

## Computing the Parametric Geo-Accumulation and Ecological Risk Indices of Some Heavy Metals along Charsadda-Peshawar Road, Pakistan

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**Abstract** Charsadda to Peshawar road is characterized with diverse surrounding environment of residential settlements, industrial zones, commercial and agricultural sectors along with heavy traffic route which is contributing to heavy metal pollution. This study is focused on heavy metals: Cadmium (Cd), Chromium (Cr) and Lead (Pb) contribution to the atmospheric pollution level. The heavy metals pollution assessment is carried out by sample collection (soil dust samples and two vegetation species *Cyperus esculentus* and *Cynodon dactylon*) from ten sites along the road which were analyzed by using atomic absorption spectrometry (AAS). Average values of pollution index (PI) as well as average value of pollution load index (PLI) for Cr, Cd and Pb in case of *Cyperus esculentus*, *Cynodon dactylon* and dust were calculated. Geo-accumulation index of roadside dust for Cr, Cd and Pb were estimated along with ecological risk due to roadside dust using potential ecological risk index (RI). The analyses of this study suggest that the indices for the Cd metal found to be of more concern than Cr or Pb which correspond to middle or low level of pollution. Statistical analysis revealed that the three metals had a weak to moderate relationship with one another indicating multiple and somewhat similar sources of pollution.

**Keywords:** Urbanization, roadside dust, heavy metals, pollution, risk, geoaccumulation.

### Introduction

Heavy metals are significant due to their toxicity and accrue in sediments and plants. These metals neither biodegrade nor leave the environment and go through a global ecological phase (Ahmadipour et al. 2014). Some heavy metals, i.e., copper, zinc and nickel, play vital role in bio-geochemical systems, while cadmium and lead are non-essential to biological system (Norouzi et al., 2012). Heavy metals enter into environment through a number of anthropogenic activities and geological cycles and their toxicity is notable in terms of bioaccumulation in tissues and bio magnification in food web, affecting the central nervous system and acting as a co-factor for other diseases (Rabitsch, 1997).

In Pakistan, heavy metal pollution is contributed largely from industries such as tanneries, construction material units, automobiles industry alongside agricultural practices that uses metal laden fertilizers and are believed as main sources of heavy metal contamination. Serious menace is posed to the human life by the accumulation of heavy metals in soils and excessive usage of agrochemicals in the changing environmental conditions (Nicholson et al., 2003; Wong et al., 2003). The heavy metals are essential part of geochemistry of most sediments and earth's crust (Nowrouzi and Pourkhabbaz, 2014). The soil contamination is of great concern in industrial areas as heavy metals intoxicate plants to prohibit growth. The elimination of metals from environment becomes impossible since they cannot be decomposed (Jamal et al., 2013). Particulate matter that is a mix of natural biogenic materials,

anthropogenic metallic components and soil is characterized as road-side dust (Ferreira-Baptista and De Miguel, 2005), which includes the combination of solid, liquid and gaseous metals that are deposited from the atmosphere (Hjortenkrans et al., 2006; Akhter and Madany, 1993). Deposition of atmospheric particulate and displaced soil is major source of roadside dust and heavy metals found therein. Furthermore, a fair contribution is made by the emissions from vehicles, heating structures, building corrosion, renovation, construction and galvanized metal structures deterioration (Al-Khashman, 2004; Howari et al., 2004). Roadside dust acts as a major contributor of the trace elements due to re-suspension back into the environment as it cannot hold long at one place. It acts as a carrier to the viral diseases by contaminating the food material sold along the roadsides. As a result of precipitation, roadside dust may be washed away and mixed as dissolved solids in the street run-off (Faiz et al., 2009).

Serious threats have been posed to the environment due to contamination of agricultural soil by heavy metals and their toxic effects as observed in plants both at acute and chronic levels. Low fertility is a major economic problem in Pakistan's agricultural soils (Rashid, 1993; Jamal et al., 2002). The exposure of Cd to the plants result in injuries in terms of chlorosis i.e., the loss of chlorophyll in plants, growth inhibition and photosynthesis reduction due to toxic effects, root tips browning and resulting in plant death. Cr accumulation in plants results in reduced growth, structural alterations, disruption of photosynthesis and respiration,

and uptake mechanism of water and minerals. Enzymatic actions of nitrogen metabolism and starch decrease due to Cr toxicity either because of direct involvement with the enzymes or through the reactive oxygen species production. Oxidative damage is also caused by Cr due to disruption of membrane lipids and DNA damage, eventually leading to the death of the plant (Jamal et al., 2013).

Since there is a lack of data on heavy metals in roadside dust and its environmental impacts in Pakistan (Faiz et al. 2009), the current research was therefore carried out to define the common heavy metals i.e., Cd, Cr and Pb concentrations in roadside dust as well as vegetation samples of Charsadda – Peshawar road. The present study could serve as a wakeup call for controlling contamination and toxicity of heavy metals pollution at multiple sites along Charsadda-Peshawar.

points selected on the road, each at an approximate distance of 3 km.

