J. Phytol. Res. **36**(2): 1-10, 2023 **ISSN 0970-5767**

ASSESSMENT OF HEAVY METAL REMEDIATION POTENTIAL OF SELECTED LOCAL PLANTS IN INDUSTRIAL SOILS: A CASE STUDY OF BIKANER CITY, INDIA

DIVYAMAN SINGH RATHORE, LEELA KAUR[*] and RAJARAM CHOYAL
Department of Environmental Science, Maharaja Ganga Singh University, Bikaner, Rajasthan (INDIA)
***Corresponding Author's Email**: leela.kaur@gmail.com

Rapid industrialization led to severe pollution which deteriorated the quality of the environment. Due to industrialization heavy metal pollution becomes a serious risk to the diversity of life. Heavy metals are responsible for contamination in the environment. Several environment techniques are being used to clean up the environment from these kinds of contaminants. Currently, phytoremediation is an effective and affordable technology that is used to extract metal pollutants from contaminated soil. The present paper aims to assess phytoremediation capacity of local plants and contents of heavy metals in soils of industrial areas of Bikaner city. Plants such as *Citrullus colocynthis, Brachiaria ramosa, Cucumis lanatus, Calotropis procera, Cucumis prophetarum, Abutilon indicum, Aerva pseudotomentosa,* and *Prosopis juliflora* are taken for the current study. These plants are evaluated for the removal efficiencies of As, Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb, and Zn metals from soils. Most of the metals like As, Cd, Cu, Pb, Co, Cr, Fe, Mn, Zn and Ni are absorbed by *Aerva pseudotomentosa*, *Citrullus colocynthis* and *Cucumis lanatus*. Which shows that these plants are good metal accumulators and they could be utilized for metal remediation of contaminated soil.

Keywords: *Aerva pseudotomentosa*, Heavy metals - Arsenic, Cadmium, Iron, Lead, Industrial soils, Phytoremediation.

Introduction

Heavy metal pollution in soil has become a serious problem in developing countries due to the increase in pollution sources[1]. About 10 million people worldwide have been affected by heavy metal-contaminated soil[2]. Contamination of soil can be both natural and unnatural. Natural contamination of soil is by increased weathering rates, land erosion, and geological processes[3]. Some contaminants can be naturally produced in soil under certain environmental conditions for example; perchlorates can be formed in soil during thunderstorms that contains chlorine and certain metals[4]. On the other hand, anthropogenic sources of soil contamination are industrial activities, sewage irrigation, industrial solid waste, mining, fertilizers, and pesticides[5]. Heavy metals such as nickel (Ni), manganese (Mn), zinc (Zn), iron (Fe), copper (Cu), arsenic (As), chromium (Cr), mercury (Hg), lead (Pb) and cadmium (Cd) have become a serious global issue[6,7]. As, Cd, Cr, Ni, and Pb are known to be highly poisonous and cause potential effects on the environment and ecology[8]. Cr, Cu, and Cd cause liver diseases[9]. Pb entering the human body can lead to kidney damage, neurological, and gastrointestinal diseases[10,11]. While excessive Zn in the human body can lead to nausea, diarrhoea, and headaches[12]. Ni causes allergies, lung cancer, kidney, and cardiovascular diseases[13]. Lead toxicity can affect the male and female reproductive system as well as birth defects and mental retardation in children[14]. A study done at Sahiwal which is a sub-urban agricultural town in the Sargodha district, Punjab (India) have contents of heavy metals such as Cd, Ni, Fe, Mn, Cu, Cr, Zn, and Co in soil which were 3.0 mg/kg, 2.7 mg/kg, 4.1 mg/kg, 1.6 mg/kg, 2.0 mg/kg, 1.5 mg/kg, 1.2 mg/kg, 0.9 mg/kg respectively[15]. Another study done by Bhayani et al.[16] found that Metoda industrial area (Rajkot, Gujarat) contains heavy metals (mg/kg) like Cu (1.98), Mn (1.58), Cr (1.58), Cd (7.67), and Pb (166.72) in soil samples. Impact of industrialization in soil of Sonepat (Haryana) could be seen as the heavy metals (mg/kg) like

Fe, Mn, Zn, Ni, Cr, Cu, Pb, Co, and Cd was 17977, 325, 91, 52, 44, 34, 32, 2, 1 respectively[17]. Soil contamination investigated and it was found that in industrial areas, heavy metals present in industrial wastewater may contaminate the soil[18]. These metals can enter the food chain through plants and accumulate in the human body which can cause serious threats to human health[19,20]. Hence it is necessary to take remediation measures to control heavy metal soil contamination. Phytoremediation is a biological cleaning process of the environment with the help of plants and this method is also considered as a green technology because of its decontamination ability of heavy metals[21]. Alternatively, this method is highly acceptable among the public due to its facility of application, low cost, and environment friendly nature[22,23]. This plant-based approach is useful to extract and remove elemental pollutants in soil[24].

The objective of the study is to investigate heavy metals concentration in soils and plants near industrial areas of Bikaner city and determine metal remediation potential of selected local plants from the study sites.

