

Lead and Cadmium Contaminations in Soil and Wild Plant Species Along Karakorum Highway Northern Pakistan: Occurrence, Transformation and Human Health Risk

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Abstract

Lead and cadmium contaminations in soil and plant may indirectly result in human health risk. This study was to assess the lead (Pb) and cadmium (Cd) concentrations in soil and wild plants and its associated human health risk along the Karakorum Highway, Northern Pakistan. Results showed that the concentrations of both Pb and Cd in soil were above the permissible limits of Dutch standards, and the mean values in wild plant species were above the permissible limit according to WHO (1996). Metal bioaccumulation factor (BAF) and translocation factor (TF) were applied to assess metal uptake and transport through plant tissues. Among 30 wild plant species, merely 1 plant species (*Debregeasia Saeneb*) for Pb and 5 plant species (*Dodonaea viscosa*, *Crysopoge gryllus*, *Debregeasia saeneb*, *Festuca hartmanii* and *Plantanus arientalis*) for Cd showed BAF > 1. For the TF values, Pb in 11 plant species were > 1, while 19 plant species for Cd were > 1. The hazard index (HI) values for soil were observed < 1 with an order of ingestion > dermal > inhalation, indicating no adverse health effects. This study suggests that some wild plant species in Northern Pakistan present low BAF and TF values, those wild plants can be used for phytoremediation purposes.

1. Introduction

Plants and soil are the most vital component of the life-supporting system in terrestrial ecological system. Heavy metals in irrigation water may transfer these toxic metals into soil and plants respectively and thus enter into the food chain (Nawab et al., 2018a,b,c, Pentari et al., 2006). As one of the most significant environmental component, the soil could control the transfer of many toxic heavy metals to the biosphere, atmosphere, and hydrosphere, thus it is usually considered as a geochemical sink for different contaminants (Kabata-Pendias, 2010). The contaminants are transferred to waters and soils, which may indirectly pose threat to human health (Nawab et al., 2019). Toxic heavy metals are recognized as pollutants in environment due to their reactivity and toxicity in plants and soil, which can cause numerous problems including water quality deterioration, habitat loss and accumulation in food plants and as a result human health is affected significantly (Massas et al., 2013), especially for Cadmium (Cd) and Lead (Pb). These hazardous heavy metals are considered as toxic due to its chronic and acute diseases found in humans (Spanu et al., 2012). The emission from industries, mining, automobile, and other anthropogenic activity are the main sources of toxic metals (Nawab et al., 2015; Nawab et al., 2018b), as well as agricultural processes and erosion (Nawab et al., 2018a,c). Toxic heavy metals can accumulate in the body of human beings and animals through inhalation, skin contact or direct ingestion (Tamuly and Devi, 2014). Due to the toxicity and persistence nature of heavy metals, they are of main importance among the man-made contaminants (Adriano, 2001). The soil pollution due to heavy metals is a serious problem in the world (Facchinelli et al., 2001; Solgi et al., 2012). The presence of these heavy metals can cause severe chemical changes in living organisms. Some studies have reported that substantial metal intake can result in lethal cancers and psychological disease (Li and Zhang, 2011). Possible threats to human's health make heavy metal pollution a continuing ecological problem (Farahat and Linderholm, 2015; Giri and Singh, 2014). Thus, it is essential to identify the sources, distribution and health risks associated with heavy metals pollution to protect natural environment and to minimize risks (Islam et al., 2014; Xiao et al., 2014).

Contamination of soil by toxic metals are of great concern because of their bioaccumulation and abundance, which might affect human via exposure and can cause serious health effects (Yousaf et al., 2016b; Zhang et al., 2016a). Various factors like absorption, distribution, metabolism, excretion, and biotransformation (ADME) in the body can influence the degree of instant or chronic toxicity (Augustsson et al., 2015; Liu et al., 2013). Repeated consumption of Cd and Pb for a long time can result in severe psychological and physiological health impacts (Augustsson et al., 2015; Liu et al., 2013; Zheng et al., 2007). Health effects due to Pb include mental diseases, anemia, mental retardation / hyperactivity, stress, and other metabolic disorders in humans (Khan et al., 2011). Moreover, Cd can affect bones, reproductive system and kidneys (Godt et al., 2006). Many heavy metals are known to alter DNA (Ref.x). Besides, children suffered more severely as compared to adults as they have sensitive circulatory and digestive systems (Khan et al., 2011; Li et al., 2007). The aim of this study was to (1) assess Pb and Cd contaminations in plants and soil, (2) their occurrence, (3) transformation and human health risk associated with the consumption of these toxic pollutants. This study was carried out along the famous Karakorum Highway, Northern Pakistan which, is now the main route of China Pakistan Economic Corridor (CPEC)

2. Material And Methods

2.1. Study area

The study was carried out along the roadside of the famous Karakoram Highway (KKH) from District Kohistan's headquarter Dasu to District Shangla's Thakot bridge (Fig. 1). The KKH is starting from Hasan Abdal to Khunjerab Pass, where it connects China and Pakistan with 1300 km long (Kamal 1979). KKH nearly links all the provinces of Pakistan. Karakorum Mountains, at 36° 51'01"N and 75°25'41"E having an elevation of 4,696 meters. This Highway is also considered as the Eighth Wonder in the World (Ispahani, 1989; Naim, 2010). The wild plant along the highway are present and the land is using for different crop in different season. The study area is mostly steep and mountainous, lower areas have the hottest summer having an average temperature of 32.5°C and have coldest winters with an average temperature of -3°C. In the higher altitude areas, the weather remains pleasant in summer. This area remains moist throughout the year due to monsoon rains and receives an annual average rainfall of 1425 mm (Muhammad et al., 2010).

2.3. Sampling

A total number of 38 soil samples were collected from Thakot Bridge (Shangla) to Dasu (Kohistan) along KKH (Fig. 1). Approximately 1.5 kg surface soil sample (~ 20 cm deep) was collected in polythene bags and were transported to lab in 48 h. The soil samples were dried for 72 hours at 60°C. For future analysis, the dried samples were passed through a 2mm mesh. A total number of 27 different plant species were also collected at soil sampling sits. The plant amples were packed in polyethylene bags and were properly labeled. Then the samples were washed and separated into stems and leaves were dried at 60°C in oven. The dried stems and leaves samples were grinded. The physical parameter (pH and EC) of soil samples were detected by conductivity and pH meters.