The map for ten sampling sites was prepared by using Arc Map 10.2 version (Fig. 1). Within the same stretch, agricultural, commercial and industrial zones were encountered involving vegetation, frequent traffic and a few residential patches (Table 1). From each site, 1 roadside dust sample and 2 common vegetation samples namely *Cyperus esculentus* (Nut grass) and *Cynodon dactylon* (Bermuda grass), were collected.

## Materials and Methods

The analysis of this study is based on 30 samples (10 dust samples and 20 samples of selected vegetables).

### Dust Sample Preparation

Table 1 Site Description of Sampling Sites of this study.

Site ID	Longitude (E)	Latitude (N)	Site Name	Site Description
1	71.57919	34.03556	Bus stand (Northern Bypass)	Commercial areas, heavy traffic
2	71.589	34.06186	Bukshi Pull	Commercial area, heavy traffic
3	71.59955	34.06747	Chok Khazana	Industrial areas, heavy traffic
4	71.60813	34.09238	Shah Alam	Industrial, commercial areas, heavy traffic
5	71.6095	34.10848	Daud Zai (mahakki)	Farms, greenery, shops, moderate traffic
6	71.00884	34.12309	Nagman Chowk	Shops, open fruits stalls, heavy traffic
7	71.63019	34.1203	Karairay	Open fields, greenery, Akhtar flour mills, moderate traffic
8	71.651	34.12064	Gul Bela	Automobiles workshops, welding units, markets, moderate traffic
9	71.673	34.12004	Sheikh Kali Lara	Trees and greenery, moderate traffic
10	71.68799	34.12909	Sardaryab (Gulabad bridge)	Truck hotels (Dhabaas), shops, rivers, moderate traffic.

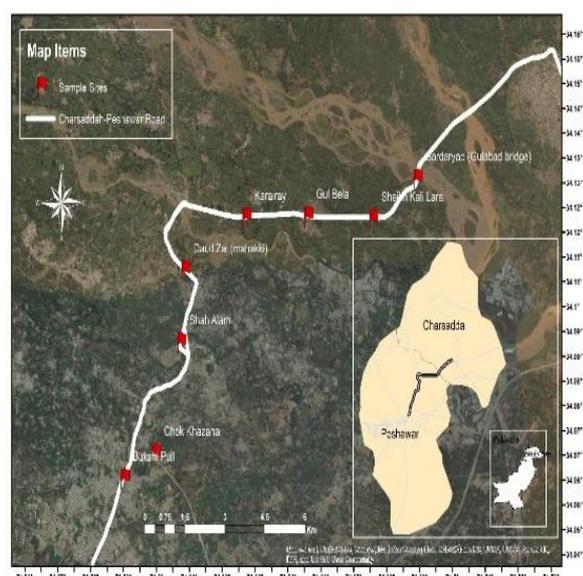


Fig. 1 The base map of study (Charsadda -Peshawar road section).

The Charsadda road (Peshawar) is located in Khyber Pakhtunkhwa, covering a total length of 28 km from Peshawar to Charsadda. Roadside dust and common vegetation samples were collected from ten sampling

A stainless-steel sieve of 0.125 mm was used to sieve the dust samples. The obtained particles are termed as dust in current study due to their easy re-suspension and inhalation through nostrils and mouth. The sieved dust sample of about 1gram was placed in oven for 30 minutes at 350°C to remove the carbon and moisture and was treated for 15 minutes with 25 ml of 25% HNO<sub>3</sub> on a hot plate. Whatman pre-washed filter papers were used to filter the solution of each sample. Prior to Atomic Absorption Spectrometry (AAS) investigation the filtrate was diluted with 100 ml distilled water.

### Plant Sample Preparation

The plant samples were washed with demineralized water and oven dried at 80°C for 24 hours. After letting them cool down, the samples were finely cut and ground into a fine powder. About 0.5 gm sample was digested with 8 ml HNO<sub>3</sub> acid on a hot plate for 20-25 minutes. After digestion, the solution was diluted to 100 ml using distilled water. The samples were filtered through Whatman pre-washed filter paper. The three metals (Cr, Cd and Pb) were quantified by AAS by using Leeds Public Analyst Method (Faiz et al., 2009). For quality assurance requirement, reference material IAEA-SDM-2 (sediment) was used for dust sample analysis.

Moreover, the background concentration used for heavy metals are with reference to their natural presence in the area's bed rock type (Turekian and Wedepohl, 1961).

