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CONTAMINATION AND BIOACCUMULATION OF HEAVY METALS IN MEDICINAL PLANTS OF DISTRICT DIR UPPER, KHYBER PAKHTUNKHWA, PAKISTAN

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Abstract

Environmental pollution caused by heavy metals (HMs) has gained more attention in recent decades due to their persistence, bioaccumulation and potentially toxic effects. This study was aimed to determine the heavy metals in soil and medicinal plant species sampled from District Upper Dir, Khyber Pakhtunkhwa (KP), Pakistan. The concentrations of HMs i.e. Cadmium (Cd), Chromium (Cr), Lead (Pb), Nickle (Ni) and Zinc (Zn) were measured in the soil (n =31) and medicinal plants (n= 31), by using graphite furnace atomic absorption spectrometry (AAS). Levels of HMs were used to estimate bioaccumulation factor (BAF). Mean concentrations of HMs in medicinal plants were 0.05 mg kg^{-1}, 0.88 mg kg^{-1}, 0.30 mg kg^{-1}, 0.43 mg kg^{-1} and 10.71 mg kg^{-1} for Cd, Cr, Pb, Ni, and Zn respectively. The concentration of Cd (24 medicinal plant species) and Cr (6 species medicinal plant species) were above the permissible limits of World Health Organization (WHO) respectively. The highest mean Bioaccumulation Factor (BAF) value was found for *Mirabilis jalapa, Sagretia thea, Zenthoxylum armantum, Ajuga bracteosa,* and *Otostegia limbata* medicinal plant species. The bioaccumulation of HMs was in the order of root>shoot>leaves. While in the soil the mean concentrations of the selected HMs were in the order of Zn>Pb>Ni>Cr>Cd. In the conclusion the contamination in medicinal plants may contribute significantly to the exposure and health risks of the population. From the current study it is recommended that the medicinal plants should be tested for toxic heavy metals before use.

Key words: Heavy metals, Contamination, Bioaccumulation, Khyber Pakhtunkhwa.

Introduction

Heavy metals (HMs) are ubiquitous in the environment and present at small concentrations in soil due to the weathering of rocks and minerals (Hashmi *et al.*, 2007; Fergusson & Kim, 1991); however, anthropogenic activities have dramatically increased the concentrations of HMs in certain ecosystems especially concenteration of Pb, Fe, and Co in the fruit's plants (Sarma *et al.,* 2012; Parveen *et al.,* 2020).

The medicinal plants use for therapeutic applications has been on the rise worldwide, particularly in Asia (Abbasi *et al*., 2011; Ahmed *et al*., 2010; Chandrasekaran and Bahkali, 2013; Jaijoy *et al*., 2010). The importance of medicinal plants is primarily due to their therapeutic effectiveness, ease of access, less costly compared to allopathic medicines and assumption that they are free from negative effects (Bohm, 2008; Huang *et al*., 2010; Nathiya & Dorrcus, 2012). Mostly, population in developing countries relies on the unconventional medicine in their basic health care (Chan, 2003; Pandey *et al*., 2010).

HMs contamination is of high concern due to their persistence, bioaccumulation and potentially toxic effects on living organisms (Censi*et al*., 2006; MacFarlane & Burchett, 2000). The problem of heavy metals entering the food chain requires systematic assessments to make timely decisions to avoid severe health effects because of the invisible mode of heavy metal toxicity (Chary *et al*., 2008). HMs can be accumulated in medicinal plants species and in the vegetables (Chan *et al*., 1993; Karri *et al*., 2008; Kabata-pendias, 2001; Gajalakshmi *et al*., 2012; Jarup, 2003), which is toxic to these plants species as well as to consumers (Memon *et al*., 2001; Houshmandfar & Moraghebi, 2011; Siddhu *et al*., 2008; Memon *et al*., 2001). Some of HMs such as Zinc (Zn), Copper (Cu) and Nickel (Ni) are essential for the plants and humans; their excessive concentration is of great concern because of their toxicity to humans and animal (Zhuang *et al*., 2009). However, metals such as lead (Pb) and Cadmium (Cd) are non-essential and are extremely toxic even at small concentrations (Khan *et al*., 2008b; Korfali *et al*., 2013; Gerendas *et al*., 1999). The Lead and Cd are considered potential carcinogens which are associated with etiology of several diseases, especially cardiovascular, kidney, blood, nerves, and bone diseases (Jarup, 2003).

