International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133; Print ISSN: 2664-7125; Impact Factor: RJIF 5.28
Received: 14-10-2020; Accepted: 29-10-2020; Published: 19-11-2020
Volume 2; Issue 4; 2020; Page No. 400-408

Heavy metal phytoextraction ability of plants growing in metal contaminated industrial area Soil

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Abstract
Rapid industrialization and population explosion have resulted in contaminating the environment in many ways. Heavy metal contamination from industries has raised the threat to the nearby residents by polluting soil and groundwater. Phytoremediation has emerged as an eco-friendly, long-lasting, durable, and financially practical procedure for the remediation and reclamation of overwhelming metal polluted land. The present study was undertaken to assess the accumulation of four heavy metals (Cr, Cu, Ni and Pb) in twenty naturally growing plant species *viz. Abutilon indicum, Alternanthera sessilis, Achyranthes aspera, Cassia tora, Cassia occidentalis, Calotropis procera, Chinopodium ambroisoides, Croton bonplandianum, Cynadon dactylon, Cyperus rotundus, Eclipta alba, Erigeron bonariensis, Euphorbia hirta, Lantana indica, Parthenium hysterophorus, Sida cordifolia, Solanum nigrum, Tridax procumbens, Urena lobata* and *Xanthium strumarium* in an industrial area of Uttarakhand, India. The results revealed that the heavy metal accumulation was heterogeneous among the different plant species and plant parts. Average shoot metal concentration in plants were Cr = 38.32, Cu = 33.69, Pb = 27.26, and Ni =20.27 µg g^{-1} dry wt. and the corresponding root metal concentration were Cr = 36.93, Cu = 24.25, Pb = 28.38, and Ni = 23.77 µg g^{-1} dry wt. The TF ranged between 0.30 ± 0.02 (*C. rotundus*) to 7.25 ± 0.02 (*P. hysterophorus*) for chromium; 0.37 ± 0.05 (*T. Procumbens*) to 9.26 ± 0.26 (*U. lobata*) for copper; 0.23 ± 0.01 (*C. rotundus*) to 11.46 ± 0.31 (*P. hysterophorus*) for lead and 0.51 ± 0.04 (*T. Procumbens*) to 7.18 ± 0.06 (*U. lobata*) for nickel. Ten out of twenty plant species showed translocation factor> 1for all the four studied metals suggesting their potential for the remediation of multi-metal contaminated soil.

Keywords: industrial area; heavy metal contamination; naturally occurring plants; metal accumulation; phytoremediation

Introduction

Various anthropogenic activities such as rapid urbanization, industrialization, indiscriminate disposal of industrial wastes, and haphazard utilization of agrochemicals are among the major reasons for soil pollution in India (Hasan 2011 [29]; Saha *et al*, 2017) [53]. Heavy metal content in soil is of major significance in relation to its fertility and nutrient status as some heavy metals are essential for growth of plants, whereas these become toxic in high concentration. Some heavy metals are not essential for plant and are toxic at high concentration but a low concentration of these can be tolerated (Alloway and Ayres 1997 [2]; Chibuike and Obiora 2014) [13]. Heavy metal toxicity in the environment is of significant concern since they do not degrade and are persistent in the environment (NRC 1999 [42]; Ali *et al* 2019) [5].

The heavy metal contamination in the environment due to industrial wastewater discharge in soil and water represents a potential threat not only to resources but to the living beings also (Gokhale *et al*. 2008; Ali *et al*, 2019) [23, 5]. Industries do not follow proper waste management practices therefore continuously adding organic and inorganic wastes in ecosystems (Kumar *et al.* 2013) [34]. The impact of industrialization on heavy metal content in soil was extensively studied in last decades worldwide (Tume *et al*. 2007 [68]; Suciu *et al*. 2008 [63]; Sayad and Sayadi 2011 [54]; Slavik *et al*. 2012 [61]; Hu *et al*. 2013; Etim and Onianwa 2013 [19]; Tariq *et al.* 2013 [67]; Gabarron *et al*. 2017, Sung and Park 2018 [65], Zwolak *et al*, 2019). In India, heavy metal contamination in the industrial area has been reported previously (Krishna and Govil 2007 [34]; Govil *et al*. 2008 [24]; Gowd *et al*. 2010 [25]; Parth *et al.* 2011 [47]; Chabukdhara and Nema 2012 [12]; Puroshoatam *et al*. 2012).