2.4. Digestion of soil samples

For the extraction of heavy metals, 0.5g of each soil sample was taken in beaker and added with 15ml tri-acid mixture (HNO₃, HClO₄, and H₂SO₄) at a ratio of 5:1:1, respectively. The samples were then kept for 24 hours at room temperature (20 ± 22°C) (Khan et al., 2011), then were put into the tubes and were placed in digestion blocks. The initial temperature was 80°C and gradually increased up to 160°C. When the digestion process was completed, the extracts of the heated samples were then cooled and filtered. The filtered extracts of soil samples were diluted to a final volume of 50 ml with double distilled water for further analysis (Khan et al., 2011).

2.5. Digestion of plant samples

The dried plant samples of 0.5 g were added to conical flask (100 ml). A mixture of acid (HNO₃ and HClO₄) with a ratio of 4:1 was added, respectively. The flasks were then heated gradually up to 160°C followed by gradual cooling. The extracts were then filtered and added with double distilled water to make the final solution of 50 ml and kept at room temperature for further analysis.

2.6. Data Analysis

2.6.1. Human health risk assessment

Exposure of human to heavy metal can be measured through human health risk assessment. It is usually used to determine any risk to human beings through inhalation, dermal exposure and ingestion exposure pathways (Qing et al., 2015; Benhaddya et al., 2016). The model consists of four main elements which are hazard identification, dose-response assessment, exposure assessment and risk characterization (Praveena et al., 2015). The Average Daily Doses (ADDs) received via the three pathways (inhalation ingestion, and dermal contact) can be calculated according to the protocols developed by (USEPA, 1989, 2001; Rastegari Mehr et al., 2016):

$$ADD_{ing} = C \times \frac{IR_{ing} \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (1)$$

$$ADD_{inh} = C \times \frac{IR_{inh} \times EF \times ED}{PEF \times BW \times AT} \quad (2)$$

$$ADD_{dermal} = C \times \frac{SA \times AF \times ABS \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (3)$$

Where C is the concentration of heavy metals in soil (mg/kg), and ADD_{ing}, ADD_{inh}, ADD_{dermal} are the average daily intake from soil ingestion, dermal contact, and inhalation absorption (mg/kg/d). The values and exposure factors to estimate the consumption and risk values are shown in Table 1. (Hu et al., 2011)

Table 1
Reference values of some parameters for health risk assessment of Pb and Cd in soil

Factor definition		unit	Value Children	Adults	References
IRing	Ingestion rate	mg d ⁻¹	100 ^a	55 ^a	US EPA, 2001
IRinh	Inhilation rate	m ³ d ⁻¹	7.6 ^b	20 ^b	Ferreira-Baptista and De Miguelb, 2005.
PEF	Particle emission factor	m ³ kg ⁻¹	1.36×10 ⁹ c	1.36×10 ⁹ c	US EPA, 2001
SA	Exposure skin area	cm ²	1150 ^a	2145 ^a	Wang et al., 2008
AF	Skin adherence factor	mg cm ⁻² d ⁻¹	0.2 ^c	0.07 ^c	US EPA, 1996, 2001
ABS	Dermal absorption factor	–	0.001 ^c	0.001 ^c	US DOE, 2004
ED	Exposure duration	year	6 ^c	24 ^c	US EPA, 1996, 2001
EF	Exposure frequency	d y ⁻¹	180 ^d	180	Ferreira-Baptista and De Miguelb, 2005.
BW	Average body weight	kg	15 ^a	70 ^a	US EPA, 1996, 2001
AT	Average life span for heavy metals	d	ED × 365	ED × 365	US EPA 1989

$$HI = \frac{ADD_i}{RfDi} \quad (4)$$

HI values of > 1 indicate possible adverse health effects and HI values < 1 indicates no possible adverse health effects (Kong et al., 2011).

2.6.2. Metal Bioaccumulation Factor (BAF)

In soil, the concentrations of Pb and Cd were calculated on the basis of dry weight. The ratio of heavy metal concentration in plants tissue from soil is metal bioaccumulation factor, calculated as follow (Ali et al., 2013)

$$BAF = C_{\text{plant tissue}} / C_{\text{soil}} \quad (5)$$

Where $C_{\text{plant tissue}}$ is the concentration of Pb and Cd in plant tissues while C_{soil} is the concentrations of Pb and Cd in soil, on a dry weight basis.

2.6.3. Metal Translocation Factor (TF)

The ability of a plant to transfer heavy metal from one part to another is known as translocation factor (TF) (Ali et al., 2013), calculated as the ratio of heavy metal content in above ground tissues to leaves to stem or roots. Calculated as follows:

$$TF = C_{\text{leaves}} / C_{\text{stem}}$$

Where C_{leaves} is the concentration of heavy metals in leaves and C_{stem} is the concentrations of the heavy metal in stems, on a dry weight basis.

2.7. Statistical analysis

Statistical analyses of obtained data in this work were performed by using SPSS version 21, statistical software packages of statistix version 10 as complementary software. Mean values and standard deviation were calculated using MS Excel, 2016.

3. Results And Discussion

3.1. Physiochemical characteristics of soil and plants samples

The Table 3 represents the properties and heavy metals (Pb and Cd) concentrations in the roadside soil in study areas. The soil pH ranged from 6.00 to 8.00, with an average of 7.10, representing neutral to slightly alkaline. Average, minimum and maximum values of electrical conductivity (EC) were 0.17ms/cm, 0.014 and 1.272 ms/cm, respectively. The Pb in plant leaves ranged from below detective level (BDL) to 28 mg/kg, while BDL to 31.4 mg/kg in shoots (Table 2). The mean values of Pb in both leaves and shoots exceeded the permissible limit (2 mg/kg) recommended by the World Health Organization (WHO, 1996). In soil samples, Pb ranged from 4.33 to 224.4 mg/kg and the mean value was 66.22 mg/kg (Table 3). According to the permissible limit in the Dutch (85 mg/kg, Iqbal et al., 2011), Pb in plant parts (leaves and shoots) and soil samples were extremely high and well above the corresponding permissible limits. The high concentration of Pb in the environment might be due to the anthropogenic

activities, such as fuel combustion, heavy traffic vehicular emission on the roads and as well small scale mining of chromite (mafic and ultramafic rocks near, Pb/Zn sulfide terrain) in study areas.