Use of plants for medicinal purposes has drawn high attention worldwide (Rates, 2000). According to World Health Organization (WHO), about 80% of the world's population consumes indigenous medicinal plants for various ailments (Rania *et al*., 2015). Bioaccumulation of HMs in the medicinal plants is very toxic and have been reported in various studies (Qishlaqi & Moore, 2007; Ernst, 2002; Fabricant & Farnsworth, 2001; Sarma *et al*., 2012). Poisoning associated with toxic metals in medicinal plants has been reported in Asia, Europe, and the United States (Olujohunge *et al*., 1994; Kakosy *et al*., 1996).

In Pakistan, there is no proper collection and processing system for the medicinal plants where people of the rural areas depend largely on traditionally prepared herbal medications (Shinwari & Khan, 2000; Wazir *et al*., 2007; Abdul-Wahab *et al*., 2008). The contamination of the medicinal plants with HMs could increase the toxicity chances (Boyd, 2009). Contamination of medicinal plants is mainly caused by the pollution of soil with toxic metals which may originate from polluted irrigation water, automobile/industrial emissions, atmospheric dusts, pesticides and fertilizers (Baye & Hymete, 2010). The toxic metals interact with soil matrix and may persist for longer time creating long-term hazards. Their availability in soil is used as a key indicator of potential risks to the environment and human health (Barthwal *et al*., 2008). Moreover, plants can also accumulate the metals for which no direct benefit and no significant physiological functions have been recognized. These metals may not be so harmful for the plants but are hazardous for human health as plants are part of the food chain (Razic *et al*., 2006). Thus, it is of importance to evaluate the concentrations of essential and toxic metals in the plants and relevant soil.

The current study was aimed to 1) assess the contamination and bioaccumulation of selected HMs in soil and medicinal plants 2) To measure the bioaccumulation and transfer factors of HMs in selected medicinal plants. The novelty of this study is; no such investigation has been done previously to ensure the presence of HMs in soil and medicinal plants in Upper Dir, KP, Pakistan.

Materials and Methods

Study area: The sample spots in the District Dir upper (Latitude 35 º 10 N; Longitude 72 º 54 E) is situated in the KP, Pakistan as shown in (Fig. 1 and Table 1).

The total area of the district is 3,699 square kilometers with a population of 575,858 (Barkatullah *et al*., 2011). District Dir upper is rich in medicinal plants (Haider *et al*., 2011) which are largely used by the local people as diuretic, blood purifier, tonic, carminative, expectorant and for the treatment of different diseases such as diarrhea, kidney problem, throat infection, constipation, gas trouble, hepatitis, hypertension, rheumatism, asthma, cough, diabetes, fever, and stomach problems (Qureshi *et al*., 2009).

Soil and plant samples collection: Soil and medicinal plant samples were collected from different locations of the District Dir Upper as shown in Fig. 1. Samples of the medicinal plants (n=31) were collected and stored in polythene bags. Approximately 1 kg soil sample was collected to a depth of 30 cm from the base of each sample plant. The samples were cleaned from stones and twigs, packed in polyethylene bags and marked.

The medicinal plants were selected based on their significance and frequent utilization in preparation of traditional drug formulations, food supplements, and medicinal properties. Herbarium sheet of the different plant species was prepared, identified and taxonomically classified with the help of a plant taxonomist and available literature. The specimens of selected medicinal plants were deposited at Department of Botany, University of Peshawar. Details of the medicinal plants used in the present study are presented as supplemental information (Table 1).

Sample preparation and analysis: Soil samples were air-dried, homogenized and sieved through a 2 mm mesh. The samples were ground in a ball mill to less than 200 µm mesh size and stored in polyethylene bags at room temperature. About 0.5 g oven-dried soil was digested in the Teflon beaker using a mixture of hydrofluoric acid (HF) and hydrochloric acid (HCl) in a 3:1 ratio at 130–140°C until complete digestion. The extracts were filtered through Whatman No. 41 filter paper, diluted to 50 ml and stored in the refrigerator before analysis on Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS) (Perkin elmer A700).