### Model for Estimation of Heavy Metal Pollution

The following parameters were assessed for estimating the pollution due to heavy metals in roadside dust and vegetation samples:

Pollution Index (PI) is the ratio of metals concentration at the sampling site to corresponding metal background concentration. It is calculated by using the formula adopted after Tokalioğlu and Kartal (2006) as below;

$$PI = \frac{C_n}{B_n} \quad (1)$$

$C_n$ , concentration in suspended particulate matter (SPM) of element  $n$  and  $B_n$ , background concentration of same element. In present study the road side dust and vegetation samples pollution level of metals are;  $PI \leq 1$  = Low,  $1 < PI \leq 3$  = Middle,  $PI > 3$  = High.

Integrated Pollution Index (IPI) of an element is its mean pollution index (PI) for a same city comprising of different sample locations. Therefore, different sample locations within one city can be investigated using IPI value to define the level of contamination of single element. The level of IPI for the current study are;  $IPI \leq 1$  = Low,  $1 < IPI \leq 2$  = Middle,  $IPI > 2$  = High.

Pollution load index (PLI) is the level of contamination that can be determined by using PLI for a definite location. This elemental pollution level parameter is estimated by a method based on the assessment of contaminants as PLI of a specific site as discussed by Daud et al. (2009) using following equations:

$$CF = \frac{C_{metal}}{C_{background}} \quad (2)$$

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \dots \times CF_n} \quad (3)$$

CF = Contamination factor,

$n$  = Number of metals

$C_{metal}$  = Metal concentration in polluted PM

$C_{background}$  = Background concentration of same metal.

The standard ranges of PLI have been set as;  $PLI < 1$  = Low contamination,  $1 \leq PLI < 3$  = Middle contamination,  $3 \leq PLI < 6$  = Considerable contamination and  $6 \leq PLI$  = High contamination. To find the contamination level for each element PLI values were calculated at site.

Geo-accumulation index ( $I_{geo}$ ) is used to evaluate the heavy metal concentration in sediments as a reference to assess the amount of pollution processes (Kouidri et al. 2016).  $I_{geo}$  values were calculated for each element at a site using:

$$I_{geo} = \log_2 \times \frac{C_n}{1.5B_n} \quad (4)$$

Where,  $C_n$  is the concentration of metal determined in the dust sample,  $B_n$  represents the same metal's background concentration in earth's crust (Turekian and Wedepohl, 1961).

Forstner et al. (1990) divided  $I_{geo}$  into seven categories depending on pollution level as;  $I_{geo} < 0$  = Unpolluted,  $0 < I_{geo} \leq 1$  = Unpolluted to moderately polluted,  $1 < I_{geo} \leq 2$  = moderately polluted,  $2 < I_{geo} \leq 3$  = moderately to strongly polluted environment,  $3 < I_{geo} \leq 4$  = strongly polluted environment,  $4 < I_{geo} \leq 5$  = strongly to extremely polluted environment and  $5 < I_{geo} \leq 6$  = extremely polluted environment.

Hakanson (1980) has established the potential ecological Risk Index (RI) for toxic metals;

$$RI = \sum_{i=1}^n E_r^i \quad (5)$$

$$E_r^i = T_r^i \times C_f^i \quad (6)$$

$$C_f^i = \frac{C_s^i}{C_n^i} \quad (7)$$

" $C_f^i$  = contaminant factor for  $i^{\text{th}}$  metal;  $C_s^i$  =  $i^{\text{th}}$  metal concentration in the sample;  $C_n^i$  = background concentration of  $i^{\text{th}}$  metal taken from the uncontaminated site due to the absence of background metal levels in the soils investigated (CEPA and CGSEM 1990);  $T_r^i$  = toxic response factor suggested by Hakanson (1980) for Cd (30), Cr (2) and Pb (5);  $E_r^i$  = potential ecological risk factor of individual metals; RI = potential ecological risk factor of multiple metals;  $r$  = response factor in  $T_r^i$  and risk factor in  $E_r^i$ ;  $n$  = pristine or uncontaminated soils;  $s$  = soil sample investigated;  $i$  = any one of the above five metals."

Modified standards for  $C_f^i$ ,  $E_r^i$ , and RI classification criteria were adopted after (Cao et al. 2007; Ali et al. 2015). Potential Ecological Risk Index (RI) is divided into four categories as,  $RI < 150$  = Low risk,  $150 \leq RI < 300$  = Moderate risk,  $300 \leq RI < 600$  = Severe risk,  $600 \leq RI$  = Serious risk.