Material and Methods

Study Area

Bikaner is one of the most developing cities in Rajasthan (India) and it is located 330 km northwest of the state capital, Jaipur. The latitude and longitude are 28.027138 and 73.302155 respectively. The present study is carried out to evaluate heavy metal contamination in industrial soil and plants of Bikaner city. Four different industrial sites were chosen for the study and these are Rani Bazar industrial area, Karni Nagar industrial area, Bichhwal industrial area, and Khara industrial area (Figure 1). It was observed that industries like agrochemical pesticides, ceramics, gypsum, textiles, wool, and paint, etc. discharge untreated wastewater directly into an open area which is near the agricultural land. Untreated wastewater is used for growing crops, particularly vegetables.

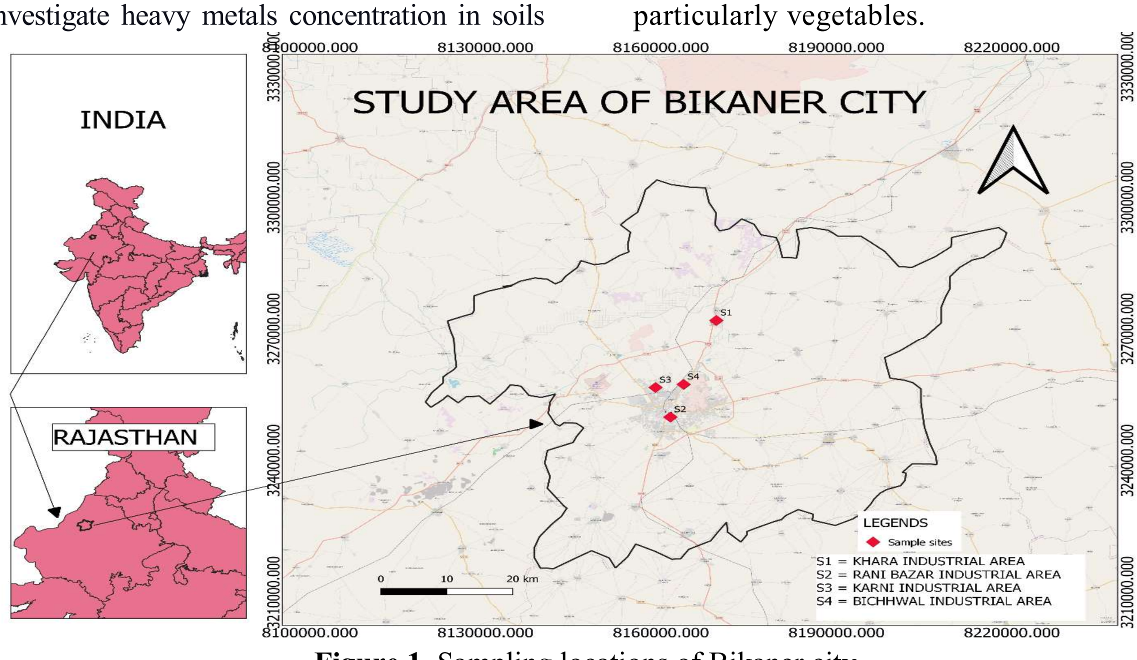


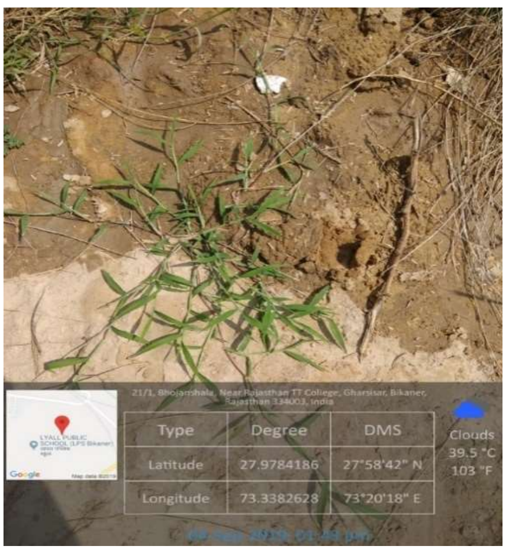
Figure 1. Sampling locations of Bikaner city.

Collection of soil and plant samples

Soil samples were taken from the depth of 5 cm, 15 cm and 25 cm. Soil and plant samples were collected in polyethylene bags which were transported to the laboratory and preserved in a refrigerator (4^0C). Plants selected from industrial areas are Bitter cucumber (*Citrullus colocynthis*), Browntop millet (*Brachiaria ramose*), Watermelon (*Cucumis lanatus*), Apple of Sodom (*Calotropis procera*), Wild gourd (*Cucumis prophetarum*), Indian mallow (*Abutilon indicum),* Bui *(Aerva pseudotomentosa*) and Junglee kikar (*Prosopis juliflora*) as shown in Figure 2.