Table 2
Trace metals (Pb, Cd) concentration in plants leaves and stem

Heavy Metal	Min	Max	Mean	Std. Deviation	Skewness	WHO standards*
Pb _L	BD	28	4.43	5.50	1.80	2.00
Pb _S	BD	31.4	4.37	5.84	2.53	2.00
Cd _L	0.16	10	3.28	2.71	0.90	0.02
Cd _S	0.10	14	3.16	2.75	1.58	0.02
*Source: WHO (1996)						

Table 2 summarizes the Cadmium (Cd) concentrations in plant leaves and shoots, ranging from 0.16 to 10.00 mg/kg and 0.10 to 14.00 mg/kg, respectively (Table 2). Compared to the recommended permissible limit (0.02 mg/kg, WHO, 1996), the Cd in all plant species and their difference sections exceeded the permissible limit. The Cd in soils varied from 0.50 to 29.00 mg/kg with a mean value of 7.26 mg/kg (Table 3). In the study area, 90% of the soil samples were higher than the permissible limit according to the Dutch standard (0.8 mg/kg, Iqbal et al., 2011).

Table 3
Physicochemical characteristic of soil samples

Parameter	Min	Max	Mean	Std. Deviation	Skewness	Dutch standard*
Pb	4.33	224.4	66.62	54.72	2.02	85.00
Cd	0.5	29	7.26	6.06	2.24	0.80
ph	6	8	7.12	0.50	-0.1716	-
ec	0.014	1.272	0.17	0.24	3.23	-
*Source: (Iqbal et al., 2011)						

3.2. Bioaccumulation factor (BAF) and translocation factor (TF)

The Fig. 2 represents the plant accumulation ability for heavy metals from polluted soils using the BAF. This indicates the bioavailability of heavy metals from soil to plants (Alloway et al., 1988). Generally, the plants with $BAF_{shoots} < 1$ are excluders, otherwise are accumulators (Baker, 1981). Additionally, if the BAF_{shoots} values exceeds 10, those plants are classified as potential hyperaccumulators (Ma et al., 2001). Among the toxic heavy metals the values are also different from one another due to their bioavailability factor and plants physiology (Soltani et al., 2017). In this work, all the plant species showed BAF_{shoots} value < 1 except for *Debregeasia Saeneb* (1.10) for Pb and *Dodonaea Viscosa* (1.85), *Crysopoge Gryllus* (1.08), *Debregeasia Saeneb* (1.50), *Festuca Hartmanii* (1.78) and *Plantanus Aorientalis* (1.20) for Cd, indicating that *Debregeasia Saeneb* can be considered as accumulator for Pb, and *Dodonaea Viscosa*, *Crysopoge Gryllus*, *Debregeasia Saeneb*, *Festuca Hartmanii* and *Plantanus Aorientalis* for Cd respectively as shown in (Fig. 2). The BAF_{shoots} values for Pb were found in order of *Eucalyptus Camaldulensis* $>$ *Crysopoge Gryllus* $>$ *Jasminum Grandiflorum* $>$ *Mallatus Philippines* $>$ *Melia Azedarach* $>$ *Cannabis Sativa* $>$ *Broussonetia Papyrifera* $>$ *Mentha Longifolis* $>$ *Querus Baloot* $>$ *Morus Alba* $>$ *Populus Nigra* $>$ *Rumex Hastatus* $>$ *Quercus Dilatata* $>$ *Artemisia Scoparia* $>$ *Dalbergia Sissoo* $>$ *Festuca Hartmanii* $>$ *Ficus Palmate* $>$ *Ailanthus Altissima* $>$ *Celtis Australis* $>$ *Grevis Tenax* $>$ *Robinia Pseudoacacia* $>$ *Eucalyptus Lanceolatus* $>$ *Plantanus Aorientalis* $>$ *Dodonaea Viscosa* $>$ *Justicia Adhatoda* $>$ *Morus Nigra* $>$ *Debregea Siasaeneb*. Moreover, The BAF_{shoot} values for Cd were in order of *Quercus Dilatata* $>$ *Celtis Australis* $>$ *Grevis Tenax* $>$ *Morus Nigra* $>$ *Justicia Adhatoda* $>$ *Melia Azedarach* $>$ *Querus Baloot* $>$ *Dalbergia Sissoo* $>$ *Broussonetia Papyrifera* $>$ *Mentha Longifolis* $>$ *Rumex Hastatus* $>$ *Morus Alba* $>$ *Eucalyptus Camaldulensis* $>$ *Mallatus Philippines* $>$ *Eucalyptus Lanceolatus* $>$ *Robinia Pseudoacacia* $>$ *Ficus Palmate* $>$ *Cannabis Sativa* $>$ *Jasminum Grandiflorum* $>$ *Ailanthus Altissima* $>$ *Populus Nigra* $>$ *Artemisia Scoparia* $>$ *Crysopoge Gryllus* $>$ *Plantanus Aorientalis* $>$ *Debregea Siasaeneb* $>$ *Festuca Hartmanii* $>$ *Dodonaea Viscosa* respectively as shown in Fig. 2.

For the TF values, the ratio of metal in shoots to leaves serves as an indicator for metal transport inside the plants parts. Plants with TF values > 1 are classified as hyper accumulator plants for metal translocation from roots to leaves (Ma et al., 2001). The results showed that TF value for Pb in 11 plants species were less than 1 and 16 plants species showed greater than 1 (Fig. 3). The Pb concentrations in plant species followed the order: *Melia Azedarach* $>$ *Mentha Longifolis* $>$ *Debregeasia Saeneb* $>$ *Morus Alba* $>$ *Querus Baloot* $>$ *Jasminum Grandiflorum* $>$ *Cannabis Sativa* $>$ *Plantanus Aorientalis* $>$ *Ailanthus Altissima* $>$ *Robinia Pseudoacacia* $>$ *Artemisia Scoparia* $>$ *Populus Nigra* $>$ *Justicia Adhatoda* $>$ *Quercus Dilatata* $>$ *Celtis Australis* $>$ *Grevis Tenax* $>$ *Morus Nigra* $>$ *Broussonetia Papyrifera* $>$ *Eucalyptus Lanceolatus* $>$ *Festuca Hartmanii* $>$ *Dalbergia Sissoo* $>$ *Mallatus Philippines* $>$ *Ficus Palmate* $>$ *Eucalyptus Camaldulensis* $>$ *Dodonaea Viscosa* $>$ *Rumex Hastatus*. Furthermore the results shows that TF for Cd in 8

plants species was below 1 and for the remaining plants species was > 1. The Cd levels in the plant species were found in order of *Rumex Hastatus* > *Crysopoge Gryllus* > *Querus Baloot* > *Jasminum Grandiflorum* > *Mallatus Philippines* > *Plantanus Aorientalis* > *Artemisia Scoparia* > *Justicia Adhatoda* > *Morus Nigra* > *Melia Azedarach* > *Debregeasia Saeneb* > *Festuca Hartmanii* > *Broussonetia Papyrifera* > *Cannabis Sativa* > *Robinia Pseudoacacia* > *Dalbergia Sissoo* > *Celtis Australis* > *Grevis Tenax* > *Mentha Longifolis* > *Ailanthus Altissima* > *Eucalyptus Lanceolatus* > *Eucalyptus Camaldulensis* > *Ficus Palmate* > *Populus Nigra* > *Dodonaea Viscosa* > *Morus Alba* > *Quercus Dilatata*.