## Results and Discussion

### Cadmium (Cd)

The Cd concentration in road side dust varies from 0.182 to 0.874  $\mu\text{g/ml}$  with an average value of 0.4494  $\mu\text{g/ml}$  (Table 2c, Fig. 2). Highest Cd concentrations were found in the roadside dusts from Chok Khazana (0.874  $\mu\text{g/ml}$ ) and the lowest in the sample from Sheikh Kali Lara (0.182  $\mu\text{g/ml}$ ). Since cadmium, in comparison to other heavy metals is a rare chemical element, its anthropogenic sources include point-sourced industrial pollution (Shi et al., 2008), automobile fuels, nickel-cadmium batteries, phosphate fertilizers etc. As it is released into the environment due to the vehicular

emissions and use of pesticides, its presence is noticed in soil and roadside dust. As a component of dust, cadmium may become inhalable imposing damaging effects on different organs with the kidney being the main target (Tchounwou et al., 2012). In *Cyperus esculentus* mean Cd concentration was 0.25544 µg/ml (Table 2a) while in the *Cynodon dactylon*, Cd ranged from 0.039 to 0.579 µg/ml with a mean value of 0.302 µg/ml (Table 2b). In case of *Cyperus esculentus*, highest concentration was encountered at Sardaryab (Gulabad bridge) and lowest at Karairay while, for *Cynodon dactylon*, highest concentration was obtained at Bus stand (Northern bypass) and lowest at Karairay. This may be taken as an indication of Cd toxicity in nearby fields of edible vegetation. The high concentration of cadmium (Cd) owes its origin to the pesticides and herbicides used in agriculture of the area, as pointed out by Alloway and Ayres (1998).

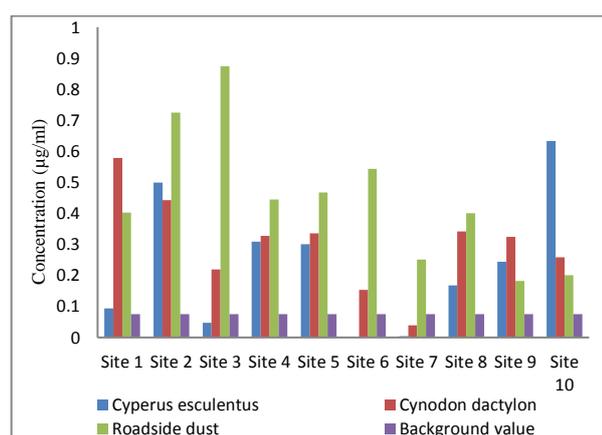


Fig. 2 Cadmium (Cd) concentrations (µg/ml) on selected sites.

### Lead (Pb)

The anthropogenic sources of lead observed at study site include automobiles, building construction materials, welding works, industries etc. The highest concentrations for Pb in road side dust were observed at Bus stand (Northern bypass), Bakhshi pull, chowk Khazana, Gul Bela, Karairay and Nagman chowk having heavy traffic load during the day. The lowest concentration of Pb was encountered at Daud Zai (Mahakki) i.e., 0.795 µg/ml, where the traffic is relatively light. The variance in the Pb concentration at some locations may owe its derivation to the traffic load and leaded gasoline usage, which contributed a lot for human exposure to Pb causing depression, gastric abnormalities, reduced appetite and muscular pains. Since 2005 Pakistan has phased out the Pb in petrol (Faiz et al., 2009) and CNG (compressed natural gas) used by most of the vehicles on this route, Hence, the Pb concentration is somehow under control and might possibly decrease as the time passes by.

Average concentration of Pb in *Cyperus esculentus* was 5.0063 µg/ml (Table 2a, Fig. 3) while in *Cynodon dactylon* it is 6.8867 µg/ml (Table 2b, Fig. 3). Highest concentration of lead in case of *Cyperus esculentus* was

encountered at Bakhshi pull (12.2053 µg/ml) while, the lowest concentration was present at Gul Bela (0.016 µg/ml). In case of *Cynodon dactylon* highest concentration of lead was found at Bakhshi pull i.e., 27.11 µg/ml and the lowest concentration was determined at Sardaryab (Gulabad bridge) i.e., 0.758 µg/ml. The highest concentrations of Pb in case of both vegetation species were detected at site 2 i.e., Bakhshi pull sourced from high traffic density and commercial market in the specific area. Lead has acute and chronic effects on humans, if they get exposed. The chemical properties of lead are similar to that of calcium, so it is often confused by the human body when ingested and gets absorbed into various body organs, targeting bone marrow, kidneys, nerve tissues and brain. As it is an element, the body cannot breakdown Pb into smaller parts. It has very harmful effects, causing disruption in kidneys, nervous system, immune system and reproductive system (Tchounwou et al. 2012). The presence of lead in almost all the road side dust samples refer to be an integral part of weathered soil of the igneous rocks, transported and deposited in the area by river channels (Bundschuh, 1992).

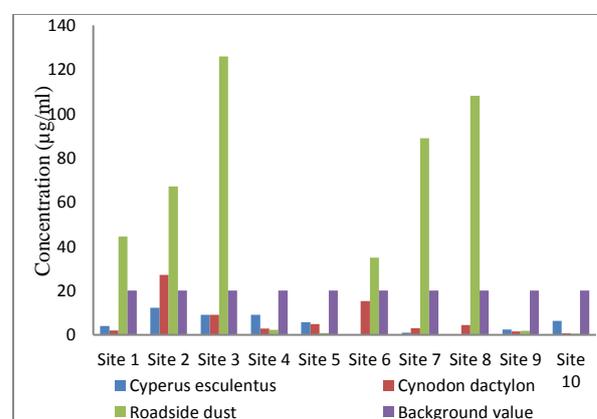


Fig. 3 Lead (Pb) concentrations (µg/ml) on selected sites of Charsadda road.