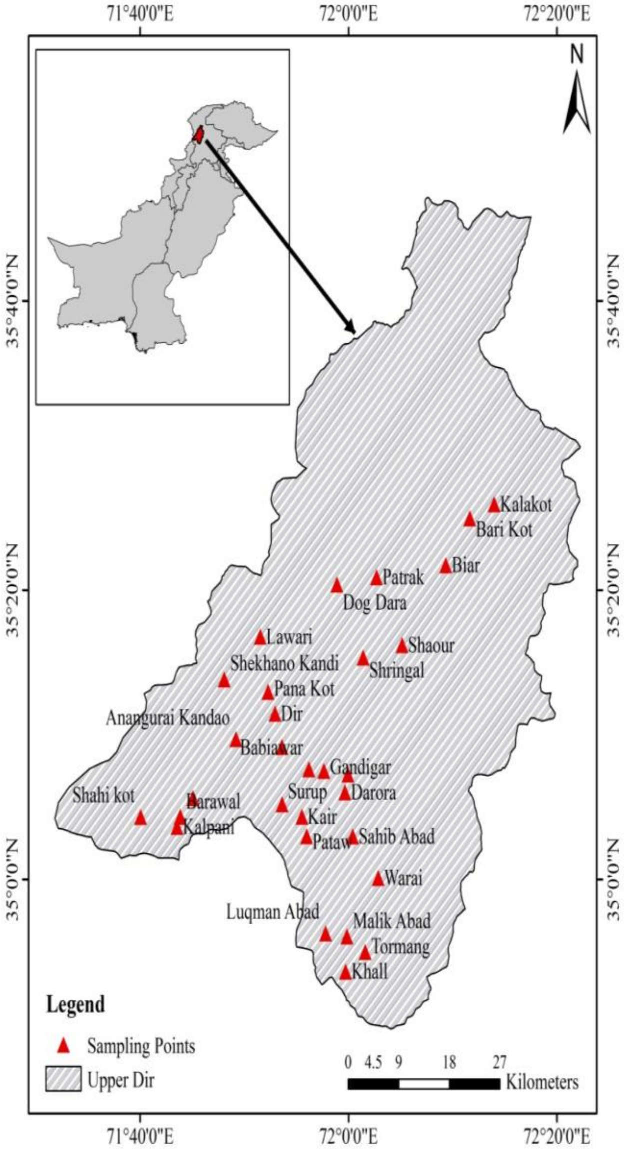

Fig. 1. GIS maps showing the sampling points in Upper Dir, KP, Pakistan.

Plant samples (root, shoot and leaves) were washed with deionized water, oven-dried at 70°C and powdered with an electric grinder. Plant samples (1.0 g) were taken in the Pyrex beaker and digested using analytical grade nitric acid (HNO_3) for about 4 h at 120-130℃ until complete digestion and disappearance of brown fumes. The solution was filtered into a centrifuge tube using Whatman No. 41 filter paper and the volume increased to 15 ml with deionized water. The extracts were used to quantify the concentration of selected heavy metals using GFAAS, (Perkin Elmer A700). All the samples were analyzed in triplicates.

Table 1. Localities from where the medicinal plant species were collected and their coordinates.