(a). Bui (*Aerva pseudotomentosa*)

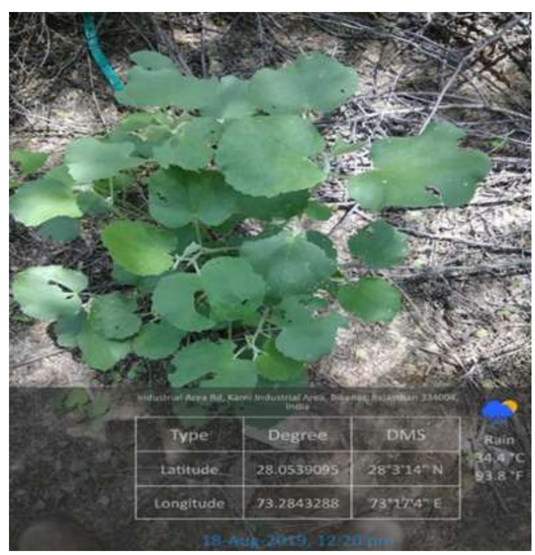
(b). Bitter cucumber (*Citrullus colocynthis*)



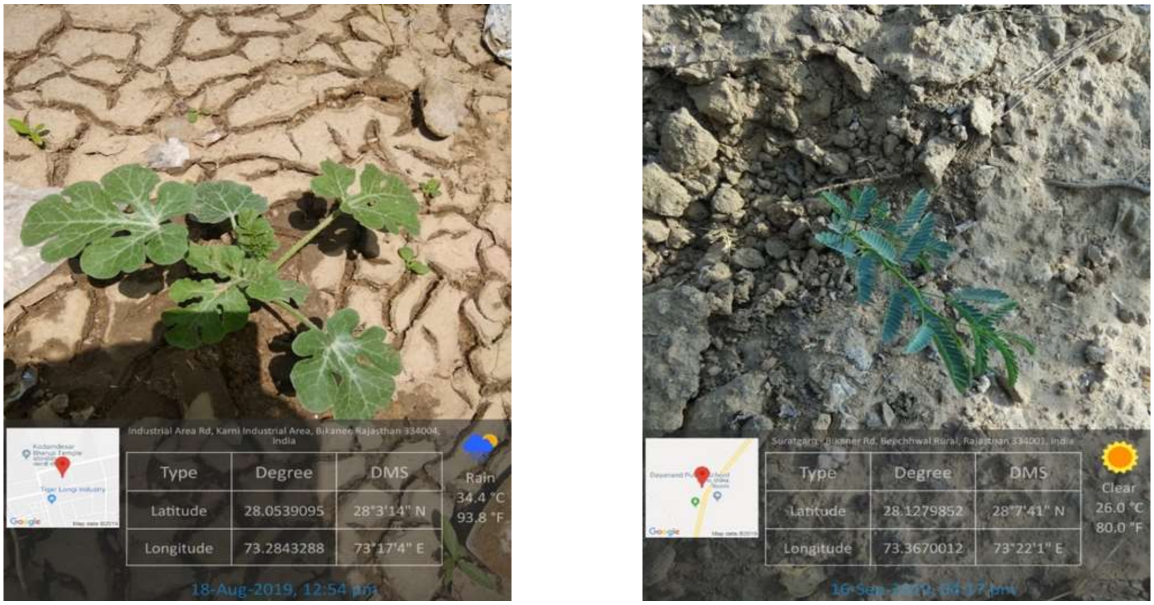
(c). Browntop millet (*Brachiaria ramosa*)

(d). Apple of sodom (*Calotropis procera)*

(e). Wild gourd (*Cucumis prophetarum*)



(f). Indian mallow (*Abutilon indicum*)



(g). Watermelon (*Cucumis lanatus*) (h). Junglee kikar (*Prosopis juliflora*)

Figure 2. Selected plant samples (a-h) of the study area.

Methods

Collected soil and plant samples were used to estimate the heavy metals such as arsenic, manganese, iron, cobalt, lead, cadmium, copper, zinc, nickel, and chromium. Collected samples were treated with acid digestion method. This method was recommended by Environmental Protection Agency[25] for heavy metal extraction. 1.0 gm of samples were placed in 250 ml flask for acid digestion on hot plate. Samples were digested with repeated addition of nitric acid (HNO_3) and hydrogen peroxide (H_2O_2). Now digested samples were filtered through Whatman filter paper No. 42 and diluted to 100 ml with deionized water for analysis. Concentrations of these heavy metals in samples were determined by using an inductively coupled plasma atomic emission spectrometer (ICPE-9000, Shimadzu's Private Ltd, Japan). Analysis condition of ICP-AES during heavy metal extraction is shown in Table 1. The obtained data were analysed in MS Excel version 2019.

Table 1. ICP-AES Analysis Condition.

RF Power	1.2 (Kw)
Plasma gas (Ar)	10 (L/min)
Auxiliary (Ar)	0.7 (L/min)
Carrier gas (Ar)	0.6(L/min)
Nebulizer	Coaxial Nebulizer
Spray chamber	Cyclone Chamber
Observation direction	Axil/Radial

Results and Discussion

Metal content in soil

Ten metals such as arsenic, cadmium, cobalt, chromium, copper, iron, manganese, lead and nickel were analysed in soil samples which obtained from four industrial areas of Bikaner city and the obtained results are presented in Table 2.