Phytoremediation is emerging technique, that is environment-friendly, long lasting and economically feasible (Dhir and Srivastava 2011 [17]; Bauddh and Singh 2012a, b [35, 36]; Kumar *et al*. 2012 [35]; Stingu *et al*. 2012 [62]; Singh *et al*, 2017 [60]; Futughe *et al*, 2020) [21]. Some plants known as hyperaccumulators are best for phytoremediation purpose due to their unique ability to uptake large amounts of heavy metals from the soil. Hyperaccumulators translocates heavy metal into their shoots via xylem and several classes of proteins (Singh *et al*. 2016) [58]. The overall process of heavy metal uptake, their translocation, sequestration, and detoxification is the key to their survival under metal contaminated soil. The sequestration and detoxification process takes place in the vacuole of plants (Kanoun-Boule *et al*. 2009; Singh *et al.* 2011) [57]. The uptake and accumulation of pollutants in a plant vary from species to species within a genus (Pandey *et al*. 2009 [46]; Ojuederie and Babalola, 2017) [44]. Till date, many researchers have worked on phytoremediation of heavy metals using edible species (Zadeh *et al*. 2008 [71]; Salaskar *et al.* 2011 [55]; Shevyakova *et al.* 2011) [56]. According to a Scopus based survey of the literature (1995−2009), in order to take a census of crop species involved in phytoremediation research of heavy metals throughout the world. It was analyzed that the most cited crop for phytoremediation was *B. juncea* (L.)

an edible oil producing crop with 148 citations, Helianthus annuus (57 citations), B. napus, and Zea mays (both 39 citations) were also placed among other eight studied crops (Vamerali *et al*. 2010). It clearly shows that a little concern is given to weed species for phytoremediation purpose. Use of edible crops for phytoremediation is not suitable as these crops are directly consumed by human beings so may exert direct toxic effects to human beings and animals. There is an urgent need to find a suitable phytoremediation candidate for remediation of heavy metal contaminated soil that is safe, environment friendly and long-lasting. Therefore the present study was framed out to find out heavy metal accumulation in naturally occurring plant species of Bhagwanpur industrial area, Uttarakhand (India) for phytoremediation purpose.

Materials and methods

Study site

The study was conducted in the industrial area of Bhagwanpur, Uttarakhand, India. Twenty native plant species *viz. Abutilon indicum, Alternanthera sessilis, Achyranthes aspera, Cassia tora, Cassia occidentalis, Calotropis procera, Chinopodium ambroisoides, Croton bonplandianum, Cynadon dactylon, Cyperus rotundus, Eclipta alba, Erigeron bonariensis, Euphorbia hirta, Lantana indica, Parthenium hysterophorus, Sida cordifolia, Solanum nigrum, Tridax procumbens, Urena lobata* and *Xanthium strumarium* were collected from the industrial area having industries like cement industry, small scale steel industries, pharmaceutical industries, electronics industry, soap industry, metal and alloy industry, rubber industry etc.

Soil physicochemical characteristics analysis and determination of heavy metals in soil and plant samples

The physic-chemical characteristics of soil samples, collected from the industrial area were analyzed following the standard methods of APHA (2005) against forest soil as a control. CFU count was analyzed to check the impact of contamination on soil microorganisms as per methodology provided by Aneja, 1993. For estimation of heavy metals, 0.2 gm of fine filtered dried soil and fine powder plant extract were digested in a tri-acid solution of HF: HNO_3: HCl (4:3:3, v/v) at 180˚C in CEM Mars 5 Microwave Accelerated Reaction System. The final volume was diluted to 100 ml with double distilled water of Elix Millipore, filtered through Whatman filter paper no 1. The digested samples of soil and plant samples were analyzed for different heavy metals (Mg, Mn, Cr, Pb, Ni and Cu) using Prodigy XP High dispersion Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). All the readings were taken in five replicates (n = 5).

Collection and Preparation of Plants for heavy metal estimation

The plants from different identified locations i.e. vicinity of different industries were collected and then brought to the laboratory. Further the identification was done. Among all the plant species, twenty most frequently occurring plant species *viz. Abutilon indicum, Alternanthera sessilis, Achyranthes aspera, Cassia tora, Cassia occidentalis, Calotropis procera, Chinopodium ambroisoides, Croton bonplandianum, Cynadon dactylon, Cyperus rotundus, Eclipta alba, Erigeron bonariensis, Euphorbia hirta, Lantana indica, Parthenium hysterophorus, Sida cordifolia, Solanum nigrum, Tridax procumbens, Urena lobata* and *Xanthium strumarium* were collected from the industrial area.

The plants were washed with running tap water to remove soil and dust. After that plants were washed with distilled water to remove micro particles and then the plant material was oven dried at 65°C till constant weight.

Fine powdered plant extract was digested and then examined for different heavy metals (Cr, Pb, Ni and Cu) using Prodigy XP High dispersion Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES).