Sample location	Plant species	GPS reading		Elevation (m)
		Latitude	Longitude	
Shahi kot	*Silybum marianum*	35° 4'19.08"N	71°40'2.44"E	5865
Barawal	*Punica granatum*	35° 4'19.45"N	71°43'49.89"E	6504
Barawal bandai	*Mirabilis jalapa*	35° 5'37.40"N	71°45'3.07"E	6714
Anangurai Kandao	*Ammi visnaga*	35° 9'42.07"N	71°49'10.49"E	5357
Kalpani	*Sagretia thea*	35° 3'38.18"N	71°43'31.83"E	25950
Chutiatan	*Pinus roxberghii*	35° 9'8.75"N	71°53'36.34"E	7361
Babiawar	*Olea ferruginea*	35° 7'36.98"N	71°56'10.51"E	3241
Gandigar	*Zanthoxylum armantum*	35° 7'30.11"N	71°57'38.03"E	929
Chumra derai	*Mentha longifolia*	35° 7'14.89"N	71°59'56.42"E	8771
Darora	*Adiantum venustum*	35° 6'1.19"N	71°59'38.49"E	8771
Sahib Abad	*Viola pilosa*	35° 2'58.00"N	72° 0'23.34"E	10239
Pataw	*Barberis lycium*	35° 2'58.54"N	71°55'57.83"E	10235
Warai	*Mentha arvensis*	35° 0'5.29"N	72° 2'49.88"E	6243
Tomang	*Verbascum thapsus*	34°54'58.38"N	72° 1'35.06"E	22710
Malik Abad	*Colocasia esculenta*	34°56'3.28"N	71°59'49.73"E	22700
Luqman Abad	*Portulaca oleracea*	34°56'15.65"N	71°57'46.95"E	5442
Khall	*Oryza sativa*	34°53'37.22"N	71°59'42.40"E	30603
Kair	*Solanum nigrum*	35° 4'20.03"N	71°55'30.49"E	52739
Surup	*Oxalis corniculata*	35° 5'11.72"N	71°53'36.55"E	12762
Dir	*Cichorium intybus*	35°11'27.11"N	71°52'55.58"E	27164
Pana Kot	*Ajuga bracteosa*	35°12'58.29"N	71°52'16.16"E	27164
lawari	*Otostegia limbata*	35°16'46.97"N	71°51'30.90"E	51138
Shekhano Kandi	*Ranunculus muricatus*	35°13'49.68"N	71°48'3.99"E	74229
Sheringal S-1	*chenopodium botrys*	35°15'20.38"N	72° 1'23.45"E	74229
Sheringal S-2	*Portulaca grandiflora*	35°15'20.38"N	72° 1'23.45"E	74229
Shaour	*Acrus calamus*	35°16'12.20"N	72° 5'7.44"E	17608
Dog Dara	*Teucrium stoksium*	35°20'23.46"N	71°58'52.18"E	37182
Patrak	*Talictrum foliolosum*	35°20'54.04"N	72° 2'40.95"E	36733
Biar	*Cedrela serrata*	35°21'43.86"N	72° 9'19.32"E	56702
Bari Kot	*Clematis grata*	35°24'57.85"N	72°11'37.61"E	33098
Kalkot	*Ziziphus mummularia*	35°25'56.93"N	72°13'57.95"E	33098

Quality control: Blank reagents and standard certified reference soil (GBW07406-GSS-6) and plant (GBW07603-GSV-2) materials were used with each sample batch preparation and analysis to verify the accuracy and precision of the digestion procedure and analysis. Reference soil and plants were obtained from the National Research Center (NRC) for Certified Reference Materials in China. All the apparatus and glassware used were acid-washed [5% HCl (v/v)] and rinsed with distilled water prior to use. The reagents used were of analytical grade.

Bioaccumulation factor: Bioaccumulation factor (BAF) is determined as the ratio of the concentration of HMs in a plant to the concentration in soil (Muhammad *et al*., 2013). BAF value indicates the accumulation of metal in a plant from soil substrate (Ghosh & Singh, 2005). The BAF values were calculated by using Eq. (1).

$$BAF = \frac{Cplant}{Csoil} \quad (1)$$

where C_{plant} and C_{soil} is the concentration of HMs in the medicinal plant and corresponding soil respectively.

Results and Discussion

HMs concentration in soil: The concentrations of Cd, Cr, Pb, Ni and Zn in soil samples collected from different locations of the study area ranged from 1 - 1.52, 1 - 6.42, 9.34 - 11.93, 1.61 - 6.77 and 23.50 - 33.55 mg kg^{-1} respectively. Mean concentrations of the selected HMs were in the order of Zn >Pb>Ni > Cr >Cd (Table 2).