Table 2. Heavy metal concentrations in plants and dust samples.

<i>Cyperus esculentus</i>			
Statistical values	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)
Average	1.257375±0.8808	0.2554±0.20836	0.20836±4.222703
<i>Cynodon dactylon</i>			
Average	0.706±0.999	0.302±0.1493	6.8868±8.7365
Dust samples			
Average	1.0237±0.6427	0.4494±0.2218	47.918±47.4076

### Chromium (Cr)

Chromium is a heavy metal, naturally present in earth's crust, and mainly found in chromite. The oxidation states of Cr range from Cr (II) to Cr (VI). In undertaken assessment, the Cr concentration in road side dust

samples from Charsadda road varies from 0.350 to 2.033 µg/ml with an average value of 1.0237 µg/ml (Table 2c, Fig. 4), with the highest in sample from Shah Alam (2.033 µg/ml) and the lowest in the sample from Gul Bela (0.350 µg/ml). This concentration may be sourced from a variety of anthropogenic sources mainly industries, chromate production tanneries and stainless-steel welding (Tchounwou et al., 2012). The inhalation of chromium dust can irritate respiratory tract, causing airway obstruction, sinus, nasal or lung cancer. The mean Cr concentration in the *Cyperus esculentus* was 1.257 µg/ml (Table 2a), while in *Cynodon dactylon* was 0.706 µg/ml (Table 2b). In case of *Cyperus esculentus*, highest concentration was determined at Chok Khazana and lowest at Daud Zai (Mahakki). In case of *Cynodon dactylon*, highest concentration was observed at Bus stand (Northern bypass) and lowest at Sardaryab (Gulabad bridge). The low values of Chromium in collected samples suggest less translocation of chromium in both plant species and thus was not spotted much in plant shoots (WHO, 1996).

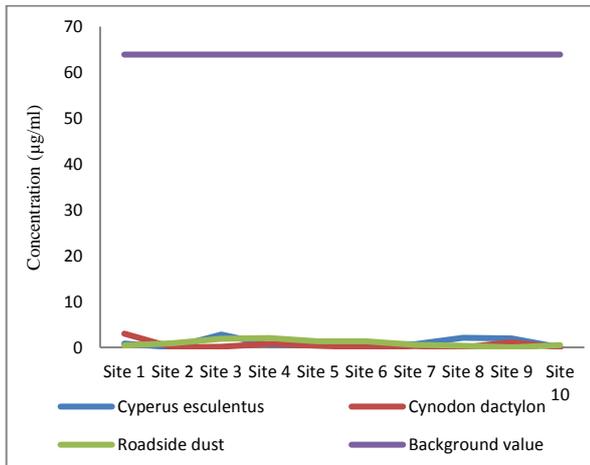


Fig. 4 Chromium (Cr) concentrations (µg/ml) on selected sites of Charsadda Road.

The Pearson correlation coefficient was analyzed between the selected elements in order to establish relationship among some heavy metal's concentration, which shows a positive correlation among all analyzed metals (Table 3a). The strong positive correlation was observed between Cr and Cd that indicate their release from a similar source in the study area. The possible common source is tanneries for the release of Cr and Cd. Another positive correlation was observed between Cd and Pb, which also justify the release of the metal from a common source of industries or automobiles. Whereas weak positive correlation was noticed in Cr and Pb that depicts less link between the presence of both metals or sharing a common source in the study area.

Table 3 (a). Correlation matrix among selected heavy metals in *Cyperus esculentus*.

	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)
Chromium (Cr)	1	-0.6124573	-0.22828500
Cadmium (Cd)		1	0.468796
Lead (Pb)			1

The metals correlation in plant tissues of both selected species is presented in Table 3(b,c). The metal existence in leaf tissue also depends on plant species, its uptake and accumulation capacity. The correlation results of plants varied from dust findings. In the case of *Cyperus esculentus*, a moderate positive relationship was identified of Pb and Cd in leaf tissue. The common source may include vehicular emissions as both lead and cadmium are present in automobile fuels. Results showed that plant uptake is low for metal translocation and accumulation as significant amount of these metals occur in soil. A negative relationship indicates that the sources of these two elements are not exactly similar and neither these elements support the plant uptake. Similar results were obtained by *Cynodon dactylon*, the positive correlation is shown between Cr and Cd and weak relation was found among Cd and Pb, showing a similar source and uptake. Whereas, a negative relationship between Cr and Pb is a weak negative relationship and the sources of these elements are independent and are also inversely proportional to each other.