Enrichment coefficient (EC) and translocation factor (TF)

Enrichment coefficient (EC) is the ration of metal content in different plants part (root/shoot) and soil. It is determined to assess the degree of heavy metal accumulation in plants growing on heavy metal contaminated soil (Kisku *et al*. 2000).

$$\text{EC} = \frac{\text{Concentration of metal in roots /shoots}}{\text{Concentration of metal at contaminated site}}$$

The translocation factor (TF) was calculated to study the translocation of metals from the root to shoot of the plant species (Gupta *et al*. 2008) [27].

$$\text{TF} = \frac{\text{Concentration of metal in plant shoots}}{\text{Concentration of metal in corresponding plant roots}}$$

Results and discussion

Physicochemical characteristics and metal concentrations in the soil

The soil samples collected from industrial area were analysed for various physicochemical parameters such as pH, EC, available nitrogen, available phosphorus and exchangeable potassium, organic carbon, organic matter colony forming units (bacteria and fungus) and heavy metal quantification (Cr, Cu, Pb and Ni) (Table 1).

Table 1

Parameteres	Control Soil	Industrial area soil
pH	7.50 ± 0.57	6.07 ± 0.34
EC (mS cm^{-1})	82.56 ± 5.43	161.13 ± 15.85
OC (%)	2.77 ± 0.07	1.09 ± 0.02
OM (%)	4.77 ± 0.39	1.88 ± 0.09
N ($kghec^{-1}$)	187.70 ± 4.12	119.38 ± 3.54
P ($kghec^{-1}$)	27.22 ± 0.97	15.53 ± 1.06
K ($kghec^{-1}$)	63.92 ± 3.22	28.26 ± 1.12
CFU B (10^7)	84.00 ± 9.32	55.33 ± 14.43
CFU F (10^6)	63.67 ± 8.34	44.33 ± 5.84
Cr (mgg^{-1})	0.002 ± 0.000	74.47 ± 2.45
Pb (mgg^{-1})	1.33 ± 0.04	45.35 ± 1.34
Ni (mgg^{-1})	0.91 ± 0.01	46.67 ± 2.15
Cu (mgg^{-1})	11.01 ± 0.43	77.37 ± 4.76

All the values are mean of five replicates ± S.E. *Significant at $p < 0.01$.

All the physicochemical parameters of contaminated soil were found significantly ($p < 0.01$) lower than the respective control except for electrical conductivity.

The physicochemical analysis of soil samples revealed that the pH of industrial area soil was slightly acidic in nature (pH =

6.07±0.34), in comparison to control (pH = 7.5±0.57). The EC of the industrial area soil was found to be 161.13 ±15.85 µScm^{-1}, which is high than that of control (82.56 ±5.43µScm^{-1}).

The contaminated soil was having low amount of organic carbon (1.09 ±0.02 %) and organic matter (1.88 ±0.09%) as compared to control. The available phosphorus (15.53±1.06mg hec^{-1}), available nitrogen (119.38±3.54 mg hec^{-1}) and exchangeable potassium (28.26±1.12 mg hec^{-1}) were also found lower than the respective control (27.22±0.97, 187.77±4.12 and 63.92±3.22 mg hec^{-1}, respectively). The colony forming units of soil were found to be low in industrial area soil i.e. 55.33 ±14.43 X 10^{7} for CFU (B) and 44.33 ±5.84 X 10^{6} for CFU (F) respectively. The heavy metal concentration was also found significantly high in industrial area soil as compare to the control (p<0.01%). The metal concentration in contaminated soil samples were found to be in the order of Cu = 77.37 ±4.76 > Cr = 74.47±2.45 > Ni = 46.67±2.15 > Pb = 45.35±1.34 whereas the respective control values were Cu = 11.01 ±0.43>Pb = 1.330.04±> Ni = 0.91±0.01> Cr = 0.002±0.00µg g^{-1}.

Metal Concentrations in naturally growing Plants of Industrial area

The roots and shoots of different weeds growing in the industrial area were analysed for Ni, Cu, Cr and Pb. The Ni and Cu concentration in shoots were found in the range of 2.02 to 72.31 µg g^{-1} and 3.83–83.62 µg g^{-1}dry wt respectively, while in roots the Ni and Cu ranges from 3.82 to 97.10 µg g^{-1} and 3.69–81.22 µg g^{-1}dry wt respectively. The average concentration of Ni and Cu in aerial parts of the studied plants was found as; Ni= 21.37, Cu = 34.25, µg g^{-1}dry wt whereas, corresponding root concentration of the metals were Ni = 23.83, Cu = 24.03 µg g^{-1}dry wt.