Arsenic content in the soil of the polluted site was 6.4 mg/kg to 7.7 mg/kg. The obtained results could be due to entry of industrial wastes from the metallurgical industry which might increase the level of Arsenic in the soil[27]. Among all the soil samples analysed from the polluted site, high arsenic level was recorded which was above the permissible limit set by FAO (Table 3).

The Cd content in the soil of the polluted site ranged from 3.3 mg/kg to 3.8 mg/kg. Among all the samples analysed from the polluted site, high cadmium concentration was recorded in the soil which was above the permissible range of the FAO standards. The obtained result could be due to utilisation of Cd as a raw material by several industries and it is also used in batteries, coating, plating, alloys, etc.[28]

Cr, Pb, Cu, Ni, Zn, and Mn ranged from 9.1 to 14.3 mg/kg, 8.9 to 13.8 mg/kg, 13.4 to 18.2 mg/kg, 17.6 to 25.6 mg/kg, 41.5 to 106.1 mg/kg, and 36 to 71.8 mg/kg respectively.

Table 2. Metal concentration in selected soil samples of the study area (mg/kg).

Study sites	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Khara industrial area	7.34	3.88	4.2	14.32	17.94	1104	71.8	21.26	8.92	57.8
Rani bazar industrial area	7.74	3.88	4.46	13	18.22	2981	46.5	25.66	9.2	106.12
Karni industrial area	6.44	3.48	4.92	9.12	13.44	1690	60	17.68	5.72	53.72
Bichhwal industrial area	7.72	3.36	5.54	14.32	15.7	2580	36	21.52	13.86	41.52

Table 3. Permissible levels of heavy metals in soil, crops, and irrigation water[26].

Chemical element	Maximum permissible levels in soil (mg/kg)
As	1.0
Cd	1.0
Co	-
Cr	100.0
Cu	200.0
Fe	-
Mn	1800
Ni	100
Pb	200
Zn	150

These metals were below the permissible limits as per FAO standards. Industrial sources like chemicals, alloys, glass, paint, paper mills, and textile were the major source of these heavy metals[29].

Metal content in plants

In the present work, studies on the removal of As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Ni were carried out by phytoremediation by using macrophytes such as *Aerva pseudotomentosa, Abutilon indicum, Brachiaria ramosa, Calotropis procera, Cucumis proferitum, Cucumis lanatus, Citrullus colocynthis* and *Prosopis juliflora*. The results of heavy metal accumulation by macrophytes are presented in Figure 3.

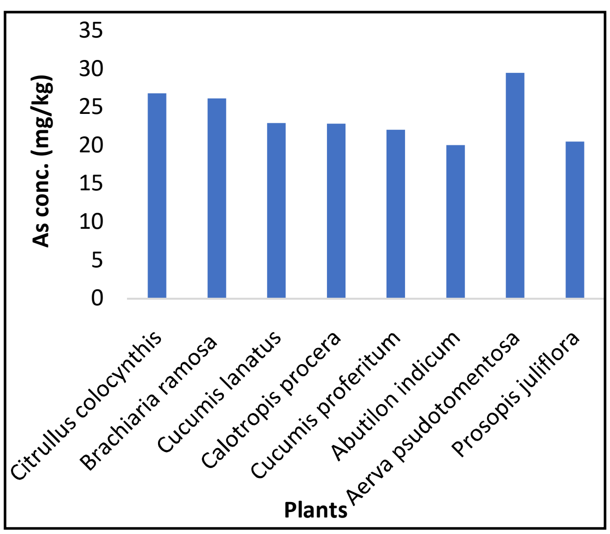
The highest As concentration was measured in *Aerva pseudotomentosa* (29.5 mg/ kg) and the lowest was observed in *Abutilon indicum* (20.8 mg/kg). The highest Cd concentration was measured in *Aerva pseudotomentosa* (16.2 mg/kg) and the lowest was observed in *Calotropis procera* and *Cucumis proferitum* (10.7 mg/kg). The concentration of Cd is above the permissible limit (0.05-0.5 mg/kg). Table 4 represents maximum concentration (mg/kg) of heavy metals allowed in plants[30]. The highest Co concentration was measured in *Citrullus colocynthis* (11.96 mg/kg) and the lowest concentration was obtained in *Cucumis proferitum* (9.02 mg/kg). The highest Cr concentration was measured in *Citrullus colocynthis* (43.5 mg/kg) and the lowest was measured in *Cucumis proferitum* (21 mg/kg) shown in Figure 3. The concentration of Cr is above the permissible limit (2 mg/kg). The highest Cu was obtained in *Aerva pseudotomentosa* (66.46 mg/kg) and the lowest was measured in *Abutilon indicum* (38.36 mg/kg). The Cu concentration in plant is above the permissible limit (5-20 mg/kg) as per given Table 4.

Table 4. Maximum concentration (mg/kg)of heavy metals allowed in plants[30].

