehmood Booti, Islam Park and Dera Gujran with Cu content of 28.13, 20.00, 18.75 and 17.5 mg/kg, respectively.

Out of 26 soil samples, 19 samples were observed below the detection limit, and only seven samples have shown Co content, ranging from 3.75 to 16.88 mg/kg. According to USEPA (SSLs), the limit for Co screening of the resident soil is 2.3 mg/kg. Only samples from Pakistan Mint, Dera Gujran, Islam Park and Mehmood Booti have shown exceeding Co content, 16.88, 14.38, 10.63 and 8.13, respectively. Pollution indexes for Co from table 5.4 show that 2 samples have PI values less than 1, and 5 samples have PI values above 3 which shows low-level contamination for Baghbanpura and Salamatpura station sites and high contamination for the others.

5. Conclusion

Based on the results and obtained PIs, approximately all concentrations of the determining trace elements in the soil samples collected from all stations of OLMT are higher than the soil quality guidelines given by Dutch, US and EU environment agencies. Therefore, these higher concentrations of heavy metals in soil samples are a health risk for the citizens. However, there was an exception to the Cu metal contamination, which was below any international soil quality guideline.

6. REFERENCES

Brissot, P., Ropert, M., Le Lan, C., & Loréal, O. (2012). Non-transferrin bound iron: a key role in iron overload and iron toxicity. *Biochimica et Biophysica Acta (BBA)-General Subjects*, 1820(3), 403-410.

Flora, G., Gupta, D., & Tiwari, A. (2012). Toxicity of lead: a review with recent updates. *Interdisciplinary toxicology*, 5(2), 47.

Khan, S., Khan, M. A., & Rehman, S. (2011). Lead and cadmium contamination of different roadside soils and plants in Peshawar City, Pakistan. *Pedosphere*, 21(3), 351-357.

Pan, L. B., Ma, J., Wang, X. L., & Hou, H. (2016). Heavy metals in soils from a typical county in Shanxi Province, China: levels, sources and spatial distribution. *Chemosphere*, 148, 248-254.

Qing, X., Yutong, Z., & Shenggao, L. (2015). Assessment of heavy metal pollution and human health risk in urban soils of steel industrial city (Anshan), Liaoning, Northeast China. *Ecotoxicology and environmental safety*, 120, 377-385.

Ran, J., Wang, D., Wang, C., Zhang, G., & Zhang, H. (2016). Heavy metal contents, distribution, and prediction in a regional soil–wheat system. *Science of the total environment*, 544, 422-431.

Rizvi, H. A. (2014). The China-Pakistan Economic Corridor. *Strategic Studies*, 34, 1-17.

Sajjad, S. H., Shirazi, S. A., Khan, M. A., & Raza, A. (2009). Urbanization effects on temperature trends of Lahore during 1950-2007. *International Journal of Climate Change Strategies and Management*.

Stern, B. R. (2010). Essentiality and toxicity in copper health risk assessment: overview, update and regulatory considerations. *Journal of Toxicology and Environmental Health, Part A*, 73(2-3), 114-127.

Tóth, G., Hermann, T., Da Silva, M. R., & Montanarella, L. (2016). Heavy metals in agricultural soils of the European Union with implications for food safety. *Environment international*, 88, 299-309.

Wei, X., Gao, B., Wang, P., Zhou, H., & Lu, J. (2015). Pollution characteristics and

health risk assessment of heavy metals in street dusts from different functional areas in Beijing, China. *Ecotoxicology and environmental safety*, 112, 186-192.

Wu, S., Peng, S., Zhang, X., Wu, D., Luo, W., Zhang, T., ... & Wu, L. (2015). Levels and health risk assessments of heavy metals in urban soils in Dongguan, China. *Journal* of Geochemical Exploration, *148*, 71-78.