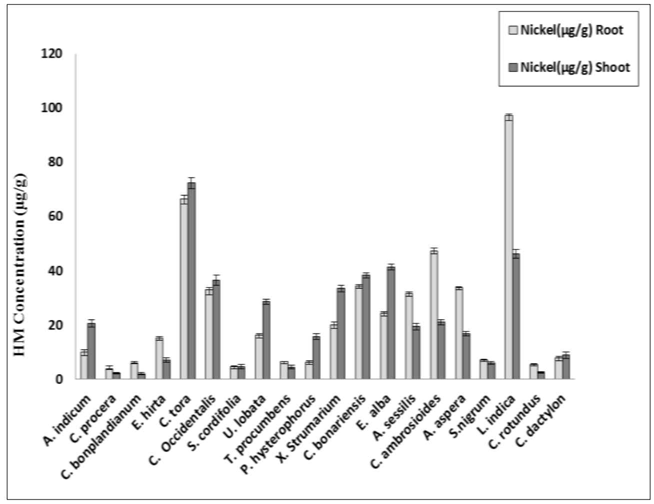

Fig 1: Nickel concentration in roots and shoots of plants of industrial area of Bhagwanpur (Uttarakhand)

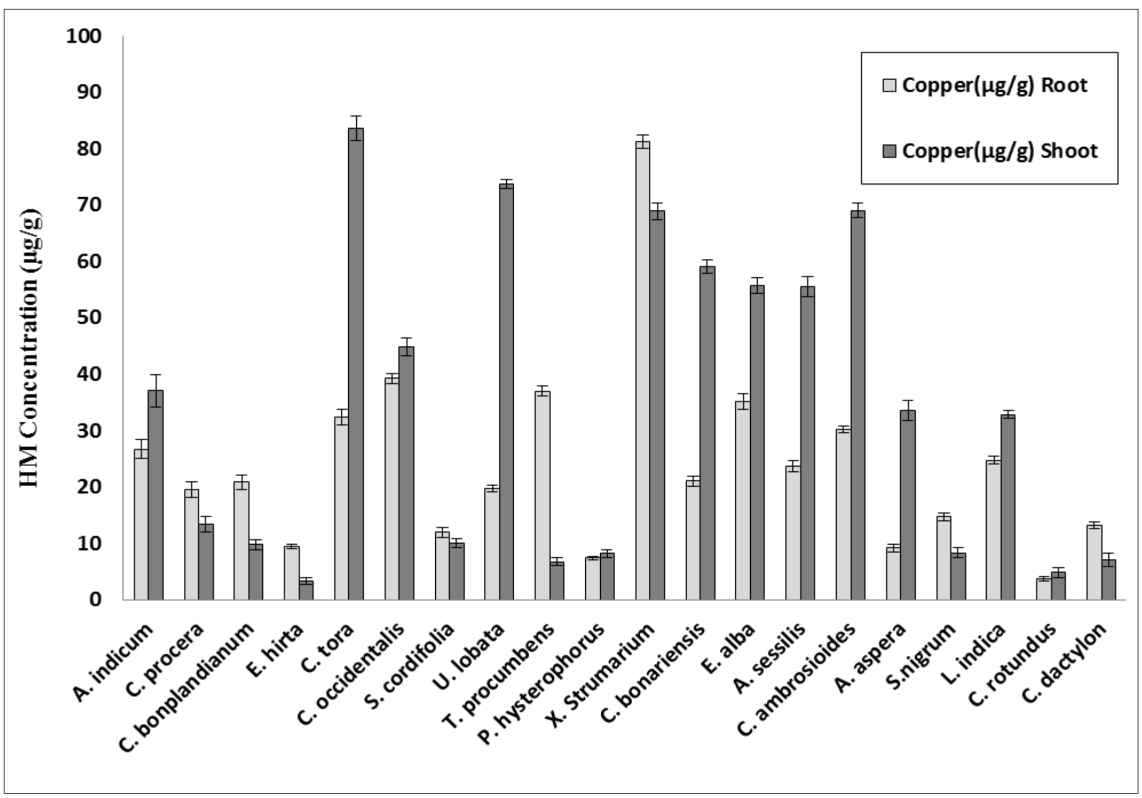

Fig 2: Copper Concentration in roots and shoots of plants of industrial area of Bhagwanpur (Uttarakhand)