Table 3 (b). Correlation matrix among selected heavy metals in *Cynodon Dactylon*.

	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)
Chromium (Cr)	1	0.6335166	-0.3997799
Cadmium (Cd)		1	0.04017742
Lead (Pb)			1

Table 3 (c). Correlation matrix among selected heavy metals in Roadside dust.

	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)
Chromium (Cr)	1	0.66875905	0.02696121
Cadmium (Cd)		1	0.51396600
Lead (Pb)			1

**Assessment of Pollution Level at Selected Sites**

In the current study, pollution index (PI), integrated pollution index (IPI), pollution load index (PLI) and geo-accumulation index (I<sub>geo</sub>) (Lu et al, 2009) have been adopted to evaluate the contamination level of heavy metal in the roadside dust and vegetation samples gathered from Charsadda road, Peshawar. Furthermore, potential ecological risk (RI) as a result of heavy metal contaminated dust is also estimated. These indices were calculated in the following sections.

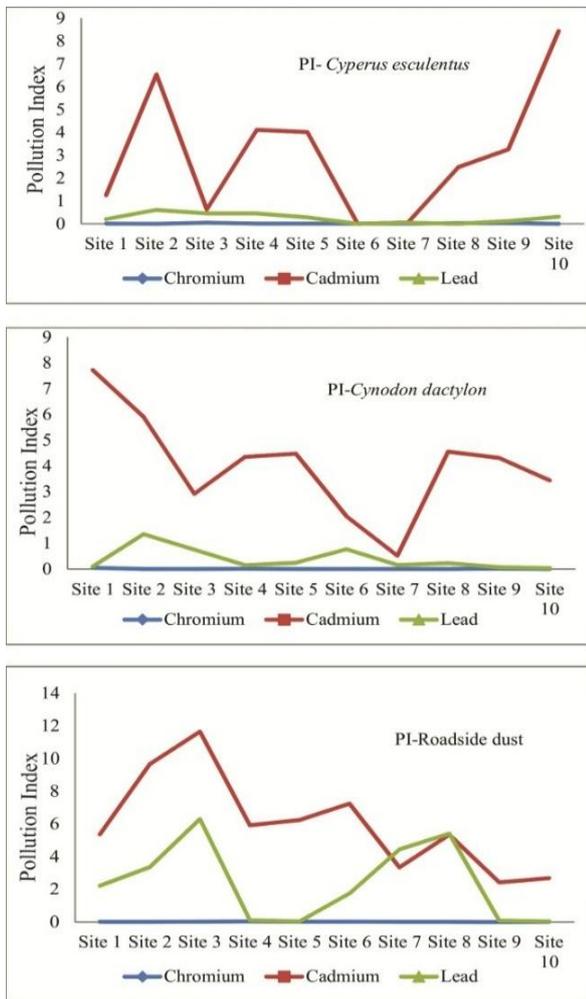


Fig. 5 Pollution Index (PI) for plant species and road-side dust in the study area.

PI was calculated for selected three elements (Cr, Cd and Pb) under observation (Fig. 5). PI of chromium for 10 samples of *Cyperus esculentus* corresponded to low pollution level. PI of cadmium was such that one sample (Bus stand {Northern bypass}) corresponded to low level of pollution, two samples (Khazana chowk and Nagman chowk) were in medium level and remaining 7 samples were in high pollution level that might owe its origin to the ongoing industrial operations and the application of phosphate fertilizers, as Cd is a main component of it. PI of Cr for all the samples were in the low pollution level indicating no threat to environment. PI of Pb for all 10 sites were observed in low level of pollution. The reason maybe the phasing out of leaded fuels since 2005. Therefore, PI of cadmium pollution is of concern around the study sites. PI of Chromium for ten samples of *Cynodon dactylon* corresponded to low level of pollution. PI of cadmium was such that one sample (Karairay) responded to low level of pollution, two samples (Khazana chowk and Nagman chowk) were in medium level and remaining seven samples were in high level of pollution because of the surrounding industrial activities. Agricultural farms around the study area, utilizing fertilizers may be the cause of elevated Cd levels. PI of Lead for one sample

(Bakhshi Pull) corresponded to middle level of pollution and all the remaining nine samples were in the low level of pollution.

PI of chromium for 10 samples of dust showed low level of pollution. PI of cadmium was such that 2 samples (Sheikh Kali Lara and Sardaryab {Gulabad bridge}) corresponded to medium level of pollution whereas, all remaining 8 samples had high level of pollution which may be due to the agricultural and industrial practices prevalent in the area. PI of lead for 4 samples (Shah Alam, Daud Zai {Mahakki}, Sheikh Kali Lara and Sardaryab {Gulabad bridge}) displayed low level of pollution, one sample was in the middle level of pollution and all remaining samples depicted high level of pollution. Therefore, according to PI, cadmium pollution is of major concern, whereas lead is also adding to the pollution levels but to a lesser extent and is expected to be eliminated in the years to come due to phasing out of leaded fuels in 2005.