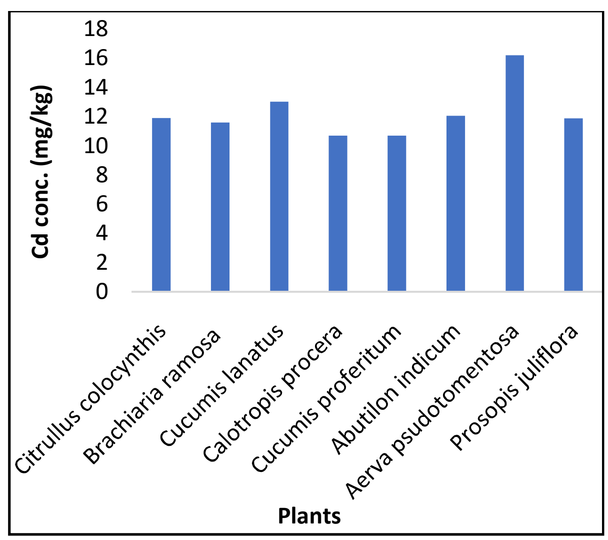
Heavy metals	Permissible limit (mg/kg)
Cu	5-20
Zn	10-50
Ni	1-10
Cd	0.05-0.5
Cr	2
Pb	0.5-10

The highest Fe was measured in *Citrullus colocynthis* (4934 mg/kg) and the lowest was measured in *Calotropis procera* (521.8 mg/kg). The highest Mn was measured in *Citrullus colocynthis* (115.56 mg/kg) and the lowest was observed in *prosopis juliflora* (27.42 mg/kg). The highest and lowest Ni concentrations were observed in *Cucumis lanatus* (79.84 mg/kg) and *Cucumis proferitum* (56.42 mg/kg) respectively. The concentration of Ni is above the permissible limit (1-10 mg/kg). *Avera pseudotomentosa* contained the highest lead concentration (49.52 mg/kg) and the lowest was found in *Cucumis proferitum* (7.39 mg/kg). The concentration of lead in *Cucumis proferitum* is under the permissible limit (0.5-10 mg/kg). Zinc concentration was highest in *Cucumis lanatus* (279.2 mg/kg) and lowest was obtained in *Abutilon indicum* (115.6 mg/kg). The concentration of Zn is above the permissible limit (10-50 mg/kg).

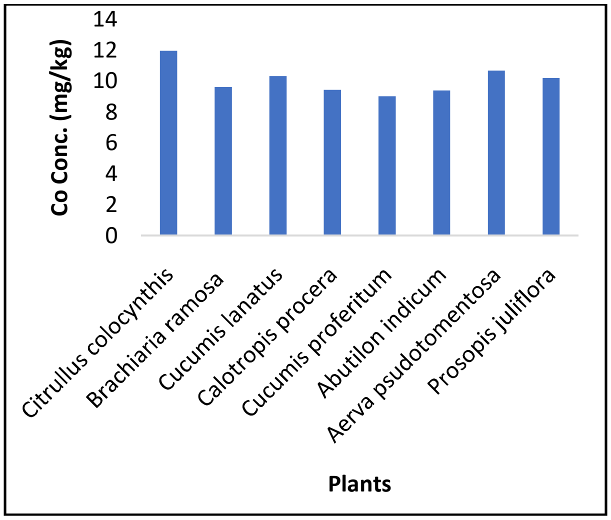
The highest and the lowest metal accumulator plants from the study sites are tabulated in Table 5. The result shows that *Aerva pseudotomentosa, Citrullus colocynthis,* and *Cucumis lanatus* were good metal accumulators. This shows that *Aerva pseudotomentosa* can phytoaccumulate As, Cd, Cu, and Pb metals, while *Citrullus colocynthis* can accumulate Co, Cr, Fe, and Mn. *Cucumis lanatus* can also accumulates Zn and Ni.