Those plant species with TF greater than 1 may imply strong transfer capability. In the present study, 59.27% plant species showed values of above than 1 for Pb and 70.37% for Cd. Further supporting that for Pb (*Artemisia scoparia*, *Populus nigra*, *Justicia adhatoda*, *Quercus dilatata*, *Celtis australis*, *Grevis tenax*, *Morus nigra*, *Broussonetia papyrifera*, *Eucalyptus lanceolatus*, *Festuca hartmanii*, *Dalbergia sissoo*, *Mallatus Philippines*, *Ficus palmate*, *Eucalyptus camaldulensis*, *Dodonaea viscosa*, *Rumex hastatus*) and for Cd (*Morus nigra*, *Melia azedarach*, *Debregeasia saeneb*, *Festuca hartmanii*, *Broussonetia papyrifera*, *Cannabis sativa*, *Robinia pseudoacacia*, *Dalbergia sissoo*, *Celtis australis*, *Grevis tenax*, *Mentha longifolis*, *Ailanthus altissima*, *Eucalyptus lanceolatus*, *Eucalyptus camaldulensis*, *Ficus palmate*, *Populus nigra*, *Dodonaea viscosa*, *Morus alba*, *Quercus dilatata*) these plants are accumulator species and *Morus nigra* is super-enriched plant and can be used for phytoremediation purposes in the study area. Li et al (2013) stated that phytoremediation efficiency of *Phyllostachys pubescens* was highest for soil Cd level of (5 mg/kg). The maximum Cd in soil is 120 mg/kg in which *Phyllostachys pubescens* can show growth.

3.3. Human health risk assessment

Due to environmental exposure, there are many pathways through which chemicals and pollutants can enter into the human body. Heavy metals can be absorbed, inhaled, or ingested (Wu et al., 2018). In this study, the core three exposure pathways for the metal intake increased in order of ingestion > dermal contact > inhalation (Table 4). The result was similar as compared to previous studies that ingestion was the main exposure pathway for most heavy metals (Egorova and Ananikov, 2017; Chabukdhara and Nema, 2013; Wei et al., 2015). However, Mugosa et al. (2015) found that dermal exposure is the most important pathway for As, Cd, Cu, and Ni. In the current study, the calculated results of ingestion, inhalation and dermal of Pb for adults ranged from 1.75E-04 to 3.05E-06 mg/kg, 2.57E-08 to 4.49E-10 mg/kg and 2.63E-07 to 4.58E-09 mg/kg, respectively. For children, they were 1.63E-03 to 2.85E-05 mg/kg, 4.56E-08 to 7.95E-10 mg/kg and 1.88E-06 to 3.27E-08 mg/kg, respectively. The Cd for adults from ingestion, inhalation and dermal ranged from 2.04E-05 to 3.52E-07 mg/kg, 3.00E-09 to 5.18E-11 mg/kg and 3.07E-08 to 5.29E-10 mg/kg, and for children (1.91E-04 to 3.29E-06 mg/kg), (5.33E-09 to 9.19E-11 mg/kg) and (2.19E-07 to 3.78E-09 mg/kg) respectively. The site where the Pb shows highest for all three pathways and for both children and adults is near Thakoot, where the vehicular emission is more frequent and as well as small scale mining of Pb/Zn sulfide. The Cd for ingestion route shows that the highest value for adults and children in Bisham, and for inhalation and dermal pathways Shang is pointed the highest value. In these two sites, the vehicular activity is also more frequent as well near to small scale mining of Pb/Zn sulfide. According to Li et al. (2001), vehicular sources including exhaust and wearing of component parts (tires, brake pads, and oil lubricants) could be the reason for elevated Cd, Cu, Pb, and Zn in the environment.

Table 4
Average dietary intake for two population due to environmental exposure to soil Pb and Cd along Karakuram highway.