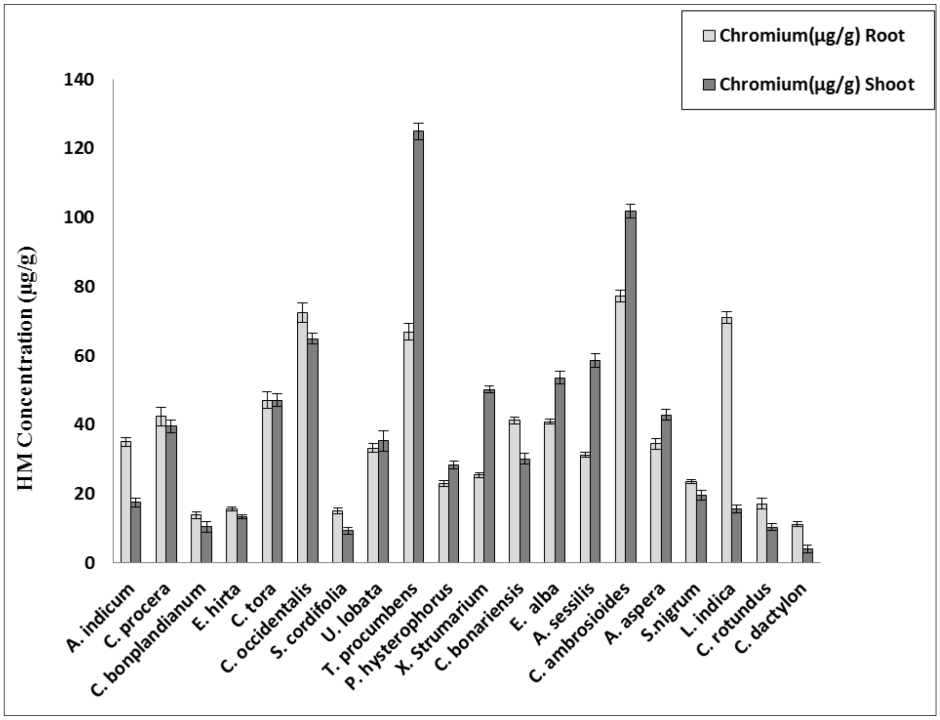

Fig 3: Chromium Concentration in roots and shoots of plants of industrial area of Bhagwanpur (Uttarakhand)

The Cr concentration was found in the range of 11.77–77.29 µg g^{-1}dry wt. in roots with a mean value of 36.86 µg g^{-1}dry wt., and 3.99–125.00 µg g^{-1}dry wt. with a mean value of 38.84 µg g^{-1}dry wt, in aerial Parts of different weeds. Maximum chromium accumulation in roots was found 77.29 µg g^{-1} DW in *C. ambrosioides*, whereas in shoots the maximum accumulation was 125 µg g^{-1} DW in *T. procumbens.*

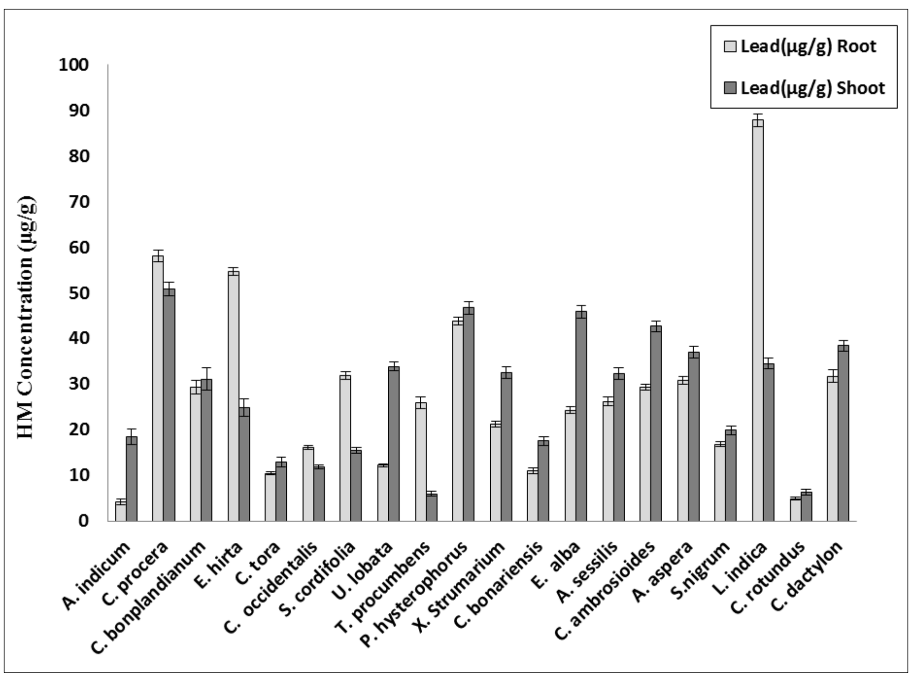

Fig 4: Lead Concentration in roots and shoots of plants of industrial area of Bhagwanpur (Uttarakhand)

Figure: 4. Lead Concentration in roots and shoots of plants of industrial area of Bhagwanpur (Uttarakhand)

The concentration of Pb ranges from 5.98 to 50.83 µg g^{-1}dry wt in shoots with an average value of 27.26 µg g^{-1}dry wt, whereas in roots the. Concentration of Pb varied from 4.21 to 87.83 µg g^{-1}.

Enrichment Coefficient (EC) with respect to roots and shoots

The Enrichment coefficient of different plant species with respect to roots and shoots are shown in Table. 2.