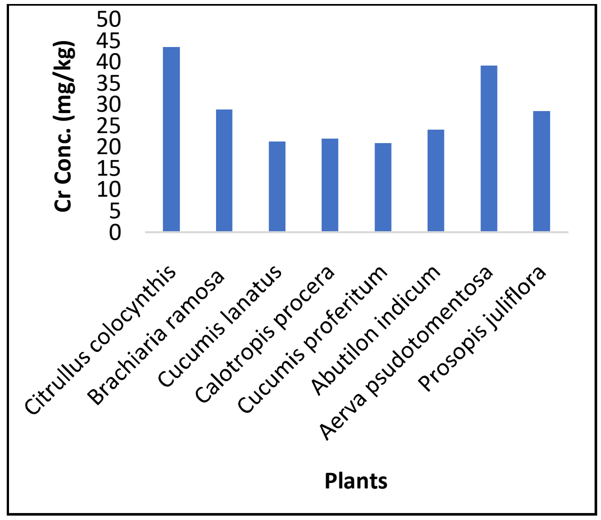
(a) Arsenic content



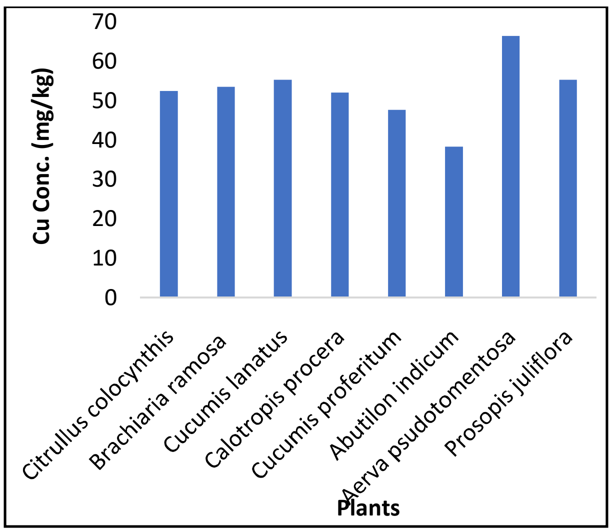
(b) Cadmium content



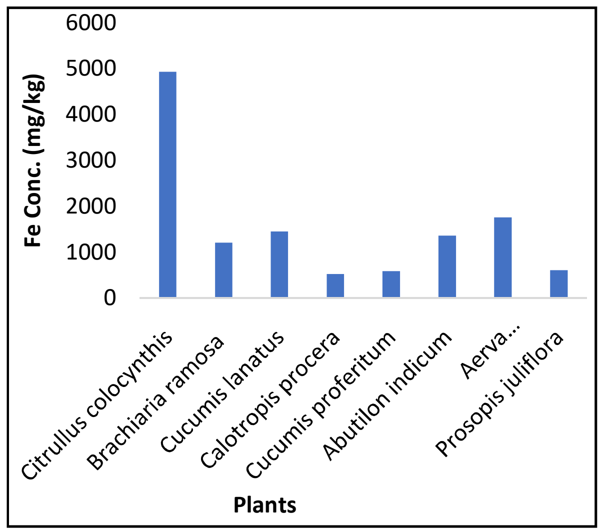
(c) Cobalt content



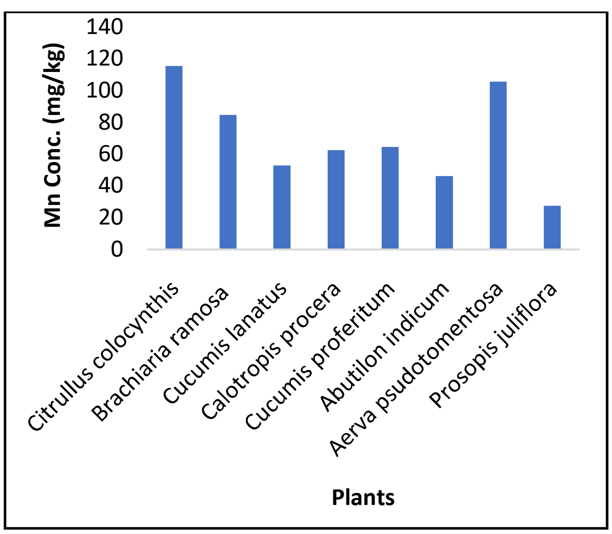
(d) Chromium content



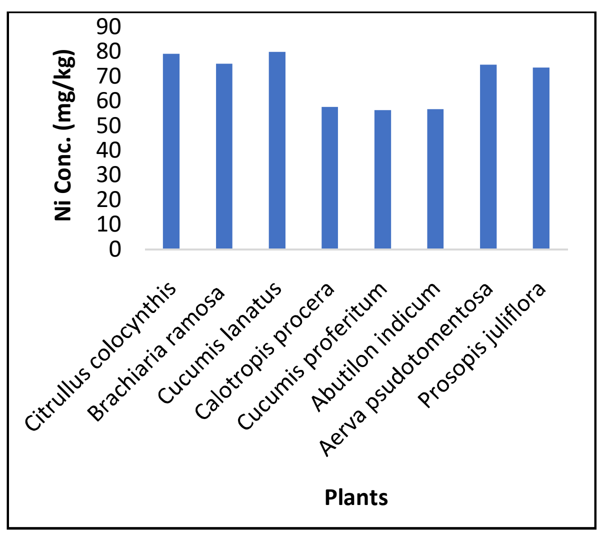
(e) Copper content



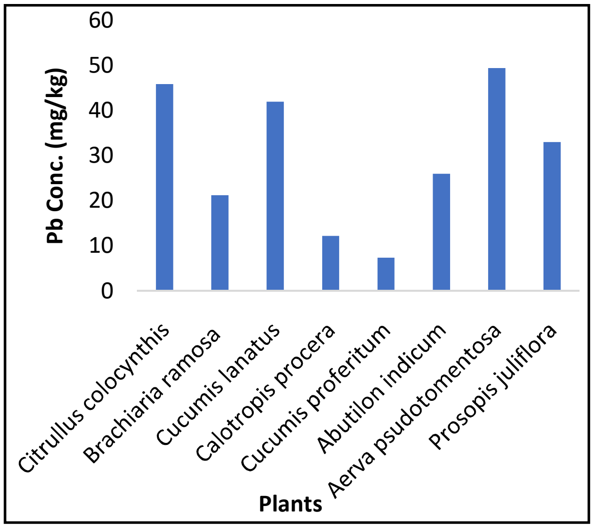
(f) Iron content



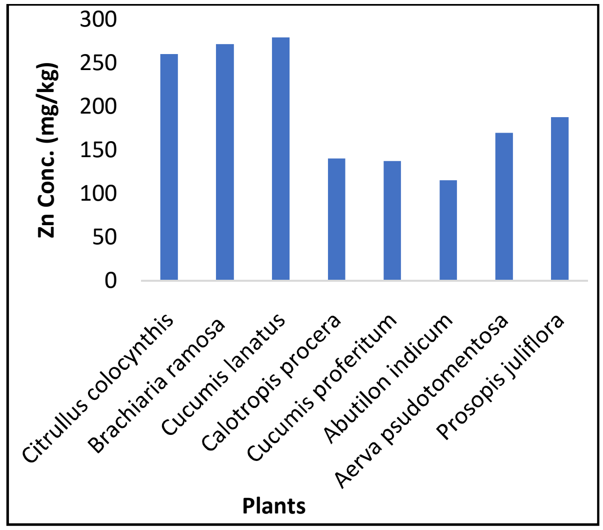
(g) Manganese content



(h) Nickel content



(i) Lead content



(j) Zinc content

Figure 3. Heavy metal contents (a-j) in selected plants.

Table 5. Highest and lowest metal accumulator plants of the study.

Metal	Highest metal accumulator plant (mg/kg)	Lowest metal accumulator plant (mg/kg)
As	*Aerva pseudotomentosa* (29.5)	*Abutilon indicum* (20.8)
Cd	*Aerva pseudotomentosa* (16.2)	*Calotropis procera* (10.7) *and Cucumis proferitum* (10.7)
Co	*Citrullus colocynthis* (11.96)	*Cucumis proferitum* (9.02)
Cr	*Citrullus colocynthis* (43.5)	*Cucumis proferitum* (21)
Cu	*Aerva pseudotomentosa* (66.46)	*Abutilon indicum* (38.36)
Fe	*Citrullus colocynthis* (4934)	*Calotropis procera* (521.8)
Mn	*Citrullus colocynthis* (115.56)	*Prosopis juliflora* (27.42)
Ni	*Cucumis lanatus* (79.84)	*Cucumis proferitum* (56.42)
Pb	*Avera pseudotomentosa* (49.52)	*Cucumis proferitum* (7.398)
Zn	*Cucumis lanatus* (279.2)	*Abutilon indicum* (115.6)