Similar study was conducted by Ullah *et al*., 2017, they reported that Cd concentration was in the range of 2.43 to 3.21 mg kg^{-1} in soil samples collected from peach gardens of Khwazakhela area, Swat, KP, Pakistan. The possible contributors of HMs in the samples can be geological sources such as weathering, erosion of bedrocks and ore deposits (Ahmet *et al*., 2006; Khan *et al*., 2008a).

Concentration of HMs in plants: The concentrations of HMs in medicinal plants is given in Table 3. The concentration ranged from 0.01 - 0.13, 0.12 - 2.18, 0.09 - 0.61, 0.10 - 0.74 and 5.03- 20.53 mg kg^{-1} for Cd, Cr, Pb, Ni and Zn respectively (Table 2).

Table 2. Mean concentration of HMs (mg kg^{-1}) in soil.

Sample location	Cd	Cr	Pb	Ni	Zn
Shahikot	1.08 ± 0.01	1.17 ± 0.03	9.55 ± 0.01	3.56 ± 0.08	25.98 ± 0.02
Barawal	1.07 ± 0.03	2.25 ± 0.03	10.05 ± 0.01	4.79 ± 0.11	27.57 ± 0.04
Barawalbandai	1.07 ± 0.01	2.09 ± 0.06	9.80 ± 0.02	2.64 ± 0.03	28.99 ± 0.06
Ananguraikandao	1.05 ± 0.01	6.42 ± 0.05	9.52 ± 0.03	3.84 ± 0.07	33.55 ± 0.39
Kalpani	1.06 ± 0.02	3.71 ± 0.05	9.34 ± 0.04	3.44 ± 0.05	33.32 ± 0.72
Chutiatan	1.04 ± 0.02	3.41 ± 0.03	9.62 ± 0.03	3.56 ± 0.05	23.60 ± 0.03
Babiawar	1.06 ± 0.03	1.22 ± 0.18	9.62 ± 0.05	3.66 ± 0.06	24.58 ± 0.01
Gandigar	1.06 ± 0.02	1.19 ± 0.04	9.55 ± 0.08	3.52 ± 0.06	25.10 ± 0.01
Chumraderai	1.02 ± 0.02	1.63 ± 0.17	9.51 ± 0.04	2.65 ± 0.20	23.99 ± 0.04
Darora	1.02 ± 0.01	1.29 ± 0.07	9.49 ± 0.05	1.61 ± 0.66	24.60 ± 0.03
Sahib Abad	1.06 ± 0.03	1.46 ± 0.12	9.49 ± 0.03	3.67 ± 0.10	23.58 ± 0.01
Pataw	1.04 ± 0.02	3.38 ± 0.03	10.54 ± 0.10	3.56 ± 0.07	31.87 ± 0.13
Warai	1.05 ± 0.03	1.57 ± 0.21	10.45 ± 0.04	3.52 ± 0.16	24.11 ± 0.02
Tomang	1.05 ± 0.02	1.27 ± 0.03	10.46 ± 0.06	3.25 ± 0.02	25.72 ± 0.03
Malik Abad	1.04 ± 0.03	1.30 ± 0.05	10.59 ± 0.04	3.45 ± 0.07	25.72 ± 0.04
Luqman Abad	1.06 ± 0.01	2.45 ± 0.05	11.92 ± 0.07	6.59 ± 0.09	29.45 ± 0.28
Khall	1.05 ± 0.01	2.30 ± 0.02	10.55 ± 0.04	5.30 ± 0.09	28.00 ± 0.03
Kair	1.01 ± 0.01	1.99 ± 0.02	10.42 ± 0.03	6.02 ± 0.08	28.70 ± 0.05
Surup	1.01 ± 0.01	2.56 ± 0.05	10.70 ± 0.08	5.72 ± 0.06	28.92 ± 0.07
Dir	1.02 ± 0.02	2.92 ± 0.06	10.72 ± 0.06	6.77 ± 0.10	29.00 ± 0.07
PanaKot	1.03 ± 0.03	1.82 ± 0.03	10.80 ± 0.02	5.53 ± 0.10	24.02 ± 0.02
Lawari	1.04 ± 0.16	2.23 ± 0.02	11.90 ± 0.06	6.37 ± 0.11	27.58 ± 0.56
ShekhanoKandi	1.03 ± 0.02	2.38 ± 0.05	11.93 ± 0.08	5.64 ± 0.07	27.46 ± 0.53
Sheringal S-1	1.01 ± 0.02	2.26 ± 0.01	10.65 ± 0.04	4.44 ± 0.01	28.84 ± 0.13
Sheringal S-2	1.03 ± 0.02	2.41 ± 0.02	10.83 ± 0.03	5.79 ± 0.02	29.14 ± 0.12
Shaour	1.00 ± 0.01	2.54 ± 0.02	10.82 ± 0.02	5.83 ± 0.14	29.20 ± 0.37
Dog Dara	1.03 ± 0.01	2.22 ± 0.03	10.75 ± 0.06	6.25± 0.06	30.24 ± 0.80
Patrak	1.04 ± 0.02	2.21 ± 0.01	10.73 ± 0.02	6.43 ± 0.09	28.91 ± 0.14
Biar	1.04 ± 0.03	2.06 ± 0.01	10.66 ± 0.03	6.22 ± 0.06	28.82 ± 0.08
Bari Kot	1.03 ± 0.03	1.77 ± 0.02	10.42 ± 0.02	3.89 ± 0.17	29.56 ± 0.38
Kalkot	1.03 ± 0.01	4.02 ± 0.04	10.81 ± 0.02	5.87 ± 0.09	29.65 ± 0.28