Soil Samples	Children Pb ADD _{ing}	ADD _{inh}	AD _{Dermal}	Cd ADD _{ing}	ADD _{inh}	ADD _{dermal}	Adults Pb ADD _{ing}	ADD _{inh}	ADD _{dermal}	Cd ADD _{ing}	ADD _{inh}	ADD _{dermal}
S ₁	3.13E-04	8.74E-09	3.60E-07	1.64E-05	4.59E-10	1.89E-08	3.35E-05	4.93E-09	5.04E-08	1.76E-06	2.59E-10	2.64E-09
S ₂	2.71E-04	7.57E-09	3.12E-07	5.26E-05	1.47E-09	6.05E-08	2.90E-05	4.27E-09	4.36E-08	5.64E-06	8.29E-10	8.46E-09
S ₃	2.85E-05	7.95E-10	3.27E-08	3.16E-05	8.82E-10	3.63E-08	3.05E-06	4.49E-10	4.58E-09	3.38E-06	4.97E-10	5.08E-09
S ₄	6.31E-04	1.76E-08	7.26E-07	3.29E-05	9.19E-10	3.78E-08	6.76E-05	9.95E-09	1.02E-07	3.52E-06	5.18E-10	5.29E-09
S ₅	2.10E-04	5.86E-09	2.41E-07	3.22E-05	9.00E-10	3.71E-08	2.25E-05	3.30E-09	3.37E-08	3.45E-06	5.08E-10	5.18E-09
S ₆	3.02E-04	8.45E-09	3.48E-07	2.70E-05	7.53E-10	3.10E-08	3.24E-05	4.77E-09	4.87E-08	2.89E-06	4.25E-10	4.34E-09
S ₇	2.33E-04	6.52E-09	2.68E-07	3.75E-05	1.05E-09	4.31E-08	2.50E-05	3.68E-09	3.76E-08	4.02E-06	5.91E-10	6.03E-09
S ₈	2.68E-04	7.49E-09	3.09E-07	3.95E-05	1.10E-09	4.54E-08	2.87E-05	4.23E-09	4.32E-08	4.23E-06	6.22E-10	6.35E-09
S ₉	2.94E-04	8.21E-09	3.38E-07	4.54E-05	1.27E-09	5.22E-08	3.15E-05	4.63E-09	4.73E-08	4.86E-06	7.15E-10	7.30E-09
S ₁₀	1.30E-04	3.62E-09	1.49E-07	8.55E-06	2.39E-10	9.83E-09	1.39E-05	2.04E-09	2.08E-08	9.16E-07	1.35E-10	1.38E-09
S ₁₁	2.95E-04	8.23E-09	3.39E-07	2.96E-05	8.27E-10	3.40E-08	3.15E-05	4.64E-09	4.74E-08	3.17E-06	4.66E-10	4.76E-09
S ₁₂	9.23E-04	2.58E-08	1.06E-06	4.47E-05	1.25E-09	5.14E-08	9.88E-05	1.45E-08	1.48E-07	4.79E-06	7.04E-10	7.19E-09
S ₁₃	3.04E-04	8.49E-09	3.49E-07	3.29E-05	9.19E-10	3.78E-08	3.25E-05	4.79E-09	4.89E-08	3.52E-06	5.18E-10	5.29E-09
S ₁₄	2.49E-04	6.94E-09	2.86E-07	8.55E-06	2.39E-10	9.83E-09	2.66E-05	3.92E-09	4.00E-08	9.16E-07	1.35E-10	1.38E-09
S ₁₅	2.48E-04	6.93E-09	2.85E-07	5.13E-05	1.43E-09	5.90E-08	2.65E-05	3.91E-09	3.99E-08	5.50E-06	8.08E-10	8.25E-09
S ₁₆	7.36E-04	2.06E-08	8.47E-07	3.68E-05	1.03E-09	4.23E-08	7.88E-05	1.16E-08	1.18E-07	3.95E-06	5.80E-10	5.92E-09
S ₁₇	3.83E-04	1.07E-08	4.41E-07	5.26E-05	1.47E-09	6.05E-08	4.10E-05	6.04E-09	6.17E-08	5.64E-06	8.29E-10	8.46E-09
S ₁₈	2.16E-04	6.03E-09	2.48E-07	1.18E-04	3.31E-09	1.36E-07	2.31E-05	3.40E-09	3.47E-08	1.27E-05	1.86E-09	1.90E-08
S ₁₉	2.52E-04	7.05E-09	2.90E-07	2.96E-05	8.27E-10	3.40E-08	2.70E-05	3.98E-09	4.06E-08	3.17E-06	4.66E-10	4.76E-09
S ₂₀	2.12E-04	5.92E-09	2.43E-07	1.32E-05	3.67E-10	1.51E-08	2.27E-05	3.34E-09	3.41E-08	1.41E-06	2.07E-10	2.12E-09
S ₂₁	9.34E-04	2.61E-08	1.07E-06	5.26E-05	1.47E-09	6.05E-08	1.00E-04	1.47E-08	1.50E-07	5.64E-06	8.29E-10	8.46E-09
S ₂₂	2.38E-04	6.65E-09	2.74E-07	1.58E-04	4.41E-09	1.81E-07	2.55E-05	3.75E-09	3.83E-08	1.69E-05	2.49E-09	2.54E-08
S ₂₃	2.83E-04	7.90E-09	3.25E-07	5.72E-05	1.60E-09	6.58E-08	3.03E-05	4.45E-09	4.55E-08	6.13E-06	9.01E-10	9.20E-09
S ₂₄	8.71E-04	2.43E-08	1.00E-06	2.70E-05	7.53E-10	3.10E-08	9.33E-05	1.37E-08	1.40E-07	2.89E-06	4.25E-10	4.34E-09

Soil Samples	Children Pb ADD _{ing}	ADD _{inh}	AD _{Dermal}	Cd ADD _{ing}	ADD _{inh}	ADD _{dermal}	Adults Pb ADD _{ing}	ADD _{inh}	ADD _{dermaal}	Cd ADD _{ing}	ADD _{inh}	ADD _{deral}
S ₂₅	2.50E-04	6.98E-09	2.87E-07	3.29E-06	9.19E-11	3.78E-09	2.68E-05	3.94E-09	4.02E-08	3.52E-07	5.18E-11	5.29E-10
S ₂₆	4.15E-04	1.16E-08	4.77E-07	1.84E-05	5.14E-10	2.12E-08	4.44E-05	6.54E-09	6.67E-08	1.97E-06	2.90E-10	2.96E-09
S ₂₇	3.31E-04	9.24E-09	3.80E-07	3.02E-05	8.45E-10	3.48E-08	3.54E-05	5.21E-09	5.32E-08	3.24E-06	4.77E-10	4.87E-09
S ₂₈	9.12E-04	2.55E-08	1.05E-06	1.91E-05	5.33E-10	2.19E-08	9.76E-05	1.44E-08	1.47E-07	2.04E-06	3.00E-10	3.07E-09
S ₂₉	3.11E-04	8.69E-09	3.58E-07	5.85E-05	1.63E-09	6.73E-08	3.33E-05	4.90E-09	5.00E-08	6.27E-06	9.22E-10	9.41E-09
S ₃₀	2.11E-04	5.90E-09	2.43E-07	1.91E-04	5.33E-09	2.19E-07	2.26E-05	3.33E-09	3.40E-08	2.04E-05	3.00E-09	3.07E-08
S ₃₁	2.35E-04	6.58E-09	2.71E-07	5.92E-05	1.65E-09	6.81E-08	2.52E-05	3.71E-09	3.79E-08	6.34E-06	9.32E-10	9.52E-09
S ₃₂	2.95E-04	8.25E-09	3.40E-07	3.22E-05	9.00E-10	3.71E-08	3.16E-05	4.65E-09	4.75E-08	3.45E-06	5.08E-10	5.18E-09
S ₃₃	7.02E-04	1.96E-08	8.08E-07	3.55E-05	9.92E-10	4.08E-08	7.52E-05	1.11E-08	1.13E-07	3.80E-06	5.59E-10	5.71E-09
S ₃₄	1.55E-03	4.32E-08	1.78E-06	4.93E-05	1.38E-09	5.67E-08	1.66E-04	2.44E-08	2.49E-07	5.28E-06	7.77E-10	7.93E-09
S ₃₅	2.55E-04	7.13E-09	2.93E-07	5.19E-05	1.45E-09	5.97E-08	2.73E-05	4.02E-09	4.10E-08	5.57E-06	8.18E-10	8.36E-09
S ₃₆	2.16E-04	6.04E-09	2.49E-07	1.38E-04	3.86E-09	1.59E-07	2.32E-05	3.41E-09	3.48E-08	1.48E-05	2.18E-09	2.22E-08
S ₃₇	1.63E-03	4.56E-08	1.88E-06	5.59E-05	1.56E-09	6.43E-08	1.75E-04	2.57E-08	2.63E-07	5.99E-06	8.81E-10	8.99E-09
S ₃₈	5.10E-04	1.43E-08	5.87E-07	3.55E-05	9.92E-10	4.08E-08	5.46E-05	8.04E-09	8.21E-08	3.80E-06	5.59E-10	5.71E-09