Conclusions

The present study is conducted in polluted sites near industrial areas where soil and plant samples were taken for heavy metal analysis. Bikaner industrial areas have high soil contamination level of As and Cd as per FAO standards. Most of the metals like As, Cd, Cu, Pb, Co, Cr, Fe, Mn, Zn and Ni are absorbed by *Aerva pseudotomentosa*, *Citrullus colocynthis* and *Cucumis lanatus*. It shows that these plants are good metal accumulators and which could be utilized for metal remediation of contaminated soil.

Acknowledgements

We are thankful to Dr. Naresh Kumar Arora (CSSRI, Karnal) for assistance in sample analysis.

References

1. Ahmad I, Khan B, Asad N, Mian IA and Jamil M 2019, Traffic-related lead pollution in roadside soils and plants in Khyber Pakhtunkhwa, Pakistan: Implications for human health. *Int J Environ Sci Technol.* **16**(4) 8015–8022.
2. Ashraf S, Ali Q, Zahir ZA, Ashraf S and Asghar HN 2019, Phytoremediation: environmentally sustainable way for reclamation of heavy metal polluted soils. *Ecotox Environ Safe.* **174** 714-727.
3. Gurajala HK, Cao X, Tang L, Ramesh TM, Lu M and Yang X 2019, Comparative assessment of Indian mustard (*Brassica juncea L.*) genotypes

for phytoremediation of Cd and Pb contaminated soils. *Environ Pollut.* **254**(PartB) 113085.