Table 2: Enrichment coefficient with respect to roots (ECR) and shoots (ECS) of the plants collected from the contaminated sites.

Plant	Chromium		Copper		Nickel		Lead	
	EC_R	EC_S	EC_R	EC_S	EC_R	EC_S	EC_R	EC_S
A. indicum	4.58 ± 0.17	2.65 ± 0.23	2.32 ± 0.13	3.48 ± 0.27	0.86 ± 0.08	2.23 ± 0.17	0.36 ± 0.07	1.99 ± 0.22
C. procera	199.67± 4.55	253.05 ± 9.25	83.46±6.19	80.42 ± 8.57	20.20±6.17	15.44±2.79	341.99 ± 7.29	391.12 ±12.20
C. bonplandianum	1.69 ± 0.08	3.64 ± 0.40	1.05± 0.06	1.21 ± 0.12	0.38 ± 0.05	0.36 ± 0.07	1.99 ± 0.09	6.12 ± 0.47
E. hirta	3.63 ± 0.08	6.14 ± 0.13	0.48 ± 0.02	0.47 ± 0.04	0.96 ± 0.07	0.93 ± 0.13	3.91 ± 0.06	3.78 ± 0.29
C. tora	5.50 ± 0.05	9.06 ± 0.26	1.55 ± 0.06	6.37 ± 0.16	4.10 ± 0.08	7.06 ± 0.19	0.65 ± 0.02	1.37 ± 0.10
C. occidentalis	8.40 ± 0.20	19.65 ± 0.42	2.27 ± 0.05	6.82 ± 0.23	2.44 ± 0.07	6.95 ± 0.36	1.26 ± 0.03	2.60 ± 0.11
S. cordifolia	2.75 ± 0.07	3.05 ± 0.11	1.10 ± 0.02	1.64 ± 0.13	0.56 ± 0.02	0.73 ± 0.20	3.91 ± 0.05	3.60 ± 0.18
U. lobata	6.78 ± 0.14	18.26 ± 0.18	1.19 ± 0.01	11.02 ± 0.13	1.27 ± 0.04	5.35 ± 0.09	1.01 ± 0.02	7.24 ± 0.16
T. procumbens	6.30 ± 0.02	28.99 ± 0.06	1.35 ± 0.01	0.50 ± 0.07	0.28 ± 0.01	0.37 ± 0.08	1.27 ± 0.01	0.64 ± 0.05
P. hysterophorus	2.67 ± 0.03	19.51 ± 0.85	0.49 ± 0.02	2.93 ± 0.30	0.64 ± 0.04	7.50 ± 0.51	4.07 ± 0.08	25.23 ± 0.79
X. strumarium	5.89 ± 0.11	40.04 ± 0.58	7.04 ± 0.09	20.54 ± 0.17	2.06 ± 0.11	12.01±0.45	2.40 ± 0.07	14.14 ± 0.50
E. bonariensis	3.47 ± 0.03	6.41 ± 0.24	0.73 ± 0.02	4.88 ± 0.09	1.61 ± 0.02	3.97 ± 0.10	0.51 ± 0.07	1.84 ± 0.11
E. alba	3.75 ± 0.08	11.43 ± 0.38	1.90 ± 0.02	6.66 ± 0.18	1.63 ± 0.04	6.86 ± 0.17	1.89 ± 0.05	7.33 ± 0.24
A. sessilis	3.03 ± 0.06	11.49 ± 0.20	1.34 ± 0.02	6.98 ± 0.22	2.28 ± 0.04	2.62 ± 0.18	1.90 ± 0.03	5.55 ± 0.20
C. ambrosioides	12.57 ± 0.06	38.33 ± 0.58	2.20 ± 0.05	11.14 ± 0.21	4.02 ± 0.11	4.10 ± 0.19	2.67 ± 0.06	9.15 ± 0.26
A. aspera	1.45 ± 0.03	3.61 ± 0.15	0.30 ± 0.02	2.06 ± 0.10	1.26 ± 0.1	1.10 ± 0.6	1.18 ± 0.01	2.98 ± 0.10
S. nigrum	2.32 ± 0.05	3.16 ± 0.25	0.80 ± 0.03	0.97 ± 0.09	0.50 ± 0.03	0.61 ± 0.08	1.20 ± 0.03	2.40 ± 0.13
L. indica	34.21 ± 0.31	21.96 ± 1.33	6.62 ± 0.09	21.92 ± 0.51	32.52±0.22	38.10±1.50	31.14 ± 0.11	30.51 ± 1.07
C. rotundus	3.10 ± 0.07	0.92 ± 0.08	0.33 ± 0.03	0.15 ± 0.04	0.48 ± 0.02	0.11 ± 0.02	0.55 ± 0.03	0.33 ± 0.4
C. dactylon	2.11 ± 0.03	0.58 ± 0.11	0.58 ± 0.02	0.29 ± 0.06	0.38 ± 0.02	0.48 ± 0.09	1.81 ± 0.02	2.78 ± 0.09