In the present study, Hazard index (HI) for all three exposure routes for both Pb and Cd were less than 1 as shown in Table 5. According to Kong et al. (2011), HI values of < 1 specify no possible adverse health effects. The result revealed that there was no adverse health effects in study area. Moreover, among the calculated HI value of ingestion, inhalation, and dermal exposure pathways for two population (adults and children) ranged from (5.00E-02 to 8.71E-04), (7.31E-06 to 1.27E-07) and (5.00E-04 to 8.72E-06) for adults while, for children ranged from (4.67E-01 to 8.13E-03), (1.30E-05 to 2.26E-07) and (3.58E-03 to 6.24E-05) for Pb respectively. While for Cd ranged from (1.91E-01 to 3.29E-03), (5.33E-06 to 9.19E-08) and (4.93E-03 to 7.56E-05) for children and for adults ranged from (2.04E-02 to 3.52E-04), (3.00E-06 to 5.18E-08) and (6.06E-04 to 1.06 E-06) for ingestion, inhalation and dermal exposure respectively as shown in Table 5. The highest values were observed in Thakoot area for Pb and Shang (Besham) for Cd where the traffic and small industrial activities (Pb/Zn sulfide mining) are found more frequently as compared to the other study area. According to Xia et al. (2011), the probable sources of Pb, Cd, Zn, and Cu are industrial activities, mining, traffic activities domestic waste, street markets, panting and construction activities.

Table 5
Hazard index due to inhalation, dermal and ingestion for Pb and Cd in Adults and children along Karakoram highway.

Soil Samples	Children						Adult					
	Pb	HI _{inh}	HI _{dermal}	Cd	HI _{inh}	HI _{dermal}	Pb	HI _{inh}	HI _{dermal}	Cd	HI _{inh}	HI _{dermal}
	HI _{ing}			HI _{ing}			HI _{ing}			HI _{ing}		
S ₁	8.94E-02	2.48E-06	6.86E-04	1.64E-02	4.59E-07	3.78E-04	9.57E-03	1.40E-06	6.83E + 03	1.76E-03	2.59E-07	5.29E-05
S ₂	7.74E-02	2.15E-06	5.93E-04	5.26E-02	1.47E-06	1.21E-03	8.29E-03	1.21E-06	6.83E + 03	5.64E-03	8.29E-07	1.69E-04
S ₃	8.13E-03	2.26E-07	6.24E-05	3.16E-02	8.82E-07	7.26E-04	8.71E-04	1.27E-07	6.83E + 03	3.38E-03	4.97E-07	1.02E-04
S ₄	1.80E-01	5.01E-06	1.38E-03	3.29E-02	9.19E-07	7.56E-04	1.93E-02	2.83E-06	6.83E + 03	3.52E-03	5.18E-07	1.06E-04
S ₅	5.99E-02	1.66E-06	4.59E-04	3.22E-02	9.00E-07	7.41E-04	6.42E-03	9.39E-07	6.83E + 03	3.45E-03	5.08E-07	1.04E-04
S ₆	8.64E-02	2.40E-06	6.63E-04	2.70E-02	7.53E-07	6.20E-04	9.25E-03	1.35E-06	6.83E + 03	2.89E-03	4.25E-07	8.67E-05
S ₇	6.67E-02	1.85E-06	5.11E-04	3.75E-02	1.05E-06	8.62E-04	7.14E-03	1.04E-06	6.83E + 03	4.02E-03	5.91E-07	1.21E-04
S ₈	7.66E-02	2.13E-06	5.88E-04	3.95E-02	1.10E-06	9.07E-04	8.21E-03	1.20E-06	6.83E + 03	4.23E-03	6.22E-07	1.27E-04
S ₉	8.40E-02	2.33E-06	6.44E-04	4.54E-02	1.27E-06	1.04E-03	8.99E-03	1.32E-06	6.83E + 03	4.86E-03	7.15E-07	1.46E-04
S ₁₀	3.70E-02	1.03E-06	2.84E-04	8.55E-03	2.39E-07	1.97E-04	3.96E-03	5.80E-07	6.83E + 03	9.16E-04	1.35E-07	2.75E-05
S ₁₁	8.42E-02	2.34E-06	6.45E-04	2.96E-02	8.27E-07	6.81E-04	9.01E-03	1.32E-06	6.83E + 03	3.17E-03	4.66E-07	9.52E-05
S ₁₂	2.64E-01	7.32E-06	2.02E-03	4.47E-02	1.25E-06	1.03E-03	2.82E-02	4.13E-06	6.83E + 03	4.79E-03	7.04E-07	1.44E-04
S ₁₃	8.68E-02	2.41E-06	6.65E-04	3.29E-02	9.19E-07	7.56E-04	9.29E-03	1.36E-06	6.83E + 03	3.52E-03	5.18E-07	1.06E-04
S ₁₄	7.10E-02	1.97E-06	5.44E-04	8.55E-03	2.39E-07	1.97E-04	7.60E-03	1.11E-06	6.83E + 03	9.16E-04	1.35E-07	2.75E-05
S ₁₅	7.08E-02	1.97E-06	5.43E-04	5.13E-02	1.43E-06	1.18E-03	7.58E-03	1.11E-06	6.83E + 03	5.50E-03	8.08E-07	1.65E-04
S ₁₆	2.10E-01	5.85E-06	1.61E-03	3.68E-02	1.03E-06	8.47E-04	2.25E-02	3.30E-06	6.83E + 03	3.95E-03	5.80E-07	1.18E-04
S ₁₇	1.10E-01	3.04E-06	8.40E-04	5.26E-02	1.47E-06	1.21E-03	1.17E-02	1.72E-06	6.83E + 03	5.64E-03	8.29E-07	1.69E-04
S ₁₈	6.16E-02	1.71E-06	4.72E-04	1.18E-01	3.31E-06	2.72E-03	6.60E-03	9.65E-07	6.83E + 03	1.27E-02	1.86E-06	3.81E-04
S ₁₉	7.21E-02	2.00E-06	5.53E-04	2.96E-02	8.27E-07	6.81E-04	7.72E-03	1.13E-06	6.83E + 03	3.17E-03	4.66E-07	9.52E-05
S ₂₀	6.05E-02	1.68E-06	4.64E-04	1.32E-02	3.67E-07	3.02E-04	6.48E-03	9.48E-07	6.83E + 03	1.41E-03	2.07E-07	4.23E-05
S ₂₁	2.67E-01	7.41E-06	2.05E-03	5.26E-02	1.47E-06	1.21E-03	2.86E-02	4.18E-06	6.83E + 03	5.64E-03	8.29E-07	1.69E-04
S ₂₂	6.80E-02	1.89E-06	5.21E-04	1.58E-01	4.41E-06	3.63E-03	7.28E-03	1.07E-06	6.83E + 03	1.69E-02	2.49E-06	5.08E-04
S ₂₃	8.08E-02	2.24E-06	6.19E-04	5.72E-02	1.60E-06	1.32E-03	8.65E-03	1.27E-06	6.83E + 03	6.13E-03	9.01E-07	1.84E-04
S ₂₄	2.49E-01	6.91E-06	1.91E-03	2.70E-02	7.53E-07	6.20E-04	2.67E-02	3.90E-06	6.83E + 03	2.89E-03	4.25E-07	8.67E-05