IPI was calculated for selected three elements (Cr, Cd and Pb) under this study. Mean values of PI for all the elements under consideration were determined for *Cyperus esculentus* and *Cynodon dactylon*, and the results were found to be as follows: the elements Pb and Cr had  $IPI \leq 1$ ; therefore, their pollution level is low. The element Cd lay in the classification range  $IPI > 2$ , which implies high level of pollution (Fig. 6). For all three metals, mean values of PI were observed in roadside dust samples, Cr had  $IPI \leq 1$ ; therefore, pollution level is low.

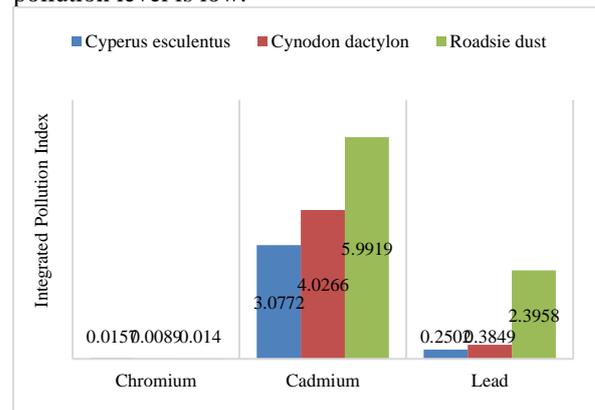


Fig. 6 Integrated Pollution Index (IPI) of samples analyzed in this study.

Pb had an IPI of 2.3958 falling in the range of  $1 < IPI \leq 2$ , thereby depicting middle level of pollution. Cd falls in the classification range  $IPI > 2$ , which implies high level of pollution. Therefore, Cd is of major concern along the understudy road. Table 4 shows the statistical values of IPI of selected samples.

Table 4 Pollution Index (PI) For *Cyperus esculentus*, *Cynodon dactylon* and Dust.

Sample types →	<i>Cyperus esculentus</i>			<i>Cynodon dactylon</i>			Dust		
Parameters of Concern (POC) →	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)
Average (IPI)	0.01579	3.0772	0.2502	0.0089	4.0266	0.3849	0.014	5.9919	2.3958
Standard Deviation	± 0.0148	± 2.8087	± 0.21	± 0.0146	± 1.9909	± 0.4313	± 0.0108	± 3.1277	± 2.37

Pollution load index was calculated for *Cyperus esculentus*, *Cynodon dactylon* and dust samples (Fig. 7). In case of *Cyperus esculentus* PLI values indicated moderate contamination with respect to Bakhshi Pull and Sardaryab (Gulabad Bridge) whereas, all remaining sites revealed low level of contamination. In case of *Cynodon dactylon*, PLI values corresponded to moderate level of contamination at Bakhshi Pull and Gul Bela, whereas, all the remaining values showed low level of pollution. In case of dust samples, Chok Khazana responded to moderate level of pollution, whereas the remaining sites depicted low level of pollution (Table 5).

Table 5 Statistical values of Pollution Load Index (PLI) for vegetation and roadside dust.

Sample types →	<i>Cyperus esculentus</i>	<i>Cynodon dactylon</i>	Dust
Average	0.476325±0.7147	0.5174±0.8577	0.52306±0.3298

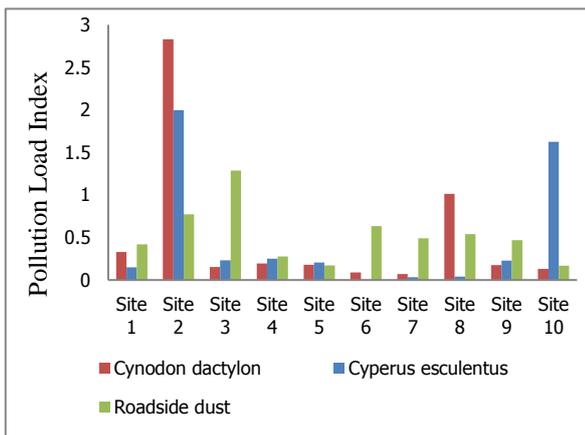


Fig. 7 Pollution Load Index (PLI) of samples.

Table 6 Statistical and average values of Geo accumulation Index.