± Standard deviation

Highest metal concentrations were observed in the plant roots followed by the shoot. Whereas the leaf samples had the lowest metal concentrations for all the plants indicating that the uptake of metals in these plants was from the soil substrate only and low translocation to the upper parts of these plants. Mean concentration of the HMs in plant samples was found in order of Zn > Cr > Ni >Pb> Cd. The WHO recommended permissible limits of Cd, Cr, Pb, Ni and Zn for plant samples are 0.02, 1.3, 2.0, 10.0 and 50 mg kg^{-1} respectively (Shah *et al*., 2013; Nazir *et al*., 2015). The present study revealed that the concentration of Cd was higher than WHO permissible limits in 24 medicinal plants species (Table 2).

Plants are a good source for bioaccumulation of heavy metals. On one hand, this property has been used for phytoremediation (Kumar *et al*., 2019), on the other hand, it may prove to be hazardous when plants are consumed as food or therapeutic agent in traditional medicine. Although there is a great concern about heavy metal contamination of herbal raw materials, information regarding permissible limit is available only for Pb and Cd (Anon., 1998).

The high concentration/accumulation of Cd in plants may be due to the high mobility of the Cd in soil (Jarup, 2003). Likewise, the concentration of Cr was higher in 9 species (*Mirabilis Jalapa, Sagretia thea, Zanthoxylum armantum, Mentha longifolia, Viola pilosa, Colocasia esculenta, Cichorium intybus, Ajuga bracteosa* and *Otostegia limbata*) (Table. 2). However, the concentration of Pb, Ni, and Zn were below the WHO permissible limits for all the plant species. To minimize the toxicity of metals in soils, organic amendments such as biochar and activated carbon are widely used to immobilize the contaminants (Puga, *et al*., 2015). Other methods adopted for reducing the mobility, availability, and toxicity of the heavy metals in soil were the application of phosphates and phytoremediation (Maria *et al*., 2014).

The lower concentrations of Ni and Zn observed in the present study showed a deficiency of these elements in the soil environment since both the metals are considered as essential micronutrients for the plants and the human body. Inadequate Zn diet and nutrition are estimated to affect one-third of the global human population (Hotz *et al*., 2004). The deficiency of Zn is affecting large areas of cultivated soils worldwide (Cakmak, 2008). Symptoms of Ni deficiency include interveinal chlorosis in young leaves resulting in necrosis of the plant tissue. Other symptoms include poor seed germination and decreased crop yield. In humans, Ni is found to be helpful for normal bone functioning and health (Gerendas *et al*., 1999).

Table 3. Mean concentrations (mg/kg) of HMs in medicinal plants.