For chromium, the enrichment coefficient with respect to roots and shoots ranged from 1.45 ± 0.03 for *A. aspera* to 199.67 ± 4.55 for *C. procera* and 0.58 ± 0.11 in *C. dactylon* to 253.05 ± 9.25 in *C. procera* respectively. The Enrichment coefficient for copper was found to be highest for *C. procera* (83.46 ± 6.19) with respect to roots, however the same plant species was found to be having the highest EC (80.42 ± 8.57) with respect to shoots. In case of nickel, the maximum EC was analysed in *L. indica* for roots (32.52 ± 0.22) and shoots (38.10 ± 1.50), whereas minimum was observed in *T. procumbens* (0.28 ± 0.01) and *C. rotundus* (0.11 ± 0.03) for roots and shoots respectively. Maximal accumulation of lead was recorded in *C. procera* with heighest EC with respect to roots (341.99 ± 7.31) and shoots (391.12 ± 12.20).

Translocation Factor (TF)

The capacity of plants to transport the metals from roots to shoots is a critical feature of phytoremediator plant species and can be analyzed by the estimation of translocation factor (TF). In the present study, all the studies plant species showed variation in TF for different metals.

Table 3: Translocation factor (TF) of the plants collected from the industrial area of Bhagwanpur

Plant	Cr	Cu	Pb	Ni
A. indicum	0.58±0.03	1.50±0.24	2.59±0.19	5.50±0.91
C. procera	1.27±0.03	0.96±0.17	0.76±0.50	1.14±0.04
C. bonplandianum	2.15±0.22	1.16±0.06	0.94±0.04	3.07±0.36
E. hirta	1.69±0.08	0.99±0.17	0.97±0.10	0.97±0.09
C. tora	1.65±0.14	4.10±0.28	1.72±0.02	2.11±0.11
C. occidentalis	2.34±0.03	3.01±0.17	2.85±0.24	2.07±0.08
S. cordifolia	1.11±0.13	1.50±0.16	1.29±0.48	0.92±0.06
U. lobata	2.69±0.04	9.26±0.26	4.21±0.22	7.18±0.01
T. procumbens	4.60±0.02	0.37±0.05	1.34±0.21	0.51±0.04
P. hysterophorus	7.29±0.02	5.97±0.01	11.66±0.31	6.20±0.06
X. strumarium	6.80±0.03	2.92±0.02	5.83±0.07	5.88±0.35
E. bonariensis	1.85±0.07	6.71±0.02	2.47±0.11	3.62±0.08
E. alba	3.05±0.04	3.51±0.06	4.21±0.19	3.88±0.27
A. sessilis	3.79±0.15	5.22±0.09	1.15±0.10	2.93±0.15
C. ambrosioides	3.05±0.04	5.05±0.21	1.02±0.02	3.42±0.01
A. aspera	2.48±0.04	6.92±0.13	0.87±0.06	2.53±0.11
S. nigrum	1.36±0.16	1.21±0.07	1.23±0.08	2.00±0.18
L. indica	0.64±0.03	3.31±0.13	1.17±0.05	0.98±0.04
C. rotundus	0.30±0.02	0.46±0.02	0.23±0.01	0.60±0.03
C. dactylon	0.27±0.01	0.50±0.04	1.28±0.13	1.54±0.17

For chromium, the translocation factor ranged from 0.27 ± 0.01 in *C. dactylon* to 7.29 ± 0.02 in *P. hysterophorus.* The translocation factor for copper was found to be maximum in *U. lobata* (9.26 ± 0.26), however the translocation factor for lead was highest in *P. hysterophorus* (11.66 ± 0.31), which was the maximum among all the plant species for all the four metals. Nickel translocation factor ranged from 0.51 ± 0.04 in *T. procumbens* to 7.18 ± 0.01 in *U. lobata.*

Discussion

The assessment of physic-chemical properties of soil is very necessary to determine the soil quality. The solubility and nutrient availability in soil is influenced by pH (Dora Neina, 2019). The pH of industrial area was found to be acidic and it is reported that the heavy metal cations are most mobile under acidic conditions (Rana *et al*. 2010 [50]; Christensen 1984) [14] and acidic pH also enhances the bioavailability of metals (Vig *et al*. 2003 [66]; Sinha *et al*. 2006 [26], Oburger *et al* 2018) [43]. Electrical conductivity is the function of the ions present in soil (Sinha *et al*. 2007 [59]; Bose and Bhattacharya 2008 [10]; Li *et al*. 2010). In soil solution, the soluble salts of soil dissociate into their respective cations and anions, carry current and impart conductivity, thus the measurement of electrical conductivity can be directly related to the soluble salt concentration. Higher the concentration of ions in solution more is its electrical conductance (Sumithra *et al*. 2013) [64].