Sample type →	Dust		
Parameters of Concern (POC) →	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)
Average	-6.8336±0.9856	1.8324±0.7459	-0.8222±2.78

The  $I_{geo}$  computation extracted that chromium falls in the range of  $I_{geo} \leq 0$ , indicating an unpolluted environment. In case of Cd, Sheikh Kali Lara and Sardaryab (Gulabad bridge) sites are unpolluted to

moderately polluted. Bus stand (Northern bypass), Shah Alam, Karairay and Gul Bela are moderately polluted, whereas, remaining sites are moderately to strongly polluted. Geo-accumulation index of element lead shows that Bus stand (Northern Bypass), Shah Alam, Daud Zai (Mahakki), Sheikh Kali Lara and Sardaryab (Gulabad Bridge) have unpolluted environment. Bakhshi Pull, Karairay and Gul Bela are moderately polluted, whereas, the remaining 2 sites are moderately to strongly polluted (Fig. 8). Table 6 shows the Igeo statistical values of dust samples for the samples, while figure 8 shows site wise Igeo.

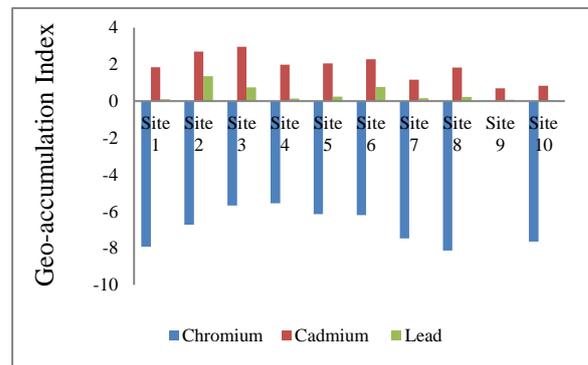


Fig. 8 Geo-accumulation index of roadside dust samples on Charsadda- Peshawar road.

Table 7 Potential Ecological Risk Index of Dust samples.

Site Code	$E_r^i$ Chromium	$E_r^i$ Cadmium	$E_r^i$ Lead	Potential Ecological Risk Index (RI)
Site 1	0.01234	161.199	11.1075	172.318
Site 2	0.0284	290.01	16.79	306.828
Site 3	0.058	349.59	31.47	381.118
Site 4	0.064	177.99	0.5595	178.613
Site 5	0.0422	187.2	0.1985	187.441
Site 6	0.0404	217.59	8.72	226.3504
Site 7	0.016	100.38	22.22	122.616
Site 8	0.0108	160.41	27.05	187.4708
Site 9	ND	72.81	0.4508	73.2608
Site 10	0.015	80.4	1.223	81.638
Average				191.7655

Potential ecological risk index was estimated for each selected site. The results indicated that ecological risk due to heavy metals was low at Karairay, Sheikh Kali Lara and Sardaryab (Gulabad bridge) owing to the presence of agricultural farms and greenery in the area as well as absence of heavy traffic. Sardaryab (Gulabad bridge) also had a river flowing so the toxicity may be diluted resulting in lesser ecological risk. Bus stand (Northern bypass), Shah Alam, Daud Zai (Mahakki),

Nagman chowk and Gul Bela corresponded to moderate level of potential ecological risk. While, potential ecological risk index developed for Bakhshi pull and Khazana chowk indicated severe ecological risk owing to heavy traffic and a number of industries nearby (Table 7, Fig. 9).

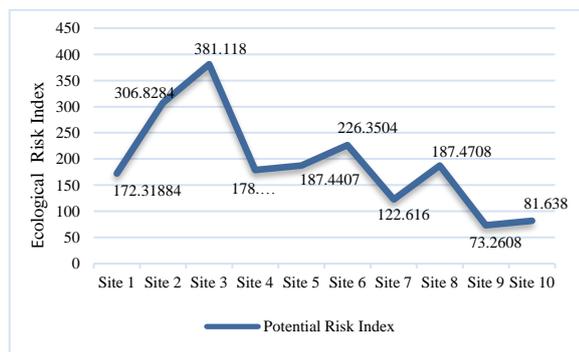


Fig. 9 Potential Ecological Risk of selected heavy metals in dust samples at under study sites, Charsadda- Peshawar road.

## Conclusion

The concentration level of selected heavy metals along Charsadda- Peshawar road was found in an order of Cd >Pb> Cr for vegetation and dust samples. *Cyperus esculentus* affected by the concentrations of all the three heavy metals were above the background value. Pb was high only in the roadside dust samples, whereas, its concentrations were below the background value in both the plant species. Chromium concentrations were fairly below the background values indicating natural presence without anthropogenic contribution. However, unexpectedly highest concentrations of Cd were found in both dust and selected vegetation samples. The pollution level of the elements was estimated using PI, IPI, PLI, Igeo and RI. It was concluded that the pollution level of this road section falls in category of “lower to intermediate level of pollution” with considerable risk. But due to the rapid growth in population of the region, and heavy traffic density along with the industrial growth, risk may be predicted to increase in the coming years. In the light of these findings, it recommended that the highways may not only be regularly monitored for toxic metal concentrations in inhalable fraction of roadside dust, but there is a dire need of temporal assessments of roadside dusts and environmental health consequences by keeping a check over traffic and other contributing sources of dust pollution in these areas.

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