Plant Name	Cd	Cr	Pb	Ni	Zn
Silybum marianum	0.08 ± 0.04	0.61 ± 0.03	0.61 ± 0.09	0.24 ± 0.21	5.83 ± 0.02
Punica granatum	0.01 ± 0.02	0.43 ± 0.05	0.15 ± 0.03	0.20 ± 0.15	7.28 ± 0.03
Mirabilis jalapa	0.04 ± 0.04	1.62 ± 0.04	0.34 ± 0.06	0.13 ± 0.08	19.48 ± 0.33
Ammi visnaga	0.03 ± 0.05	0.33 ± 0.02	0.13 ± 0.02	0.11 ± 0.03	5.03 ± 0.09
Sagretia thea	0.12 ± 0.57	1.59 ± 0.03	0.29 ± 0.08	0.30 ± 0.05	19.20 ± 1.50
Pinus roxberghii	0.03 ± 0.08	0.38 ± 0.03	0.12 ± 0.04	0.28 ± 0.07	5.70 ± 0.03
Olea ferruginea	0.01 ± 0.02	0.48 ± 0.03	0.24 ± 0.09	0.35 ± 0.17	5.84 ± 0.01
Zanthoxylum armantum	0.01 ± 0.05	1.79 ± 0.05	0.22 ± 0.07	0.26 ± 0.09	18.84 ± 0.65
Mentha longifolia	0.06 ± 0.03	2.00 ± 0.04	0.40 ± 0.14	0.38 ± 0.20	20.54 ± 1.14
Adiantum venustum	0.08 ± 0.03	0.31 ± 0.04	0.13 ± 0.02	0.62 ± 0.09	5.43 ± 0.03
Viola pilosa	0.05 ± 0.05	1.46 ± 0.06	0.46 ± 0.11	0.57 ± 0.19	19.20 ± 0.64
Barberis lycium	0.13 ± 0.03	0.49 ± 0.02	0.22 ± 0.19	0.43 ± 0.35	7.82 ± 0.05
Mentha arvensis	0.08 ± 0.06	0.37 ± 0.03	0.19 ± 0.04	0.38 ± 0.04	6.76 ± 0.04
Verbascum thepsus	0.06 ± 0.03	0.34 ± 0.01	0.09 ± 0.04	0.27 ± 0.04	5.48 ± 0.04
Colocasia esculenta	0.03 ± 0.03	1.38 ± 0.01	0.21 ± 0.09	0.34 ± 0.11	18.09 ± 0.65
Portulaca oleracea	0.05 ± 0.02	0.87 ± 0.04	0.22 ± 0.09	0.61 ± 0.12	6.64 ± 0.03
Oryza sativa	0.07 ± 0.02	0.37 ± 0.01	0.20 ± 0.14	0.75 ± 0.06	5.39 ± 0.04
Solanum nigrum	0.05 ± 0.08	0.67 ± 0.06	0.21 ± 0.18	0.64 ± 0.10	6.11 ± 0.03
Oxalis corniculata	0.04 ± 0.05	0.36 ± 0.05	0.36 ± 0.04	0.58 ± 0.08	6.65 ± 0.01
Cichorium intybus	0.03 ± 0.05	1.31 ± 0.03	0.32 ± 0.12	0.46 ± 0.01	9.48 ± 0.02
Ajuga bracteosa	0.06 ± 0.03	2.19 ± 0.03	0.52 ± 0.06	0.73 ± 0.18	18.24 ± 0.75
Otostegia limbate	0.03 ± 0.02	1.71 ± 0.02	0.31 ± 0.06	0.52 ± 0.04	18.59 ± 0.74
Ranunculus muricatus	0.06 ± 0.05	0.68 ± 0.07	0.39 ± 0.17	0.64 ± 0.17	8.75 ± 0.04
Chenopodium botrys	0.04 ± 0.08	0.45 ± 0.01	0.39 ± 0.09	0.61 ± 0.02	6.25 ± 0.04
Portulaca grandiflora	0.01 ± 0.05	0.46 ± 0.03	0.26 ± 0.06	0.21 ± 0.07	14.72 ± 0.03
Acrus calamus	0.02 ± 0.05	0.56 ± 0.04	0.29 ± 0.18	0.48 ± 0.08	11.80 ± 0.04
Tecurium stoksium	0.03 ± 0.03	0.69 ± 0.06	0.11 ± 0.06	0.35 ± 0.22	7.32 ± 0.05
Talictrum foliolosum	0.02 ± 0.04	0.31 ± 0.04	0.11 ± 0.02	0.10 ± 0.06	5.90 ± 0.03
Cedrela serrata	0.07 ± 0.04	0.59 ± 0.06	0.49 ± 0.08	0.28 ± 0.08	7.06 ± 0.08
Clematis grata	0.02 ± 0.06	0.12 ± 0.04	0.35 ± 0.17	0.33± 0.18	5.91 ± 0.02
Ziziphus mummularia	0.05 ± 0.06	0.63 ± 0.03	0.44 ± 0.20	0.70 ± 0.24	5.99 ± 0.01