For the assessment of soil health, soil organic carbon is a key attribute which is generally correlating positively with crop yield (Bennett *et al*. 2010) [7]. The available nitrogen, available phosphorus and potassium were found to be low in industrial area soil, It may be due to the low organic matter in industrial area soil as Organic matter releases many plant nutrients as it is broken down in the soil, including N, phosphorus (P) and sulphur (S) (Bot and Benites 2005) [11]. The biological properties of soil can be used as indirect indicators of soil quality as the complex fauna and microbial web of soil affects its physical and chemical properties as it is involved in many different biological processes (Delgad and Gomez 2016) [16]. The colony forming unit count was also found to be low in soil contaminated with industrial activities which could be a resultant of exposure of toxic metals for short-term or long-term results in the reduction of microbial activities and diversity in soil (Lasat 2002 [37]; McGrath *et al*. 2001) [40].

Heavy metal concentrations in plants vary from plant species to species (Mahmud *et al*. 2008 [39]; Ojuederie and Babalola, 2017) [44]. Nickel is one of the essential nutrients for plants. The nickel is required in very low concentration. The nickel concentration in plants generally ranged between 0.05 and 10 µg g^{-1} dry wt. (Nieminen *et al*. 2007). In the present investigation, the Ni concentration was found to be high than the normal range. Although nickel is an essential element for plants but is toxic for plants at higher concentration (Ahmed and Ashraf, 2011) [1]. Nickel adversely affects the seed germination, enzymatic activities, plant growth and development (Sengar *et al.* 2008; Bauddh and Singh 2009; Ahmed and Ashraf 2011 [1]; Gupta *et al.* 2017) [60]. Copper is also an essential metal for normal plant growth and development. In excess, copper impairs important cellular processes and ultimately inhibits plant growth (Yruela 2005, Arif *et al*. 2016) [6]. The copper concentration normally ranged from 2.1 and 8.4 µg g^{-1} in plants growing in non-contaminated areas. (Kabata-Pendias and Pendias 2001), which is quite low in comparison to the copper concentration in the plants growing in Bhagwanpur industrial area.

The Cr concentration in different plant species is ranging from 0.03–14 µg g−1 (Bowen 1979), however in crops, chromium was found to promote growth and yield at low concentration i.e. 0.05–1 mg L^{-1} (Peralta-Videa *et al*. 2009; Paiva *et al*. 2009) [45]. Chromium concentration in some plant species were recorded more than the limits prescribed by Bowen (1979). The plant growing on non-contaminated land was found to be having lead concentration in the range from 0.05 and 20 µg g^{-1} (Bowen 1979; Kabata-Pendias and Pendias 2001). Majority of the studied plant species found to be having high lead concentration beyond the suggested limits.

Enrichment coefficient has been used as an important criterion to assess the degree of accumulation of metals in the roots and shoots of the plants with respect to their concentration in the growing medium (Chao *et al*. 2007; Chakroun *et al*. 2010; Kumar *et al*. 2013 [34], Romeh, 2018) [52]. Most of the plant species under study, showed a high enrichment coefficient. According to the previous studies, the plants having high EC i.e. >1 have remarkable capability to extract metals from substrate (Backer *et al*. 1994; Wei *et al*. 2002). *C. procera, C. occidentalis, U. lobata, X. strumarium, E. alba, A.sessilis, C. ambroisoides* and *L. indica* exhibited EC more than 1 for all the for metals with respect to roots and shoots.

Translocation factor is an important criterion for determination of phytoremediation potential of plant species as it determines the metal distribution in different plant tissues (Dean 2007 [15]; Khan *et al.* 2008). The plants showing Translocation Factor more than one are suitable for phytoextraction purpose (Gupta and Sinha 2006 [26]; Yoon *et al*. 2006, Mahmud *et al*. 2008) [39]. In the present investigation, ten out of twenty plant species showed translocation factor more than one for all the four metals.

Conclusion

The present study reports the physico-chemical properties of metal contaminated soil and heavy metal accumulation potential of naturally growing plant species of industrial area of Bhagwanpur (Uttarakhand). The Findings of the study suggests that the high enrichment coefficient and translocation factor of naturally growing plant species reveals their ablity as a phytore to accumulate and translocate different metals, however Ten plant species *viz. C. tora, C. occidentalis, U. lobata, P. hysterophorus, X. strumarium, E. bonariensis, E. alba, A. sessilis, S. nigrum* and *C. ambrosioides* showed high translocation factor for all the four studied metals that indicates their exceptional ability as a potential phytoremediation candidate.

Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest in the publication.

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