	Children						Adult					
S ₂₅	7.14E-02	1.98E-06	5.47E-04	3.29E-03	9.19E-08	7.56E-05	7.64E-03	1.12E-06	6.83E + 03	3.52E-04	5.18E-08	1.06E-05
S ₂₆	1.19E-01	3.29E-06	9.09E-04	1.84E-02	5.14E-07	4.23E-04	1.27E-02	1.86E-06	6.83E + 03	1.97E-03	2.90E-07	5.92E-05
S ₂₇	9.45E-02	2.63E-06	7.24E-04	3.02E-02	8.45E-07	6.96E-04	1.01E-02	1.48E-06	6.83E + 03	3.24E-03	4.77E-07	9.73E-05
S ₂₈	2.61E-01	7.24E-06	2.00E-03	1.91E-02	5.33E-07	4.39E-04	2.79E-02	4.08E-06	6.83E + 03	2.04E-03	3.00E-07	6.14E-05
S ₂₉	8.89E-02	2.47E-06	6.81E-04	5.85E-02	1.63E-06	1.35E-03	9.51E-03	1.39E-06	6.83E + 03	6.27E-03	9.22E-07	1.88E-04
S ₃₀	6.03E-02	1.68E-06	4.62E-04	1.91E-01	5.33E-06	4.39E-03	6.46E-03	9.45E-07	6.83E + 03	2.04E-02	3.00E-06	6.14E-04
S ₃₁	6.73E-02	1.87E-06	5.16E-04	5.92E-02	1.65E-06	1.36E-03	7.20E-03	1.05E-06	6.83E + 03	6.34E-03	9.32E-07	1.90E-04
S ₃₂	8.44E-02	2.34E-06	6.47E-04	3.22E-02	9.00E-07	7.41E-04	9.03E-03	1.32E-06	6.83E + 03	3.45E-03	5.08E-07	1.04E-04
S ₃₃	2.01E-01	5.57E-06	1.54E-03	3.55E-02	9.92E-07	8.17E-04	2.15E-02	3.14E-06	6.83E + 03	3.80E-03	5.59E-07	1.14E-04
S ₃₄	4.42E-01	1.23E-05	3.39E-03	4.93E-02	1.38E-06	1.13E-03	4.73E-02	6.92E-06	6.83E + 03	5.28E-03	7.77E-07	1.59E-04
S ₃₅	7.29E-02	2.02E-06	5.59E-04	5.19E-02	1.45E-06	1.19E-03	7.80E-03	1.14E-06	6.83E + 03	5.57E-03	8.18E-07	1.67E-04
S ₃₆	6.18E-02	1.72E-06	4.74E-04	1.38E-01	3.86E-06	3.18E-03	6.62E-03	9.68E-07	6.83E + 03	1.48E-02	2.18E-06	4.44E-04
S ₃₇	4.67E-01	1.30E-05	3.58E-03	5.59E-02	1.56E-06	1.29E-03	5.00E-02	7.31E-06	6.83E + 03	5.99E-03	8.81E-07	1.80E-04
S ₃₈	1.46E-01	4.05E-06	1.12E-03	3.55E-02	9.92E-07	8.17E-04	1.56E-02	2.28E-06	6.83E + 03	3.80E-03	5.59E-07	1.14E-04

4. Conclusions

The results of the present study revealed that Pb and Cd are the main metal pollution factors in the soil along the roadside of the Karakorum Highway. The overall mean concentrations of heavy metal in roadside soil along Karakorum Highway (KKH) were 66.62 mg/kg and 7.26 mg/kg for Pb and Cd, respectively. Also, elevated Pb and Cd concentrations were found in the plant leaves and shoots. The overall mean Pb in plant leaves and shoots were 4.43 mg/kg and 4.37 mg/kg and overall mean Cd in plants leaves and shoots was 3.28 mg/kg and 3.16 mg/kg respectively. Cd and Pb are the main pollutants of traffic pollution indicated by the United States Environmental Protection Agency (US EPA) and as well as released during mining and smelting process. According to the human health risk assessment of the present study, no adverse effects on human health was observed near roadside in the study area. The results showed that some of the plant species grown on roadside showed good bioaccumulation factor and translocation factor and can be used for phytoremediation .

Declarations

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Author Contributions

Dr. Javid Nawab and Dr. Sana Ullah conceived and designed the experiments and organized the manuscript. Hameed Ullah, Auran Zeb and Khush Bakht performed the main experiments and wrote the draft. Dr. Javid Nwad and Yanqing Sheng revised the manuscript. Muhammad Tayyeb helped in making the location map. All authors have given approval to the final version of the manuscript.

Data Availability

Data available is available upon a reasonable request from the correspond authors.