4. Tao H, Liao X, Li Y, Xu C, Zhu G and Cassidy DP 2020, Quantifying influences of interacting anthropogenic-natural factors on trace element accumulation and pollution risk in karst soil. *Sci Total Environ.* **721** 137770.
5. Zhang WJ, Jiang FB and Ou JF 2011, Global pesticide consumption and pollution: with China as a focus. *Proc Int Acad Ecol Environ Sci.* **1**(2) 125-144.
6. Carvalho MEA, Castro PRC and Azevedo RA 2020, Hormesis in plants under Cd exposure: From toxic to beneficial element. *J Hazard Mater.* **384** 121434.
7. Singh H, Yadav M, Kumar N, Kumar A and Kumar M 2020, Assessing adaptation and mitigation potential of roadside trees under the influence of vehicular emissions: A case study of *Grevillea robusta* and *Mangifera indica* planted in an urban city of India. *PLoS ONE* **15**(1) 1-20.
8. Protano C, Zinnà L, Giampaoli S, Spica VR, Chiavarini S and Vitali M 2014, Heavy metal pollution and potential ecological risks in rivers: A case study from Southern Italy., Bull. *Environ Contam Toxicol.* **92**(1) 75-80.
9. Liu X, Song Q, Tang Y, Li W, Xu J, Wu J, Wang F and Brookes CP 2013, Human health risk assessment of heavy metals in soil–vegetable system: A multi-medium analysis. *Sci Total Environ.* **463–464** 530–540.
10. Năstăsescu V, Magdalena M, Goumenou M, Docea AO, Renieri E, Udeanu DL, Oprea E, Arsene AL, Dinu-Pirvu CE and Ghica M 2020, Heavy metal and pesticide levels in dairy products: Evaluation of human health risk. *Food Chem Toxicol.* **146** 111844.
11. Zerizghi T, Guo Q, Tian L, Wei R and Zhao C 2022, An integrated approach to quantify ecological and human health risks of soil heavy metal contamination around coal mining area. *Sci Total Environ.* **814** 152653.
12. Slowiczek L 2019, What happens when a person takes too much Zinc. *Medical news today* Acessed on Sept. 30, 2023 https://www.medicalnewstoday.com/articles/326760
13. Genchi G, Carocci A, Lauria G, Sinicropi MS and Catalano A 2020, Nickel: Human health and environmental toxicology. *Int J Environ Res Public Health.* **17**(3) 679.
14. Loh N, Loh HP, Wang LK and Wang MHS 2016, Health effects and control of toxic lead in the environment. *Nat Resour Control Process.* **17** 233-284.
15. Batool F, Hussain MI, Nazar S, Bashir H, Khan ZI, Ahmad K, Alnuwaiser MA and Yang HH 2023, Potential of sewage irrigation for heavy metal contamination in soil–wheat grain system: Ecological risk and environmental fate. *Agri Water Manag.* **278** 1-9.
16. Bhayani D, Siddhapura SP, Sindhav SR and Jadeja BA 2023, Potentiality of weed plants for phytoremediation of heavy metal polluted soil. *Int J Environ Climate Change.* **13**(5) 400-412.
17. Rani J, Chaudhary S and Agarwal T 2023, Impact of industrialization on heavy metals contamination in agricultural soils of Sonepat, a satellite township of New Delhi, India. *Sustain Agri Food Environ Res.* **12**.
18. Oliveira A and Pampulha ME 2006, Effects of long-term heavy metal contamination on soil microbial characteristics. *J Biosci Bioeng.* **102**(3) 157-61.
19. Sarwar N, Malhi SS, Zia MH, Naeem A, Bibi S and Farid G 2010, Role of mineral nutrition in minimizing cadmium accumulation by plants. *J Sci Food Agri.* **90** 925-937.
20. Rehman MZU, Rizwan M, Ali S, Ok YS, Ishaque W, Saifullah, Nawaz MF, Akmal F and Waqar M 2017, Remediation of heavy metal contaminated soils by using Solanum nigrum: a review. *Ecotox Environ Safe.* **143** 236 -248.

21. Raza A, Habib M, Kakavand SN, Zahid Z, Zahra N, Sharif R and Hasanuzzaman M 2020, Phytoremediation of cadmium: Physiological, biochemical, and molecular mechanisms. *Biology.* **9**(7) 1-46.

22. Dhaliwal SS, Singh J, Taneja PK and Mandal A 2020, Remediation techniques for removal of heavy metals from the soil contaminated through different sources: A review. *Environ Sci Pollut Res.* **27** 1319-1333.

23. Huang R, Dong M, Mao P, Zhuang P Paz-Ferreiro J, Li Y, Li Y, Hu X, Netherway P and Li Z 2020, Evaluation of phytoremediation potential of five Cd (hyper) accumulators in two Cd contaminated soils. *Sci Total Environ.* **721** 137581.

24. Berti WR and Cunningham SD 2000, Phytostabilization of metals: In Raskin I and Ensley BD (Eds.) *Phytoremediation of Toxic Metals: Using Plants to Clean-up the Environment.* Wiley Interscience, John Wiley and Sons, New York, pp 71-88.

25. EPA Method 3050B 1996, Acid digestion of sediments, sludges and soils, Revision 2 December 1996.

26. FAO 2007, The Environmental Management (Soil Quality Standards) Regulations.

27. Lu Z, Qi X, Zhu X, Li X, Li K and Wang H 2021, Highly effective remediation of high-arsenic wastewater using red mud through formation of $AlAsO_4$ @ silicate precipitate. *Environ Pollut.* **287**(1-3) 117484.

28. Sharma H, Rawal N and Mathew BB 2015, The characteristics, toxicity and effect of cadmium. *Int J Nanotechno Nanosci.* **3** 1-9.

29. Das TK and Poater A 2021, Review on the use of heavy metal deposits from water treatment waste towards catalytic chemical syntheses. *Int J Mol Sci.* **22**(24) 1-27.

30. Kabata-Pendias A 2010, Trace elements in soil and plants. Boca Raton, Florida: CRC Press.