±Standard deviation

Bioaccumulation factor: The BAF is an important tool for estimating the soil to plant transfer of the heavy metals, contamination of the food chain and human exposure. The BAF values for the different medicinal plants are shown in Table 4.

The highest mean BAF value was found for *Mirabilis jalapa, Sagretia thea, Zanthoxylum armantum, Ajuga bracteosa* and *Otostegia limbata* (Table 4). The variation in the BAF values may be due to the difference in medicinal plants, sampling locations, and soil properties.

Conclusion

The present study revealed that medicinal plants of the study area are bio-accumulated with heavy metals and the source may be geological inputs. The contamination of medicinal plants was in the order of Zn>Pb>Ni>Cr>Cd. The concentration of Cd and Cr was above the WHO permissible limits for some of the medicinal plants. The observed contamination in medicinal plants may contribute significantly to the exposure and health risks of the population. It is recommended that the medicinal plants should be evaluated for toxic heavy metals before use.

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Table 4. Bioaccumulation factor of heavy metals in selected medicinal plants.

Plant name	Cd	Cr	Pb	Ni	Zn
Silybum marianum	0.07	0.52	0.06	0.07	0.22
Punica granatum	0.01	0.19	0.01	0.04	0.26
Mirabilis jalapa	0.04	0.77	0.03	0.05	0.67
Ammi visnaga	0.03	0.05	0.01	0.03	0.15
Sagretia thea	0.11	0.43	0.03	0.09	0.58
Pinus roxberghii	0.03	0.11	0.01	0.08	0.24
Olea ferruginea	0.01	0.39	0.02	0.10	0.24
Zanthoxylum armantum	0.01	1.50	0.02	0.07	0.75
Mentha longifolia	0.06	1.23	0.04	0.14	0.86
Adiantum venustum	0.08	0.24	0.01	0.38	0.22
Viola pilosa	0.05	1.00	0.05	0.15	0.81
Barberis lycium	0.13	0.14	0.02	0.12	0.25
Mentha arvensis	0.07	0.24	0.02	0.11	0.28
Verbascum thapsus	0.05	0.27	0.01	0.08	0.21
Colocasia esculenta	0.03	1.06	0.02	0.10	0.70
Portulaca oleracea	0.05	0.35	0.02	0.09	0.23
Oryza sativa	0.06	0.16	0.02	0.14	0.19
Solanum nigrum	0.04	0.33	0.02	0.11	0.21
Oxalis corniculata	0.04	0.14	0.03	0.10	0.23
Cichorium intybus	0.03	0.45	0.03	0.07	0.33
Ajuga bracteosa	0.06	1.20	0.05	0.13	0.76
Otostegia limbata	0.03	0.76	0.03	0.08	0.67
Ranunculus muricatus	0.06	0.28	0.03	0.11	0.32
Chenopodium botrys	0.03	0.20	0.04	0.14	0.22
Portulaca grandiflora	0.01	0.19	0.02	0.03	0.51
Acrus calamus	0.01	0.22	0.03	0.08	0.40
Teucirum stoksium	0.03	0.31	0.01	0.05	0.24
Talictrum foliolosum	0.02	0.14	0.01	0.02	0.20
Cedrela serrata	0.06	0.28	0.05	0.05	0.24
Clematis grata	0.02	0.07	0.03	0.08	0.20
Ziziphus mummularia	0.05	0.16	0.04	0.12	0.20

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