Conflict of interest

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Figures

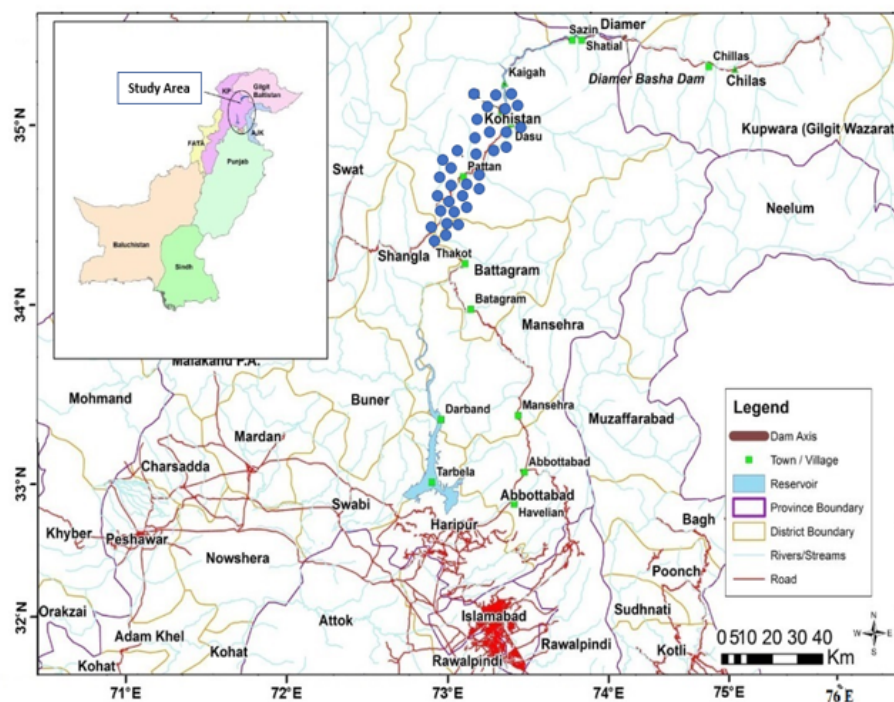


Figure 1

Location map of the study area showing the sampling points

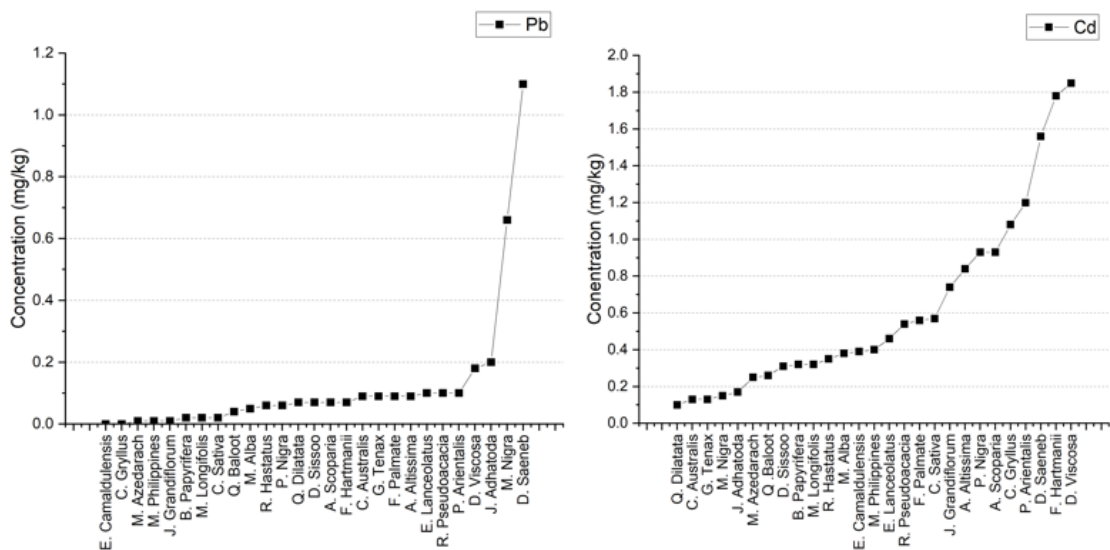


Figure 2

Bioaccumulation factor (BAF) value of Pb and Cd in different plants species in the study area.

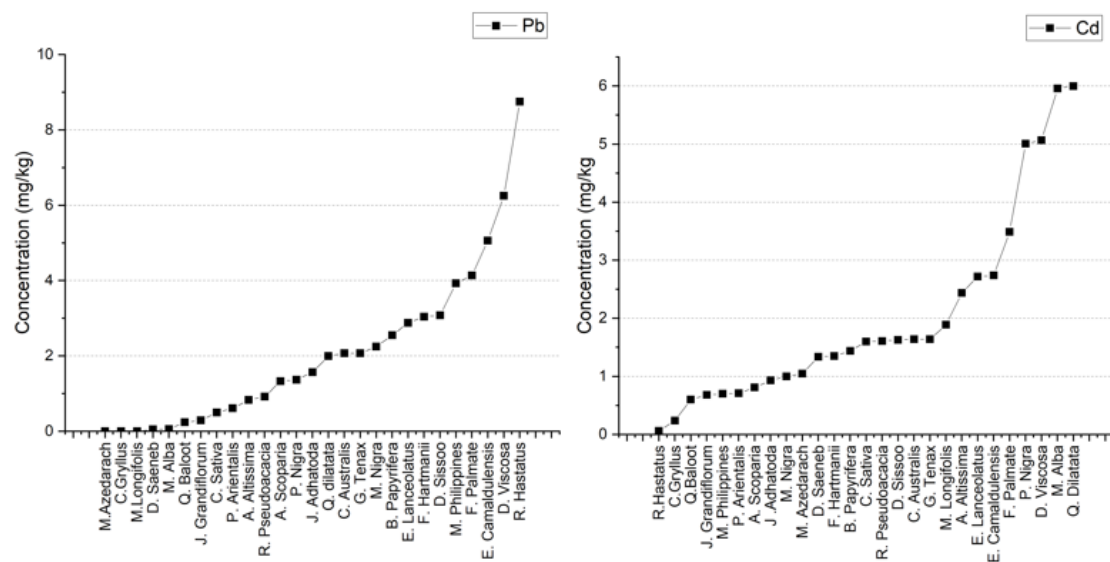


Figure 3

Translocation factor of Pb and Cd in different plants species in the study area.